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# Closing the Gap Between Theory and Practice to Promote Equity in STEM: Coaching Teachers with UDL Strategies to Empower Students

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**CLOSING THE GAP BETWEEN THEORY AND PRACTICE TO PROMOTE EQUITY IN STEM: COACHING TEACHERS WITH UDL STRATEGIES TO EMPOWER STUDENTS**

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**Abstract**

U.S. schools have witnessed educational reforms that have shifted science curriculum and pedagogy within classrooms. Yet, all these reforms have failed to reduce the racial and gender gaps in STEM fields. In 2016, New York State implemented the New York State Science Learning Standards (NYSSLS) to address these gaps. Problems remain, however, with the NYSSLS standards. The NYSSLS do not offer teachers pedagogical practices with regards to implementation. Students are expected to engage in practices as they emulate scientists, without any direction for teachers to support students through these practices, and they exemplify a deficit mindset by placing the blame of content accessibility on racially and academically marginalized students. The rationale for this qualitative action research study was to address the gaps identified in the research and the problems in the NYSSLS through the addition of universal design for learning and culturally responsive teaching. The data for this study included three cycles of action research, interviews, and field observations with seven fourth-grade teachers from two school districts who participated in professional development (PD) sessions prior to implementing a STEM lesson. Findings from this study indicated that when teachers are supported with PD sessions that offer hands-on training through the eyes of the students, vicarious experiences while working with their colleagues on lesson planning, and support with coaching during lesson implementation, the identified barriers to learning are minimized. Such experiences were found to increase teachers' self-efficacy in supporting students through STEM lessons and diminish deficit mindsets about certain students, although there was also evidence that suggested oppressive normativity was a problem in a special education classroom. Additionally, it was found that as teachers gain self-efficacy in teaching STEM lessons, they let go of their authoritative power by allowing students to collaborate and take control over their

learning. Barriers to learning are then diminished as students become empowered to access the content in the NYSSLS, problem-solve, and successfully navigate the practices.

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I would also like to acknowledge all educators who are strong enough to relinquish their power and empower their students.

## Dedication

I am forever grateful for my family. First and foremost, I dedicate this work to my sons, Brandon and Timothy. I thank you for the many hours of time not shared between us over the past four years. Although I seemed secluded in my office, your unwavering understanding and support fueled me, and I felt the two of you within my heart and soul as I worked.

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To my parents, Andrew and Dena Poulos, I dedicate this work to you for all the missed weekends together. Life is short, and I thank you for understanding and giving me the gift of time. Mom, you have surrounded me with a love for learning my whole life. You are a kind, compassionate, and brilliant educator, and I aspire to emulate your leadership.

To my dear peer, Sandra Morris. Your footprint is forever in my soul. “I appreciate you.”

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# Chapter 1

## The Power of an Offer

I was one out of eight candidates for a public school Director of Science and Engineering Technology position. While I nervously awaited my turn for the panel interview, a man exited through the door with a confident smile on his face. His blue pressed suit was the perfect balance of not brand new, yet polished and dignified. The top of his shoes looked pristine, yet with each step the soles told a story of experience. He nodded to me, thanked the clerical worker sitting at her desk, and proudly left the building. A few moments passed and I was offered an invitation to enter through the door he exited. I sat in the chair he vacated and answered rounds of questions from various stakeholders in their educational community. At the culmination of my interview, I thanked the panel members for the opportunity. As I departed, I saw another man texting on his phone while awaiting his turn. His blue suit was a bit less worn than the last candidate. Sitting with one leg resting on the other, the soles of his shoes looked as if he floated in and never contacted the ground. Remembering the awkward nod previously sent my way, I pretend I didn’t notice this man and just wished the clerical worker a good day on my way out.

A week later I was contacted for a final interview round. I felt small in that armchair. Why was I not big enough to fill its whole space? While sitting as tall as possible, I felt my shoulders begin to curl with a bit of insecurity. I forced myself to scan the table and make brief eye contact with all. Four men to my right and two women and two men to my left. One other man, who sat much taller and prouder than I, faced me directly from the other end of the heavy wooden table that successfully separated us. I couldn’t help to notice how both women had stoic looks that emulated a power that seemed to match the smirks worn by some of the men. I suddenly felt my hair tickling the tips of my shoulders and another wave of insecurity filled me. I briefly wondered if my seat could be adjusted so I would appear taller, but I didn't dare to investigate and try.

I immersed myself in the world of STEM as far back as I can remember. As a child I marveled at the organization of living things. When I was only 16 years of age in high school, I worked in a college level lab where I was trained on a scanning electron microscope. Most described this tool as the ultimate 3D magnifier. However, I felt I was transported into a microscopic dimension, shrinking myself, and feeling small in the enormity of the detailed world this microscope presented. As I entered into the field of education, I wanted my students to view the world as I did, with the aww and wonder of hidden marvels that many overlook and walk past. During my 25 plus years of STEM teaching, my own wonder and passions continued to grow, and I felt the need to share these experiences in classrooms beyond my own. As I spoke about my passions to the interview committee, my emotions drifted away from insecurity and my subsequent responses to their questions felt more natural.

After a round of questions, one man to my right gave a mini nod to the man at the head of the table. As the nod met his eyes, his mouth curled into a tiny smile as he stated that they would like to offer me the job. I graciously accepted and the two women broke into beaming smiles. I stood and made my way around the table to shake hands with all. The last person I reached is the man who offered his small nod of approval. He grasped my hand with a firm shake. Before slowly breaking the grasp, he began to share that he's an engineer and throughout his whole career he only worked with one woman engineer. He further explained that she was one of the best employees he had ever worked with and stated he didn't understand why there are not more females in the field of engineering. Then, he explicitly stated one goal he would like me to accomplish as the new Director of Science and Engineering Technology. The high school recently started a STEM Academy. Only two girls out of twenty-seven students in total applied. It was my mission to change that.

The offer to serve in this role changed my personal perspective. Five years later I am more confident in myself and embrace the true me: A women with a passion for STEM. I contently allow my hair to flow past my shoulders. I confidently walk into engineering classrooms and proudly smile at the girls that now make up 47% of the STEM Academy applicants. The offer for me to lead the Science and Engineering Departments could possibly pave the way for many other women to follow their passions in STEM fields. I currently coach STEM teachers at the grassroots level, within their classrooms. I continue to learn alongside the teachers as we strive to discover equitable, pedagogical practices that eliminate barriers to learning and cultivate self-efficacious STEM students. As I teach forward, I hold onto my past experiences, as those experiences are my personal why when coaching other educators.

Regrettably, my past personal insecurities are shared among many with regards to STEM fields. According to the United States Bureau of Labor and Statistics (2022), STEM related occupations are projected to increase by 10.8% from 2021 to 2031. Nevertheless, even with this growth of STEM related careers, racial and gender diversity among STEM employees is problematic. The STEM fields of physical science, computer science, and engineering are dominated by a predominantly White-male population, with an underrepresentation of Black, Latinx, and women professionals (Bruijnzeel, et al., 2022; Canning et al., 2019; Martin & Fisher-Ari, 2021). Black people account for only 6% of the work force in the physical science and only 5% in engineering fields. Latinx workers are reported at 8% in the areas of physical science and 9% in engineering fields. Although women make up 53% of all college STEM Degrees, only 40% are earned in physical science and just 15% are in engineering (Pew Research Center, 2018). Furthermore, according to the National Center for Science and Engineering Statistics (2023), Black females make up only 2% of the engineering workforce, elucidating the amalgamating effect of intersectionality.

The underrepresentation of historically marginalized groups in STEM fields is attributed to sociocultural influences such as racial and gender biases (Martin & Fisher-Ari, 2021; Wang & Degol, 2017), low self-efficacy (Casad, et al., 2018; Ellis, 2016; Owens, et al., 2021), scientific identity (Camacho et al., 2021; Martin & Fisher-Ari, 2021), and White privilege in STEM degree attainment (Pew Research Center, 2022; Reigle-Crumb et al., 2019). Despite the plethora of research that identifies the underrepresentation of historically marginalized students of color and females in STEM fields, there is a lack of research that investigates ways to implement pedagogical approaches in K-12 STEM education that can diminish implicit biases among teachers and enhance self-efficacy of marginalized students. The purpose of this action research study was to explore how coaching teachers to utilize the Universal Design for Learning (UDL) and Critically Responsive Teaching (CRT) frameworks in conjunction with the 5-E lesson plan design can support teachers in the creation of inclusive learning environments where all students develop self-efficacy in STEM.

## Statement of Problem

When hired as the Science Director in 2019, I was informed of the lack of girls participating in the high school STEM Academy. At that time, girls only represented .07% of the overall population in the STEM Academy. Upper level science courses were still tracked, with a noted inequity between the Regents and Honor sections. Specifically, our chemistry courses were still offered as “Regents” or “Honors.” For the 2019-2020 school year, White students made up 77.8% of the demographics in Regents Chemistry sections as compared to 85.3% in Honors

Chemistry sections, Latinx students represented 18.5% in the Regents sections and 7.8 % in the Honors, Asian/Asian-White students made up 1.8% of the Regents sections and 6.9% of the Honors, Black students made up 1.4% of the Regents sections with no representation in the Honors sections, and those that identified as multiracial made up .5% in Regents sections with no representation in honors sections. I felt compelled to shift this mindset and generate a culture that all students can achieve at a high level in our upper level science courses. I also felt that these efforts need to start earlier in elementary school so all students can begin to see themselves as scientists at a young age and enhance their self-efficacy in STEM fields throughout their K-12 experience.

While U.S. schools have witnessed educational reforms that have shifted scientific practices within classrooms, educators have failed to reduce the racial and gender gaps in STEM fields. Since the deployment of Sputnik in 1957, America entered the international STEM race. Yet, despite the U.S.'s decree that we are a Nation at Risk (1983), we will leave No Child Left Behind (Busch, 2001), by Tapping America's Potential in 2005, as we are a Nation Accountable entering into the Next Generation Science Standards (NGSS), the underrepresentation of women, and Black, and Latinx people in STEM fields has persisted. In 2016, New York State, where this research took place, implemented the New York State Science Learning Standards (NYSSLS), which were adapted from the foundations of the National Research Council's Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (National Research Council, 2012), and the NGSS.

In my 30 year experience as a STEM educator, three main problems persist with the new standards. The first problem encompasses the fact that the standards do not offer guidance for teachers on "how" to incorporate these standards into lessons. Research alone on STEM pedagogical practices is scarce. Cagle et al. (2018) reported on 197 peer reviewed journal articles that focused on education and pedagogy in STEM fields. The researchers stated that only 10% of the literature focused on improving educational practices in STEM and only 3% of the literature focused on improving students' self-efficacy.

The second problem is that the NYSSLS shifted the focus away from inquiry learning, that was previously a focus in the NYS Science Core Curriculum (Liu & Fulmer, 2008), and served as the foundation of scientific pedagogy over the past three decades. The National Research Council (1996) described inquiry as the activities of students as they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. The "inquiry" is now hidden in the standards and scientific "practices" are emphasized. The new "practices" are meant to have students emulate scientists during STEM activities. Reference to scientific "practice" is nearly nonexistent in educational literature with no theoretical foundation to support this shift (Emden, 2021).

This dearth of theoretical foundation and lack of support for educators perpetuates the third problem that is long standing with all science reforms thus far: accessibility of scientific knowledge for all students. The authors of both NYSSLS and NGSS claim to be structured with a focus on equity; however, both sets of standards refer to marginalized groups that need special attention to be successful in gaining access to the standards. This reference exemplifies a deficit mindset, as the blame is put on the students' lack of ability to access content in the standards. On the contrary, the UDL and CRT frameworks are asset-based pedagogical approaches and designed with the premise that all students are capable of learning and that barriers within the curriculum can be eliminated with the implementation of specific pedagogical strategies and scaffolding (Cook & Rao, 2018). Furthermore, the authors of the NGSS document acknowledge a gap in research that offers strategies to support “non-dominant” groups. These non-dominant groups are identified as: economically disadvantaged students, students from historically marginalized racial or ethnic groups, students with disabilities, students with limited English proficiency, gender, students in alternative education programs, and gifted and talented students. Therefore, I argue that successful implementation of the NYSSLS for all students is reliant on educators closing the gap between theory and practice. Closing the gap requires teaching methodologies, like the Universal Design for Learning (UDL) framework (Cast, 2018) and the Culturally Responsive Teaching (CRT) framework (Gay, 200), that I suggest will promote inclusive learning environments for STEM, provide equitable access to content, increase students’ Self-regulated learning (SRL), and ultimately increase self-efficacy during scientific practices.

## Theoretical Framework

This action research study utilized the UDL and CRT frameworks through a lens of social cognitive and social constructivist theories to support teachers with strategies that promote inclusive learning environments during STEM lessons. Rogers-Shaw et al. (2018) expressed the importance of access to curriculum to achieve social justice goals and cited the UDL framework as an effective approach to meeting all learners’ needs. Additionally, Smith et al. (2019) suggested that UDL should be utilized as a basis in teacher training and qualification programs. Furthermore, professional development can be universally designed, modeled after practices in the UDL framework, to support teachers’ understanding of UDL strategies (Novack & Rodriguez, 2016). Culturally Responsive Teaching (CRT) was added as an additional asset-based pedagogy for Cycle three of this study (Kieran & Anderson, 2019).

### UDL Framework

The UDL framework is intended as a guiding tool for designing instruction that offers accessibility of content to as many learners as possible by reducing barriers to learning. Barriers to learning puts the breaks on the learning process as students "get stuck" at a particular point in a lesson. Specific barriers include the students' lack of background knowledge (O'Reilly et al., 2019), students' limited content vocabulary (Eichhorn, et al., 2019), social emotional barriers such as low self-efficacy (Alim et al., 2017; Griggs & Moore, 2023; Kieran & Anderson, 2019) and insufficient feedback from teachers (Elliott et al., 2018). Organizational barriers can also prevent students from success. Organizational barriers include limited opportunities for teachers to collaborate with their colleagues (Allen & Heredia, 2021; Olson & Roberts, 2020), a lack of teachers' own self-efficacy in teaching science (Van Garderen et al., 2012), administrative incentives to prioritize assessment preparation (Furtak & Heredia, 2014), and utilizing curriculum materials that do not support the standards (Allensworth, et al., 2022).

The Center for Applied Special Technology (CAST) constructed the UDL framework around three guiding principles:

1. Providing multiple means of representation
2. Providing multiple means of action and expression
3. Providing multiple means of engagement

Under the tenets of these three guiding principles are a total of nine guidelines and thirty-one checkpoints that were constructed from the review of existing literature on UDL best practices (CAST, 2018). Each checkpoint includes a specific strategy that provides access to learning goals, builds upon knowledge base and skills, and empowers learners through means of self-regulation (Root et al., 2022). To ensure ongoing assessment of equity for all learners, CAST established a community of professionals dedicated to equity, research, community input, and the ongoing evolution of the CAST guidelines, as needed (CAST, 2020).

**UDL and Culturally Responsive Teaching**

Chardin and Novak (2020) explained how teachers can consider equity by lesson design and work towards more equitable learning experiences through the implementation of UDL principles. Similarly, researchers have cited the benefits of combining UDL with CRT. Kieran and Anderson (2019) describe CRT as a means of designing instruction from the perspectives of student diversity as a strength rather than deficits. Furthermore, the researchers suggested that CRT can be combined with UDL to increase student success with meeting teachers' higher expectations of learning outcomes. Takemae et al. (2022) describe the combination of CRT and UDL as a "cross pollination" of two asset-based pedagogies that can strengthen teacher training.

**UDL and Discipline Specific Studies**

Originally, UDL was designed to benefit students with disabilities via the implementation of assisted technology. More recently, discipline specific studies have appeared in the literature with regards to the implementation of UDL practices in the areas of mathematics (Lambert, 2021; Root 2022), science (King-Sears & Johnson, 2020; Pacheco-Guffrey, & Ingle, 2019; Van Garderen et al., 2012), English language arts (Dazzeo & Rao, 2020; Gravel, 2018), and social studies (Mackey, 2019). Moreover, various researchers report on the potential for the UDL framework to provide successful pedagogical approaches to curriculum development in science classes (Adu-Boateng & Goodnough, 2021; King-Sears, et al. 2015, 2020; Rappolt-Schlichtmann, et al., 2013; Thomas et al., 2015). Israel et al. (2014) explained that the UDL framework should offer teachers choices with regards to how to deliver evidenced-based practices during instruction. The researchers further elucidated that UDL will therefore look different in different settings as a result of embedding UDL practices into different implementation models. Hanuscin and Van Garderen (2020) described how elements of the UDL framework can be embedded within the 5-E lesson design to reduce or eliminate learning barriers during inquiry based physical science lessons.

**The 5-E Lesson Model**

Bybee et al. (2006) developed a constructivism-based instructional model called the 5-E Learning Cycle. Constructivist-based learning focuses on how the learner constructs knowledge from experience (Singh & Yaduvanshi, 2015). The five stages of the 5-E model consist of Engage, Explore, Explain, Elaborate, and Evaluate. In the 5-E model, students tap into prior knowledge to make connections and learn something new (Sema Altun Yalçın et al., 2012). In science-designed 5-E lessons, a phenomenon is introduced during the Engage phase at the start of the lesson that acts as a bridge for students to connect prior knowledge to newly introduced content. The phenomenon is then revisited at the end of the lesson to loop the learning cycle and eliminate any preconceived misconceptions. Potential barriers to learning can be present in each of the 5- E components. Elements of the UDL framework can be incorporated into each component of the 5-E lesson design to eliminate these learning barriers for students.

Meyer et al. (2014) explained that the UDL framework is constructed under the premise that barriers to learning are found within the curriculum as opposed to the individual learner. Additionally, the researchers elucidated that the underlying philosophy of the UDL framework is to cultivate individuals to become “experts” as learners while on their “continuum of development” (p. 21). The 5-E lesson model, along with the NYSSLS, also places emphasis on students as “experts” as they engage in the practices. Both the 5-E lesson design and NYSSLS rely on the foundation of constructivist theory which postulates that knowledge is actively constructed by an individual through direct learning experiences (Mayer, 1992). Additionally, self-regulated learning and self-efficacy is necessary for students to emulate scientists during scientific practices. Therefore, social cognitive and constructivist learning theories can act as a backbone for the development of strategies to support teachers in the evolution from students to expert learners.

**Social Cognitive Theory**

Social cognitive theory (SCT) encompasses both cognitive factors and motivational self-regulation mechanisms (Admawati et al., 2018; Bandura et al., 2003; Caprara et al., 2008; Thibaut et al., 2018; Zimmerman, 1990). Social cognitive theory paved the way for models of academic self-regulation (Caprara et al., 2008). Bandura et al. (2003) reported the importance of self-efficacy to regulate and manage one’s academic development (self-regulated learning). Self-efficacy is defined as one's perceived ability to perform a task to attain a specific goal (Bandura, 1977). Self-regulated learning (SRL) is defined as a self-directed process where one transforms mental abilities to academic skills and consists of processes, such as self-efficacy, and particular strategies to optimize self-efficacy (Zimmerman 1990, 2002).

Various studies are cited in literature that report on the importance of social cognitive theories in STEM education. However, when considering these social cognitive theories in isolation, educators risk the establishment of inequitable learning environments that may result in the marginalization of historically marginalized students of color and women in STEM fields. Analysis of these motivational theories in the literature illustrates overlaps, and perhaps an interdependency. These social cognitive theories can be supported throughout a 5-E STEM lesson with the utilization of strategies from constructivist learning theories.

**Social Constructivist Theory**

Constructivist Learning Theories underpin the importance that learning and meaning making results from prior information and interpretation of newly presented information (Galkiene & Monkeviciene, 2021; Murphy, 2022). Piaget's cognitive theory (1973) described how knowledge is constructed and reconstructed through personal experiences. Bruner (1977) further built upon Piaget's work. The researcher explained that learners compare new ideas to old ones to search for similarities and differences (Galkiene & Monkeviciene, 2021). Vygotsky's social constructivist theory (1978) explained that learners should be engaged during the learning process and learn from one another to construct their own knowledge. This theory elucidated that learning occurs with support from both the teacher and classmates (Galkiene & Monkeviciene, 2021). Vygotsky further explained how social interactions were necessary to mediate learning within a learners' zone of proximal development (Murphy, 2022). I propose that the UDL framework embraces all these social cognitive theories and provides many strategies that can be embedded into the foundation of a single STEM lesson.

## Research Questions

The following research questions guided this study:

**Primary Research Question**: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices?

**Sub-Question 1**: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during each of the 5-E components of the lesson?

**Sub-Question 2**: What UDL strategies were perceived as effective in reducing or eliminating learning barriers within specific components of the 5-E lesson?

**Sub-Question** 3: What additional strategies do 4$^{th}$ grade teachers recommend to further reduce or eliminate barriers to learning.

# Research Design and Methods

To answer the above research questions, I employed an action research methodology. The epistemological worldview that guided my study is transformative. The transformative worldview is based on the premise that the research conducted includes an agenda that leads to change in the action of all participants, including the researcher, in addition to the schools in which they work (Creswell & Cresswell, 2018). Incorporating an action research approach allowed for co-planning and collaboration with teachers and the flexibility needed for our ever-evolving educational setting. The selected framework offered a means to explore how coaching teachers to utilize the UDL and CRT frameworks can support teachers during STEM lessons. It is my hope that the UDL and CRT frameworks will eventually be embraced school-wide, to eliminate barriers of learning across curricula.

## Role of the Researcher

I am currently Executive Director for Instructional Technology and Science, Technology, Engineering, Art, and Math (STEAM), grades K-12. I view my role as an educational coach. My professional role includes determining specific areas of need for professional development, providing professional development, and evaluating the effectiveness of professional development. Through my experiences, I have found the most effective means for implementing change is to work alongside teachers. I co-teach to try new initiatives or model new approaches. I facilitate Professional Learning Teams in which I am one with the team that generates a collective mission statement and action plans to carry out goals. In this regard, I view my positionality as both an insider and outsider. I am an insider as I work within the organization and alongside the teachers with a common goal of student success. However, my position as the teachers' supervisor places me as an outsider, as I have a hierarchical position with a different level of power within the workplace (Anderson & Jones, 2000.) Reflecting on my multiple positionalities guided me to determine the best methodological approach for my research.

While reflecting on my positionality, I took a bird's eye view and envisioned myself on a river. At times the river runs slowly, and at other times the river picks up speed and carries me very fast. Either way, as I meander through my educational journey, my surrounding view is ever changing. My educational world twists to reveal new problems, turns to offer different perspectives, yet most importantly, continuously flows as I work to solve problems that are in motion around me. I realized that a research plan may be relevant for this moment, yet by the time the research is carried out, I may have been transported by the river's current, and my research design may not be exactly what is needed to solve the ever-evolving problems at hand. To me, active research allows one to gain real-time knowledge in the natural environment while being in the position to drive change. Kunz (2016) described methodological activism as methodological designs that work for change, so the researcher can situate themself within the process being studied. As an educational coach, I am situated within the learning environment along with the teachers. Specifically, action research supports professional development for teachers and results in real time changes that strengthen pedagogical practices to support student achievement. This confirmed my necessity to incorporate an action research approach for my qualitative research design.

**Data Collection Procedures**

Due to the cyclic nature of action research, there is no clearly defined beginning or end to the process. Data for this dissertation were analyzed from two of three cycles of action research. Cycle one consisted of identifying an area of need for professional development and coaching during the Spring of 2022. Based on field observations and reflections from elementary school teachers during coaching sessions, a need was identified to further support fourth grade teachers with the implementation of the 5-E lesson plan design and NYSSLS standards.

***Cycle One***

During cycle one, all fourth-grade teachers in four elementary schools from the Waterway School District, a suburban school district located in New York, were supported to implement a new 5-E STEM lesson aligned with the NYSSLS via coaching and co-teaching. The demographics of students in the Waterway School District were reported as 82% White, 12% Latinx, 3% Asian, 2% multiracial, and 1% Black. Gender was reported as 48% of female, and 52% male. 9.1% of students were eligible to participate in the federal free and reduced price meal program. 1.1% of students were English language learners and 13.0% of students were classified with disabilities. All fourth-grade classes were heterogeneously grouped, representing students with special education needs, gifted students, and consisting of students from diverse backgrounds that represented the overall demographics of the school district. The only exception was one section of students with special needs that required a small group setting of seven to one.

Teachers attended a professional development session in April of 2022. Then, I co-taught this lesson with each teacher in their classes. My collective observations from students' responses to the lesson and feedback from the teachers illuminated barriers present in the lesson design and elucidated the need to implement pedagogical strategies to eliminate these barriers. Hence, the second cycle began in May of 2023 where we applied UDL strategies to help eliminate learning barriers identified during the first cycle.

***Cycle Two***

I obtained permission from the school district and Molloy IRB committee in April of 2023 to collect data for the second cycle of this action research study. Three fourth grade teachers within one of the elementary schools in the Waterway School District volunteered to be part of the second cycle. They were initially interviewed in May of 2023 to gain a brief understanding of their background experience in teaching, impressions of the 5-E lesson design, and experience with UDL implementation, if any. The teachers then attended a PD session on the UDL framework and how it can be utilized to support the 5-E science engineering lesson taught the year prior to their fourth-grade classes. Specific UDL strategies were implemented to support each of the 5-E elements: Engage, Explore, Explain, Elaborate, and Evaluate. Teachers were given a scripted lesson module. The module outlined what to emphasize during each of the 5-E components of the lesson, and identified the UDL strategies incorporated. Teachers then carried out the lesson while I was present in the room. If they felt stuck, I supported them by jumping in and co-teaching.

The goal of cycle two was for teachers to observe students' responses to the lesson with the embedded UDL strategies, and to analyze the students' evaluation reflections to determine if they felt the UDL strategies reduced barriers to learning. I noted the areas the teachers felt intimidated to carry out on their own, as these areas would need to be further supported during future professional development sessions Then, in follow up individual interviews, and a subsequent focus group session, the teachers gave feedback on how to strengthen the PD session so that a new group of teachers can be trained and feel confident with the implementation of the UDL supported 5-E lesson plan. Specifically, professional development strategies and the UDL approach from cycle two were adjusted to further support teachers, enhance the teachers' own self-efficacy to carry out the lesson, and to eliminate any remaining learning barriers for students during cycle three.

***Cycle three***

Cycle three was carried out in the Fall of 2024 with a new group of fourth grade teachers from Dockside Elementary School, also located in a suburban school district within New York. The demographics of students were reported in this district as 85% White, 10% Latinx, 3% Asian, 1% multiracial, and 1% Black. Gender was reported as 48% of female, and 52% male. 13% of students were eligible to participate in the federal free and reduced price meal program. 2% of students were English language learners and 14.0% of students are classified with disabilities.

I obtained permission from the new school district and Molloy IRB committee to collect data for cycle three of this action research study. Four fourth grade teachers from Dockside Elementary School volunteered and participated in cycle three of this study. They were initially interviewed to gain a brief understanding of their background experience in teaching, impressions of the 5-E lesson design, and experience with UDL implementation, if any. The teachers then attended a PD session that was presented through the eyes of a student. Specific UDL strategies were implemented to support each of the 5-E elements: Engage, Explore, Explain, Elaborate, and Evaluate. Teachers carried out the lesson with the UDL strategies while I was present in the room. If they felt stuck, I supported them by jumping in and co-teaching.

The goal of cycle three was to determine if the suggestions implemented from cycle two increased the teachers' perception of feeling supported to carry out a 5-E STEM lesson with UDL strategies integrated throughout each component. As in cycle two, I aimed to understand the teachers' perception of how they felt the students reacted to the lesson, specifically with regards to successful UDL strategies that reduced barriers to learning, and to identify any barriers that may still exist. Additionally, during cycle three, I also aimed to analyze the teachers' responses to determine if the suggestions implemented by teachers in cycle two were helpful to further support teachers to support their students.

## Significance

This study addresses two identified gaps in the literature:

1) Implementing strategies to eliminate the barriers that prevent students from accessing knowledge-based content in the NYSSLS.
2) Supporting teachers to support students as learners as they emulate scientists while engaging in the "practices" of the NYSSLS.

The rationale for this qualitative study was to address the gap in research and utilize strategies from the UDL framework to eliminate unnecessary barriers to learning and assist teachers while students engage in the "practices" of the NYSSLS. Additionally, through teachers' perceptions, it offered a means to learn the possible benefits of implementing the UDL strategies to support teachers. A deeper understanding of teachers' perceptions can guide future professional development to support other teachers with the implementation of the NYSSLS, in addition to offering insights so all students gain access to the content and engage in equitable STEM learning experiences.

## Definition of Key Terms

The following key terms are utilized throughout this dissertation and are defined in this section to provide a clear understanding within the context of this research study.

**Action Research.** Action research is an inquiry based study that is done by or with insiders to an organization or community, but never to or on them. It combines reflection with action to identify and implement solutions to social problems (Herr & Anderson, 2014).

**Asset-based Pedagogy**. Asset-based pedagogies place value on students' insights, languages, and cultural practices, as well as seek to critique injustices, oppression, and other social-political issues (Flint & Jaggers, 2021).

**Constructivism.** Constructivism is an approach to teaching and learning based on the premise that learning is the result of mental construction. Students learn by learning new information and connecting it to what they already know (Bada & Olusegun, 2015).

**Culturally Responsive Teaching.** Using cultural knowledge, prior experiences, frames of reference, and performance styles of ethically diverse students to make learning encounters more relevant and to and effective (Gay, 2000).

**Equity.** Equity implies fair access to educational resources that advances social justice by allowing for self-determination and full participation in society (Feinstein & Meshoulam, 2014).

**5-E Lesson Design.** The 5-E lesson model consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Each phase has a specific function and contributes to students' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills (Bybee et al., 2006).

**Inclusive Learning Environments.** An inclusive approach to education where each individual's needs are taken into account and that all learners participate and achieve together (Milanovic, et al., 2023).

**New York State Science Learning Standards (NYSSLS).** The New York State Science Learning Standards are based on guiding documents grounded in research in science and scientific learning and reflect the importance of every student's engagement with natural scientific phenomenon at the nexus of three dimensions of learning: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts (New York State Education Department, 2023). The NYSSLS are based on the Framework for K-12 Science Education (National Research Council, 2012) and the Next Generation Science Standards (National Research Council, 2013).

**Self-Efficacy.** Perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave (Bandura & Wessels, 1994).

**Self-Regulated Learning (SRL):** A self-directed process where one transforms mental abilities to academic skills and consists of processes, such as self-efficacy, and particular strategies to optimize self-efficacy (Zimmerman 1990, 2002).

**Social Cognitive Theory.** A psychological perspective on human functioning that emphasizes the critical role played by the social environment on motivation, learning, and self-regulation. By interacting with others people acquire knowledge, skills, strategies, beliefs, and attitudes (Schunk & Usher, 2012).

**STEM.** The acronym STEM stands for Science, Technology, Engineering, and mathematics (Breiner, et al., 2012).

**Universal Design for Learning (UDL).** Universal Design for Learning (UDL) is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn. The UDL framework guides the design of instructional goals, assessments, methods, and materials that can be customized and adjusted to meet individual needs. (CAST, 2018).

**Zone of Proximal Development.** The distance between the actual developmental level, as determined by independent problem solving, and the level of potential development, as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978).

## Summary

The NYSSLS raised expectations for teachers to put students at the center of the learning environment as they participate in practices to emulate scientists and engineers. As with previous science reforms, there are barriers to learning that prevent all students from accessing the knowledge embedded within the standards as well as mastering the practices throughout a 5-E lesson design. Ahmad et al. (2018) reported that a constructivist approach to science education, with a focus on the students building their own knowledge during the learning process, resulted in students acquiring skills and a positive attitude toward science. The UDL framework and 5-E lesson plan design are rooted in constructivist theory (Allen et al., 2016; Omotayo & Adeleke, 2017) and together can provide strategies for teachers (Ergin, 2012; Banihashem et al., 2021) that reduce or eliminate barriers to learning for all students (Bahtaji, 2021; Root et al., 2022).

To successfully implement UDL and CRT strategies during science and engineering practices, teachers need to be provided with collaborative professional development support (Van Garderen et al., 2012; Allen & Heredia, 2021; Allensworth et al., 2022). This professional development should include a strong foundation in social cognitive theories (Stewart, et al., 2020), including self-efficacy (Van Aalderen-Smeets, et al., 2018; Falco & Summers, 2019) and self-regulated learning (Zheng, et al., 2020; Blackmore, et al., 2021; Wang, et al., 2021) to underpin the importance of scaffolding learning with UDL strategies to successfully bridge students across their zone of proximal development from one stage of the 5-E lesson design to the next.

In the next four chapters of this dissertation, I will elaborate on the content of this study. In Chapter 2, I will discuss the historical development of theory that leads up to the theoretical frameworks utilized to conceptualize this study. In Chapter 3, I explain the rationale of the methodology selected for the study, describe each cycle of the action research methodology in detail, give an overview of the site locations where the research will be conducted, describe the sample of participants, and elaborate on the process of data collection. In Chapter 4, I will describe the method of data analysis and how I utilized the chosen theoretical framework to analyze the data and discuss the thematic findings. Chapter 5 will offer a summarization of the study, my conclusions, a discussion on how my research adds novel findings to the literature, and finally, future implications for practice and research.

# Chapter 2

## Literature Review and Theoretical Frameworks

STEM fields are the most rapidly growing areas of employment in the United States. According to Pew Research Center (2018) STEM employment has grown 79% since 1990, with computer science jobs showing the biggest increase of 338%. This trend is expected to continue with a 9.2% increase of STEM jobs, as compared to 3.7% of employment overall, through the year 2029 (Pew Research Center, 2021). Despite the rapid growth of STEM related jobs, there remains a dearth of diversity among STEM employees. These inequities are prevalent in various STEM fields. Black and Latinx workers are underrepresented in all STEM areas and females underrepresented in the areas of physical sciences, computing, and engineering (Canning et al., 2019; Falco & Summers, 2019; Leggett-Robinson & Villa, 2020; Wood & Palmer, 2014). Black people make up only 6% of the work force in physical science fields, and 5% in engineering fields. The percentage of Latinx workers in physical science was reported at 8% and engineering at 9%. Additionally, women were reported to earn 53% of all STEM college degrees, yet only 40% earn degrees in the physical sciences and 15% earn a degree in engineering. Furthermore, although the earnings of STEM workers are higher than those who are not in STEM fields; the gender wage gap in STEM occupations is wider than in non-STEM jobs (Pew Research Center, 2018).

Sociocultural influences are attributed to the underrepresentation of historically marginalized groups in STEM fields. Researchers attribute the underrepresentation of historically marginalized students of color and women in STEM fields to many factors including low self-efficacy (Ellis et al., 2016; van Aalderen-Smeets et al., 2019), White privilege in STEM degree attainment (Riegle-Crumb et al., 2019), the ethnocentric and androcentric culture surrounding

STEM (Beck et al., 2021), gender-ability stereotypes (Bloodhart et al., 2020) and scientific identity (Camacho et al., 2021).

Several studies also identified curricular and pedagogical reasons for the racial and gender gaps in STEM fields. Eastman et al. (2017) investigated the relationship between underrepresented students and their personal experiences with engineering and reported that students stated they need “more personal, caring, and collaborative STEM experiences” (p. 908). Additionally, Canning et al. (2019) investigated how STEM professors' fixed mindset may undermine women’s performance. Their findings demonstrated that a professor’s fixed mindset beliefs trigger a stereotype threat among women. An abundance of research cites various sociocultural factors that result in the underrepresentation of historically marginalized students of color and women in STEM fields; however, there is a deficit in research reporting on ways to implement pedagogical practices in education that can enhance STEM self-efficacy for all learners.

Educational curricula reform shifted scientific practices in classrooms many times over the past decades. One commonality among all the science reforms is that none have reduced the inequality “gap” in certain STEM fields. Traditional science instruction consisted of decontextualized content and separate inquiry based activities (Park et al., 2022). Most recently, in 2016, the Board of Regents adopted the P-12 New York State Science Learning Standards (NYSSLS). One unique aspect of these standards is that they were developed from two different policy documents (Windschitl & Stroupe, 2017). The NYSSLS were developed from the foundations of the National Research Council’s Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (National Research Council, 2012), in addition to the Next Generation Science Standards (NGSS). The new state standards initiated a paradigm shift in focus from content to process. The new standards integrate engineering design practices into the science standards and have the potential to actively engage students by transposing their roles from passive learners to active participants (Park et al., 2022).

In 2018, New York State released a roadmap to transition to the new P-12 NYSSLS. The roadmap included the development, adoption, and implementation timeline. P-8 standards are currently rolled out as of the 2023-2024 school year, and 9-12 standards are expected to be fully implemented by 2026. Despite yet another reform in standards, three main problems persist with the NYSSLS. First, teachers are not guided on "how" to incorporate the standards into lessons. Instead, model lessons are offered without explicit support for teachers with theory based pedagogical strategies to guide learners throughout the learning process (Christian, et al., 2021). Second, a major shift in the language within the new standards takes the focus away from "inquiry" and incorporates a shift to "practices." Implementing these practices is difficult, as teachers are unsure of what practices actually look like during lessons (Osborne, 2014). Third, the standards alone are not enough to provide equitable learning opportunities for all students, as they do not offer a means to eliminate barriers to learning in STEM lessons. When teachers do not support students with scaffolded instruction, barriers to learning remain (Lannin, et al., 2023).

Exacerbating the problems, after the rollout of the NYSSLS follows the implementation of NYS tests in grades 5 and 8, and Regents exams in grades 9-12. Bybee (2013) expressed the concern of going "directly from standards to assessments without addressing curriculum and instruction as the teaching and learning connection" (p.31). Missing between the rollout of the standards and assessment are pedagogical strategies grounded in theory and research to assist teachers in supporting students through the learning process.

As described in Chapter 1, this action research study is focused on promoting equity in STEM by coaching teachers with UDL strategies for STEM lessons to enhance students' self-efficacy throughout the 5-E learning cycle in STEM lessons. In the following sections, I provide an overview of the NYSSLS, an expanded description of the NYSSLS and more detailed explanation of the problems associated with the rollout of these standards, the foundations of social cognitive and social constructivist theory, the Universal Design for Learning framework, Culturally Responsive Teaching, and the 5-E lesson plan cycle. The culmination of this chapter summarizes gaps in the literature and explains the significance of this study.

## New York State Science Learning Standards

The NYSSLS are based on Framework for K-12 Science Education (National Research Council, 2012) and adopted from the Next Generation Science Standards (National Research Council, 2013). The state standards reflect the importance of every student's engagement with natural scientific phenomenon at the nexus of three dimensions of learning: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts (New York State Education Department, 2023). Practices refer to the ways in which scientists and engineers interact with the natural and designed world (Krajcik et al., 2014). Duschl (2012) describes the disciplinary core ideas not a simple list of facts, but rather as powerful explanatory ideas that guide learners to explain aspects of the natural world. The crosscutting practices include patterns, cause and effect, scale, proportion, and quantity, systems and system models, energy and matter, structure and function, and stability and change. The integration of the practices, core ideas, and crosscutting concepts is referred to as three-dimensional learning (National Research Council, 2012).

### Challenges Within the NYSSLS

One challenge identified with the implementation of the NYSSLS is the shift from inquiry to practices (Emden, 2021; Osborne, 2011, 2014; Pruitt, 2014). Prior to the adoption of the NYSSLS, inquiry learning was grounded in decades of research and infused into every science classroom in the United States (Osborne, 2014). Although model lessons based on the NYSSLS still hint at the expectation of students to learn through an inquiry process, both the terminology and application of inquiry learning is not explicitly represented. Instead, there is a purposeful shift from inquiry to these practices. Pruitt (2014) explained the reason for the shift was that teachers often considered inquiry as a teaching method, rather than a way to assist students to connect content knowledge to the work that scientists do. There are eight practices listed in the NYSSLS: (1) asking questions and defining problems, (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics and computational thinking, (6) constructing explanations and designing solutions, (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information. This shift toward the importance of practices uprooted the concept of inquiry based learning and left science educators to struggle with a foundation for lesson development.

The shift to promote the importance of practices is not supported in the literature. Emden (2021) explained that the origin of "practices" remains unclear, and the philosophical foundation of the premise to shift from "inquiry" to these "practices" is greatly lacking in the research. Moreover, these "practices" only recently appeared in literature, as described by Osborne (2011, 2014). Osborne (2014) stated that "many of the aspects of the practices and how to incorporate them in the teaching of science will be unfamiliar" (p. 192). The researcher further explained that there is a body of knowledge and skills that are associated with the practices that need to be taught to students. Since the focus on these eight practices shifts the students' positionality from passive learners to scientists, successful incorporation of these practices into lessons requires teachers to scaffold knowledge and skills, in addition to encouraging and supporting students emotionally, as they productively struggle to work through the role of scientists. Yet, there is little support both within the standards themselves and within the literature providing teachers with specific strategies needed to successfully support students to emulate scientists while working through a NYSSLS based lesson.

Supporting teachers with the implementation of crosscutting concepts is also a challenge. Rivet et al. (2016) described how the crosscutting concepts act as the bridge between the core ideas of each discipline to the practices carried out by students as they emulate scientists. However, the researchers reported that the crosscutting concepts were one of the most difficult components to address while supporting teachers with the new standards. They further explained that the connection between the crosscutting concepts and the other two dimensions of the standards are vague, and that teachers struggle with the incorporation of the crosscutting concepts into their curriculum.

Another identified challenge is the incorporation of engineering practices into instruction. Stuart et al., (2021) reported that teachers displayed a lack of confidence with integrating engineering design in their classrooms. The researchers also reported that pre-service programs usually do not prepare prospective educators to incorporate the engineering principles of the NGSS. They further elucidated that many curricula used in science instruction include weak, if any, connections to engineering skills. Furthermore, engineering is interdisciplinary in nature and incorporates skills from both science and mathematics (Estapa & Tank, 2017). Harwell et al. (2016) state the importance of professional development to support teachers with integrating math and science during engineering lessons. Collectively, these challenges generate many barriers to learning for students and can amplify the already existing inequities among historically marginalized groups in STEM.

## Theoretical Framework

This section explains these theoretical frameworks that underpinned the development of my study in addition to providing a theoretical lens that will guide my analysis in Chapters 4 and 5. Specifically, this action research study aims to utilize the UDL Framework, CRT Framework, social cognitive theories, and social constructivist theories, to support teachers in supporting students to promote inclusive STEM pedagogical practices during a 5-E lesson.

### Social Cognitive Theory

Social cognitive theory accentuates learning from the social environment (Schunk & Usher, 2012). Bandura’s triadic reciprocality model was based on social cognitive theory and illustrated the interactions between behavioral, environmental, and personal variables, as they pertained to cognition and human motivation (Schunk, 2020). Triadic reciprocality is utilized as a lens to understand the uniqueness of individual learners as a product of their own interactions with their environment. Specifically, Bandura’s model explained that the environment influences one’s thinking, which in turn influences one’s behavior, that in turn influences one’s environment. Social cognitive theory paved the way for various models of social cognition, such as self-efficacy and self-regulated learning and more recently, productive struggle and growth mindset.

### Self-Efficacy

Self-efficacy is one subset of Bandura’s social cognitive theories. Bandura (2007) described self-efficacy as one’s perceived ability to perform a task to attain a specific goal.

Furthermore, Bandura et al. (2003) explained that self-efficacy is important for a learner to manage one's academic development, which is referred to as self-regulated learning (SRL). SRL is when a learner utilizes processes, such as self-efficacy, along with strategies that optimize self-efficacy to transform mental abilities to academic skills (Zimmerman, 1990, 2002). Bandura (2003) described four major principles that contribute to the development of self-efficacy: mastery experiences, vicarious experiences, social persuasion, and psychological arousal.

**Teaching Self-Efficacy**

Utilizing the construct of Bandura's self-efficacy, Tschannen-Moran et al. (1998) described teaching self-efficacy as a "teacher's belief in his or her own capability to organize and execute courses of action required to accomplish a specific teaching task in a particular context" (p. 233). Sandholtz et al. (2014) explained that elementary teachers are tasked with teaching all the subjects to their students and that their self-efficacy differs by content area. Banilower et al. (2018) stated that elementary teachers feel more prepared to teach life science as compared to the physical sciences and engineering. The researchers further reported that only 3 percent of teachers feel prepared to teach engineering standards and 51 percent expressed that they are not adequately prepared. This elucidated the need to enhance teacher's self-efficacy in the areas of physical science and engineering. Historically, there is a dearth of research focused on professional development practices to enhance teachers' self-efficacy in these STEM areas, with a more recent sprinkled emergence in the literature. Ingram et al. (2024) reported that pre-service teachers self-efficacy increased with regards to carrying a STEM lesson when the professional development was structured so that the teachers both conducted the inquiry-based STEM lesson as the student, in addition to facilitating the same lesson as a teacher.

**Self-Regulated Learning Strategies**

Self-regulation is important in education as it develops life-long learning skills (Zimmerman 2002). The goal of implementing SRL strategies is to explicitly coach students through self-regulation processes such as goal-setting, effectuating specific strategies, and reflective self-assessment. Zimmerman et al. (1992) reported that the combination of self-efficacy and goal setting contributes to academic attainment. Achievement goal theory (AGT) is within the constructs of social cognitive theory. Lin and Wang (2018) reported that the level of achievement goal orientations were predictors for metacognitive and self-regulatory strategies. In addition, the researchers explained that students who applied a mastery learning approach to goal achievement were more likely to carry out SRL when planning academic activities, monitoring thinking and academic behavior, and correcting and modifying their behaviors through self-regulated processes.

Zimmerman (1990) clarified the difference between self-regulated processes and the self-regulated learner. Specifically, self-regulated processes include perceptions of self-efficacy and strategies that can enhance self-efficacy, such as intermediate goal setting. Comparatively, self-regulated learners transform their mental abilities into academic skills to achieve their goals (Zimerman, 1990, 2002). Self-regulatory processes fall into the three cyclical categories forethought, performance, and self-reflection (Zimmerman, 1990, 2002). Forethought includes the components of goal setting and adopting strategies to attain goals. The performance phase incorporates strategies for self-monitoring of performance. During the reflective phase, students utilize self-evaluative methods and attribute causation to results, which ultimately influence future methods (Schunk & Zimmerman 1994, 1998).

Despite the abundance of research that supports the effectiveness of SRL strategies, educators seldom incorporate these strategies via explicit means into instruction (Kinstner et al., 2010). If the learning process is designed as teacher centered, rather than student-focused, then pedagogy itself becomes a barrier to student learning. Similarly, if the standards call for student centered instruction and teachers do not have the strategies to successfully scaffold the learning process for students, then barriers to learning will also exist. Barriers to learning have the potential to limit SRL and therefore one's self-efficacy. According to the philosophy of UDL, barriers to learning are within the constructs of the curriculum and not the individual learners (Meyer, et al., 2014). Therefore, utilizing the UDL framework to construct NYSSLS curriculum can support science and engineering practices by minimizing learning barriers through the support and development of scaffolding and self-regulated learning strategies, and ultimately cultivate self-efficacious students.

**Self-Regulated Learning Strategies in STEM Education**

Students should utilize specific SRL strategies during STEM activities. The identification of these specific strategies requires an analysis of the specific tasks performed by the learner (Lajoie et al., 2015; Lin et al., 2018). Recent research explores SRL strategies in STEM fields and include: identifying of self-regulated student profiles while engaging in engineering design (Zheng et al., 2020); investigating teacher support of SRL skills in secondary science (Porter & Peters-Burton, 2021); the role of SRL on science and design knowledge gains (Zheng et al., 2020); and the longitudinal changes of students' SRL profiles over time in a computer-aided design course (Li et al., 2020). In fact, Porter and Peters-Burton (2021) report that although secondary science teachers incorporated SRL coaching strategies of observation and emulation, over 50 percent of the teachers did not explicitly encourage students to self-reflect, which would guide students toward future cycles of SRL. Therefore, the identification of the specific SRL strategies needed for STEM lessons, in addition to supporting teachers with explicit coaching techniques to support students throughout the process is essential.

**Growth Mindset**

The ability for all students to persevere through STEM lessons requires a teacher that portrays a growth mindset. Carol Dweck proposed the motivational theory of growth mindset. Dweck (2016) described growth mindset as a belief about one's basic qualities, the belief that these qualities are cultivated by efforts and taking the initiative to utilize strategies and acquire help from others. Growth mindset refers to the belief that intelligence and abilities are malleable, whereas a fixed mindset refers to the belief that intelligence and beliefs are mostly innate (Nottingham & Larsson, 2019). Teachers that model either a growth or fixed mindset for themselves and their students ultimately influence student achievement.

Research supports the notion that a teacher's mindset influences the achievement of students. Muenks et al. (2020) reported that when students perceived their college professors to have a fixed mindset, they had lower class attendance, displayed less engagement, earned lower grades, expressed an interest to drop the class, and expressed less interest in STEM by the end of the semester. Canning et al. (2019) reported that faculty mindset was a direct predictor of student achievement and motivation. Additionally, mindset delineated as a stronger indicator for student success compared to other faculty's characteristics such as "gender, race/ethnicity, age, teaching experience, or tenure status" (p. 1). Conversely, the researchers reported that the perceived fixed mindset professors resulted in racial achievement gaps twice as large as compared to professors perceived to have a growth mindset. Moreover, Canning et al. (2021) reported that professors' fixed mindset may trigger stereotype threat among women in STEM, as they earned lower grades as compared to their male counterparts. These findings imply a correlation between the teachers perceived mindset and students' self-efficacy to successfully struggle through STEM courses.

**Social Constructivist Theory**

Piaget's (1973) cognitive theory explained that knowledge is both constructed and reconstructed through personal experiences resulting from interactions with objects and phenomena. Bruner (1977) expanded on Piaget's theory and explained that learners compare new ideas to old experiences as they search for similarities and differences to construct meaning (Galkiene & Monkeviciene, 2021). A social constructivist view of teaching and learning encourages interaction with the environment and others through exploration, inquiry, in addition to peer-to-peer and peer-to-teacher interactions as students explain their ideas to make meaning. Vygotsky's (1978) Social constructivist theory added the importance of learners interacting with one another and their teachers as they are engaged in the learning process to construct their own knowledge. Vygotsky further explained how social interactions were necessary to mediate learning within a learner's zone of proximal development.

**Zone of Proximal Development**

Zone of proximal development (ZPD) is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978). Admawati and Jumadi (2018) explained that Vygotsky's ZPD is central to all social constructivist theories because it describes the difference between what a student can learn on their own and what they are able to learn with assistance. Vygotsky also explained that higher psychological functions in humans are a product of both cultural and historical development (Murphy, 2022). Tuomi (2012) reported that neuroscientists found close links between brain memory research and Vygotsky's ideas about learning and development. Educators who familiarize themselves with neuroscience research tend to incorporate experiences into curriculum that promote higher level complex thinking and support students through these learning opportunities through scaffolding through their ZPD (Murphy, 2022).

## Universal Design for Learning Framework

The Center for Applied Special technology (CAST) applied the concepts of universal design to curriculum materials and methods in the early 1990's and named it the Universal Design for Learning (Hitchcock, et al., 2002). UDL is defined as a set of principles and techniques utilized for lesson design along with instruction materials that enhance accessibility (Courey et al., 2013). The framework is based on the foundation of growth mindset, self-efficacy, and self-regulation theories (Meyer, et al., 2014). The UDL framework was originally designed to shift the burden of reducing obstacles for learning away from special education teachers and students and offer a means to support all learners in the general classroom setting (Rose & Meyer, 2002). More recently, the UDL framework is utilized in various discipline specific areas (Dazzeo & Rao, 2020; Garderen et al., 2012; Lambert, 2021; Mackey, 2019). In 2018, CAST conducted a review of existing literature of reported UDL best practices and subsequently constructed the UDL Reporting Criteria. These criteria were designed with the intent to provide guidelines for researchers and practitioners for designing and reporting on UDL implementation (Cook & Roa, 2018). To streamline the implementation and reporting process, CAST also devised the UDL Guidelines Checklist with a total of nine guidelines and thirty-one checkpoints.

### Structure of the UDL Framework

The UDL framework consists of three guiding principles: providing multiple means of representation, action and expression, and engagement. Within each of the three principles, the framework if focused on providing access to learning goals, building skills and knowledge, empowering learners through self-regulation strategies, and gaining a deeper understanding while utilizing executive functions (Root et al., 2022). Hitchcock, et al. (2002) explained that UDL framework aims to challenge with appropriate supports. For example, goals are to provide appropriate challenges, materials are presented in flexible formats to support transitions between media and multiple representations of content for all learners, methods chosen are flexible and diverse to provide both support and challenges, and assessments are flexible, ongoing, and incorporate choice.

**Neuroscience of UDL**

UDL is grounded in neuroscience research. The framework is based on three classes of neural networks that are involved in the learning process: affective networks, recognition networks, and strategic networks. Affective networks are responsible for determining priorities and are involved with motivation. Recognition networks are responsible for sensing and interpreting information in the environment and transforming the messages into usable knowledge. Strategic networks are responsible for planning, organizing, and initiating one's actions (Meyer, et al., 2014). The UDL model of these three classes of brain networks aligns with other researcher's theories. Vygotsky described three prerequisites for learning: engagement with learning tasks, recognition of information to be learned, and strategies to process information (Meyer, et al., 2014). Similarly, Bloom's taxonomy divided educational objectives into three categories: cognition, psychomotor, and affective (Simpson, 1972).

**UDL and STEM**

The Universal Design for Learning (UDL) framework offers a means to construct curriculum that increases accessibility to content, fosters a supportive sociocultural environment, and in turn cultivates self-efficacious STEM students. Accessibility to content knowledge, scaffolding of the knowledge and skills, and positive sociocultural support are required for the successful implementation of the NYSSLS. According to the philosophy of the UDL, barriers to learning are within the constructs of the curriculum and not the individual learners (Meyer, et al., 2014). Additionally, the researchers elucidated that the underlying philosophy of the UDL framework is to cultivate individuals to become "experts" as learners while on their "continuum of development" (p. 21). In recent literature, scholars interpreted the utilization of UDL as a social justice approach to cultivate inclusive learning environments (Griggs & Moore, 2023; Hanesworth, et al., 2019; Lanteigne, et al., 2022; Worster & Rohde, 2020).

**Culturally Responsive Teaching**

Meeting the needs of all students entails embracing their individuality and understanding their backgrounds and cultures. Literature in the 1990s cited a disproportionate number of African Americans and Hispanic students that experienced academic failure (Siwatu, 2007). Gay (2000) and Ladson-Billings (2000) called for the need for pedagogical training in cultural responsiveness. Gay (2000) defined culturally responsive teaching (CRT) as "using the cultural knowledge, prior experiences, frames of reference, and performance tyles of ethnically diverse students to make learning encounters more relevant to and effective for them" (p. 29). CRT acknowledges and capitalizes on strengths of students, their personal experiences, knowledge, and cultural practices to serve as resources for teaching and learning (Budinoff & Subbian, 2021).

**UDL and CRT**

UDL and CRT are both considered asset-based pedagogies. These asset-based pedagogies focus on the strengths that induvial learners bring into the classroom, rather than a deficit-based mindset. Various researchers report on the benefit of considering both UDL and CRT to address the needs of historically marginalized learners. Kieran and Anderson (2019) describe the overlap between UDL and CRT. The researchers explain that both UDL and CRT are focused on the potential barriers within instruction, lesson materials, and assessments rather than student-centered deficits. Chardin and Novak (2020) explained the link between social justice and UDL and the importance of creating more inclusive and equitable classrooms by designing a framework that is culturally responsive and equitable. Coleman and Davis (2020) reported on the beneficial impact of asset-based instructional practices on critical thinking and STEM academic efficacy among Black middle school boys. Since the NYSSLS introduction and NGSS appendix fuel normalized oppression by exemplifying a deficit mindset for historically marginalized groups, the combination of UDL and CRT is essential for inclusive education.

## 5-E Lesson Plan

One of the earliest described learning cycles was the Atkin and Karplus learning cycle from the early 1960's (Bybee, et al., 2006). The Atkin-Karplus learning model consisted of three cycles: exploration, invention, and discovery. Based on cognitive theory, the learning cycle allows students to make connections between prior knowledge and new learning experiences (Brown & Abell, 2007). Various versions of "E" learning cycle emerged over the years, with the 5E lesson plan design as one of the most well-evidenced practices in science education over the past 50 years (Hanuscin & van Garderen, 2020). The 5-E model incorporates engagement, exploration, explaining, elaborating, and evaluating into the learning cycle. Ergin (2012) described the 5-E lesson design as a constructivist model of teaching that incorporates higher level thinking by promoting exploration, inquiry, and direct experiences, while encouraging students to communicate with one another. Ergin, et al. (2008) reported that the 5-E model resulted in higher student success during science lessons and were more likely to develop a positive attitude toward the subject taught, as compared to traditional means of teaching.

## Crosscutting Concepts: 5-E Lesson, NYSSLS and UDL

McFadden et al. (2021) explain how the 5-E lesson design can be utilized to implement the standards in the NGSS. The researcher further explained how the 5-E lesson model can be utilized to support teachers with planning lessons to integrate the multiple performance expectations within the NGSS. I propose that strategies from the UDL framework can be integrated within each phase of a 5-E NYSSLS lesson to coach teachers to support students while they engage in scientific practices.

### 5-E Engage and UDL Supported NYSSLS

During the first phase of the 5-E lesson cycle, students are mentally engaged and offered the opportunity to tap into their prior knowledge. The NYSSLS incorporated anchoring phenomena into STEM practices. When presented with a phenomenon, students generate their own questions to gain a stronger understanding of the phenomena presented (Park et al., 2022). The presentation of phenomena offers the opportunity to elucidate any student misconceptions. Phenomena are strategically placed in the introduction to a new lesson (engage phase), and the resulting student-generated questions are the springboard for further metacognitive learning activities throughout the learning process. Once students begin their metacognitive journey by generating their own questions, they can begin the cycle of reflective thinking. Lemley et al. (2019) explained that metacognition occurs when students evaluate their own thinking by posing questions that offer a way to investigate and reflect on their learning process. Deverel-Rico and Heredia (2012) explained that phenomena based instruction increases accessibility to content for all learners by supporting exploration and inspiring curiosity and excitement about science.

A challenge related to utilizing an anchoring phenomenon is the assumption that all students have prior knowledge related to the presented phenomenon and the self-efficacy to share observations and generate questions. Research indicates the importance of incorporating student's personal experience and prior knowledge to reduce the inequities present in traditional science teachings (Barton & Tobin, 2002; Lee, et al., 2007; Hayes, et al., 2016). Strategies from the UDL framework can be implemented by teachers during the phenomena phase to scaffold learning through students' zone of proximal development and support them to generate their own questions.

One creative way to engage students throughout the 5-E NYSSLS lesson is the use of story lines. A story line includes presenting a phenomenon to spark questions, a sequence of investigations to figure out part of the story, and a culminating performance expectation to put the story together. Some possible UDL strategies to implement during the engage/phenomena phase include: choosing a phenomena that elicits related prior knowledge connected to the lesson objective; utilizing visuals (the presented phenomena); utilizing a graphic organizer, such as a T-chart, to list their observations and related student generated questions; offering an alternate means to report their observations or thoughts such as sketching or drawing, guiding students with explicit directions in each step, such as record your observations (list/draw) under the "what I notice" part of the T-chart and record (list/draw) your questions under the "what I wonder" part of the T-chart. These strategies implemented also scaffold students from the cognitive level (observations of phenomena) to the metacognitive level (generating their own questions about the observed phenomena).

**5-E Explore and UDL Supported NYSSLS**

The second phase of the 5-E cycle allows students to explore while the teacher acts as a facilitator or coach. This hands-on minds-on phase of the learning cycle is also referred to as the "meaning making" portion of the lesson. During this phase students explore first and explain later, which deviates from traditional teaching where students would be given background knowledge before proceeding into the hands-on part of the investigation. NYSSLS incorporated many practices, where students emulate scientists during explorations. Students are expected to carry out an investigation to discover relationships, patterns, make initial connections to the phenomena, and begin to construct their own explanations from the exploration phase (Koval, et al., 2018).

A challenge with the exploration component of the NYSSLS is that students need to emulate the highly complex tasks scientists navigate as they conduct empirical investigations (Hayes, et al., 2016). Often, teachers utilize cookbook style protocols from traditional science laboratories that do not offer students the opportunity to reach a higher cognitive level of engagement. Strategies from the UDL framework can be implemented by teachers during the exploratory phase to support students with scaffolding and self-regulated learning as they actively carry out the practices within the NYSSLS. One strategy to increase engagement includes activities that foster the use of student imagination to solve relevant problems in creative ways. These activities should be tied into the story line. To support scaffolding and self-regulated learning throughout the storyline during the exploratory phase, the following UDL strategies can be implemented: creating cooperative groups and setting clear goals, roles, responsibilities and expectations; explicitly stating self-regulatory goals to reduce the frequency of outbursts in response to frustration; support planning and strategy development through the use of checklists and a sequence of steps, and facilitate the management of information through the use of graphic organizers for data collection and analysis.

**5-E Explain and UDL Supported NYSSLS**

The third phase of the 5-E learning cycle initiates students to construct understanding and explain the ‘how” of the lesson. During this phase, the teacher asks the students to offer their own explanations. Content specific terminology is introduced during this phase. Based on the standards, students are expected to generate their own definitions of new scientific vocabulary through their exploratory experiences. Teachers are expected to guide students to connect their experiences from the exploratory portion of the cycle to this content portion. The NYSSLS places an emphasis on evaluation and explanation, as the standards call for modeling, evaluating, and argumentation, while students evaluate and construct explanations based on evidence and models. Students are also expected to engage in discourse and communicate while utilizing scientific language and practices.

A challenge with the explanation phase is the difficulty students have composing arguments and linking their claims to evidence (Jimenez & Erduran, 2007). Additionally, without proper scaffolding, students struggle to generate their own definitions for newly introduced vocabulary. Strategies from UDL can be incorporated by teachers during the explanation phase of the lesson to support students. These strategies include the incorporation of explicit opportunities for review and practice, scaffolds that connect new information to prior knowledge, and revisiting key ideas and providing explicit linkages between ideas. Additionally, small group interactions and fostering environment of community learners is important to establish collaboration and discourse among peers. When established, students can work together to make connections to phenomena and exploratory portion to devise their own definitions to new scientific terminology (Hayes, et al., 2016). Other important UDL strategies needed throughout the explain phase is to explicitly increase mastery-oriented feedback, encourage perseverance, efficacy, and improvement.

**5-E Elaborate and UDL Supported NYSSLS**

The fourth phase of the 5-E learning cycle encourages an in-depth analysis with real-world connections. Student understanding should continue to build, and any remaining misconceptions should be clarified. This is accomplished through peer-to-peer and peer-to-teacher conversations, and students receive feedback to strengthen their understanding. The NYSSLS focuses on the clarification of misunderstanding and building on content knowledge. During this phase, students can build upon the story line and make real world connections. Real world problems can also be identified, and students can generate possible solutions to real-world problems. This phase, once again, demands high cognitive and metacognitive levels of thinking and learning.

The major challenge with this phase is the lack of literature on how teachers can move students from simply conducting activities to scaffolding towards a high level of cognitive involvement expected within the NYSSLS (Hayes, et al., 2016). Research indicates the importance of discourse during scientific practice (Colley & Windschitl, 2016; Lin & Chan, 2018). Additionally, scaffolded participation in dialogue in both small group and whole class, both with and without the teacher, has been found to increase academic language acquisition and scientific reasoning (Fridberg, et al., 2018; Hong, et al., 2013; Linn et al., 2013). UDL strategies that can support the elaboration phase to reduce misconceptions, initiate higher level cognitive thinking to build upon the understanding of newly acquired information, and strengthen problem solving include: Highlighting and discussing the big ideas and relationships; transferring previously learned skills to new unfamiliar scenarios; provide scaffolds to transfer generalization from prior knowledge to new situations; encouraging students to communicate their ideas in both small and larger groups; and explicitly state that they will build upon their own knowledge as they share ideas with others.

### 5-E Evaluate and UDL Supported NYSSLS

The fifth phase of the 5-E learning cycle acts to both evaluate students' understanding and provide feedback. Although formative assessment occurs throughout all 5 phases, this phase of the cycle provides an opportunity to evaluate individual students as they express their understanding and provide additional feedback. Hayes et al. (2016) explained that formative assessments of higher-order thinking should be embedded within and throughout science lessons. They further elucidated that formative and summative assessments should include open-ended components that encourage students to synthesize and apply what they have learned in novel ways.

Clear strategies for assessment for the NYSSLS remain unclear (Cian, et al., 2019). Edgerly et al. (2018) reported on the importance of creating a positive feedback culture during science lessons. UDL strategies for formative and summative assessment can include supports for planning and strategy development, prompts to "show and explain," checklists for self-monitoring progress and skills for student self-reflection, and providing assessment options for recruiting interest.

## Significance of Current Study

STEM education should foster creative, inquisitive, independent thinkers who can observe, analyze, problem solve, and formulate accurate and innovative interpretations of their world. As cited in the literature at the start of this chapter, inequities persist with regards to racial and gender diversity among people employed in various STEM fields and is most prevalent in the areas of engineering and physical sciences. As with previous science reforms, the NYSSLS still contain barriers to learning that prevent students from accessing the knowledge embedded within the standards as well as mastering the practices throughout a 5-E lesson design. The purpose of this study is to address two identified gaps in the literature:

3) Implementing strategies to eliminate the barriers that prevent students from accessing knowledge-based content in the NYSSLS.
4) Supporting teachers to support students as learners as they emulate scientists while engaging in the “practices” of the NYSSLS

UDL is a dynamic approach to curriculum development, as it encompasses the understanding and growth of an individual learner and their dependency on social interactions to make sense of their world. I propose that strategies from the UDL framework can be utilized to eliminate unnecessary barriers to learning and assist teachers while students engage in the “practices” of the NYSSLS.

The following research questions will guide this study:

**Primary Research Question**: How do teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices?

**Sub-Question 1**: How do teachers coached in UDL strategies perceive their effectiveness in supporting students during each of the 5-E components of the lesson?

**Sub-Question 2**: What UDL strategies were perceived as effective in reducing or eliminating learning barriers within specific components of the 5-E lesson?

**Sub-Question** 3: What additional strategies do teachers recommend to further reduce or eliminate barriers to learning.

## Conclusion

This chapter described the theoretical frameworks of social cognitive, social constructivist, and the UDL framework that guided my inquiry on how to coach teachers to support students through a 5-E NYSSLS aligned lesson. The inequities in STEM professions were reviewed as were some reasons for barriers to learning in STEM education. This chapter concluded with the crosscutting concepts that support my research questions, specifically how UDL strategies can be embedded within each component of a 5-E NYSSLS aligned lesson to eliminate unnecessary barriers to learning within the NYSSLS. My chosen research design is discussed in Chapter Three, along with how I envision conducting this action research study with fourth grade science teachers.

# Chapter 3

## Research Design and Methodology

This chapter describes the research methods I utilized to conduct a qualitative, action research study in heterogeneously grouped 4th grade classes within two suburban school districts in New York. This research utilized the UDL framework, through the lenses of social cognitive and social constructivist theories (Meyer et al., 2014) in conjunction with the CRT framework and NYSSLS to develop lessons that exemplify inclusive STEM pedagogy. Specifically, I sought to understand how teachers' pedagogies and reflections change with the implementation of the UDL and CRT frameworks in conjunction with the NYSSLS.

### Research Problem as Established in Literature

As established in previous chapters, I identified two critical issues with the implementation of the NYSSLS that need to be addressed. Firstly, teachers are presented with a shift in pedagogical focus from inquiry designed lessons to the “practices’ as outlined in the NYSSLS. However, the “practices” are merely outlined in the standards without specific examples illustrating how to incorporate them into the curriculum. Furthermore, these “practices” shift the students’ positionality to emulate “scientists” within the classroom. This requires teachers to scaffold the knowledge and skills within the students’ ZPD and to encourage and support students emotionally, as they productively struggle to work through the role of scientists. Secondly, the introductory document for the NYSSLS and Appendix D of the NGSS standards report on 2-7 marginalized groups in the fields of STEM, respectively, that need special attention to be successful in these standards. However, The NGSS Appendix D offers limited research indicating strategies to support each of the “non-dominant” groups, and they acknowledge a gap in the research which would offer strategies that can apply to all groups of students. To address these two critical issues, this action research study is guided by the theoretical frameworks of Universal Design of Learning (Meyer et al., 2014) in addition to social cognitive theory and social constructivism. The UDL framework will be utilized in this study to design specific pedagogical practices for NYSSLS curriculum development with the intent to reduce barriers to learning and increase students' self-efficacy in STEM. Additionally, through the lens of social constructivism, curriculum will be designed that encourages students' personal interpretations of their world via collaborative interactions with their peers and teacher.

The rationale for this qualitative action research study was to address the gaps identified in the research regarding supporting students as learners as they emulate scientists while engaging in the "practices" as outlined by the NYSSLS and to eliminate barriers that prevent students from accessing knowledge-based content in the NYSSLS. UDL can be implemented as a possible curriculum framework to support the NYSSLS. Additionally, it is important to learn through the lens of the teachers' experiences how implementing UDL strategies can potentially eliminate barriers for students. Utilizing an active research approach towards professional development has the potential to initiate a reflective process for teachers throughout the entire implementation process. This in turn sustains continuous learning that can potentially facilitate teachers to deeply reflect on their practices and ultimately lead to the needed change towards inclusive STEM pedagogical practices.

**Research Purpose and Questions**

The purpose of this qualitative action research study was to explore how coaching teachers to utilize the Universal Design for Learning framework in conjunction with the 5-E lesson plan design can support teachers in the creation of inclusive environments where all students develop self-efficacy in STEM. The following research questions guided this study:

**Primary Research Question**: How do 4th grade teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices?

**Sub-Question 1**: How do 4th grade teachers coached in UDL strategies perceive their effectiveness in supporting students during each of the 5-E components of the lesson?

**Sub-Question 2**: What UDL strategies were perceived as effective in reducing or eliminating learning barriers within specific components of the 5-E lesson?

**Sub-Question** 3: What additional strategies do 4th grade teachers recommend to further reduce or eliminate barriers to learning?

In the following sections of this chapter, explanation will be provided for the following components of this study: (a) research paradigm, (b) role of the researcher, (c) participants, sampling techniques, and setting, (d) data collection procedures, (e) data analysis procedures, (f) authenticity criteria, (g) limitations, and (h) a summary.

To answer the research questions in this study, I utilized qualitative methodology. Qualitative research studies are conducted in the natural setting, placing the researcher in a position to directly observe and collect data within the context of where the problem occurs (Bogdan & Biklen, 2016). This fosters the potential for a deep understanding of the social setting, activities, and perceptions of participants. (Bloomberg & Volpe, 2019). Descriptive data is collected and inductively disseminated in the written form, with a focus on the process rather than the outcome of a study (Bogdan & Biklen, 2016). Qualitative studies are interpreted through the lens of constructivist, critical, or advocacy philosophical frameworks. Conversely, quantitative research investigates relationships and cause and effect phenomena through the lens of a postpositive paradigm (Creswell & Creswell, 2018). Creswell and Poth (2018) explained how philosophical assumptions and interpretive frameworks guide the researcher to select a specific qualitative research design. My qualitative study employs an action research methodology.

**Procedures**

The epistemological worldview guiding this study was transformative, which is aligned to action research in addition to the social cognitivist and social constructivist theoretical frameworks described in chapter two. Epistemological assumptions ask "how" in the pedagogical approaches of educational research (Bogdan & Biklen, 2016). The transformative worldview is based on the premise that the research conducted will include an agenda that leads to change in the action of all participants, including the researcher, in addition to the schools in which they work (Creswell & Creswell, 2018). The term "action research" was first phrased by social psychologist Kurt Lewin (1946), as his work followed a repetition of steps throughout the research design. Historically, the foundation of action research is grounded within John Dewey's philosophies of human experiences, active learning, and knowledge generation (Herr & Anderson, 2015). Different researchers take on different perspectives of action research, yet all have one commonality: All action research is characterized by its cyclical pattern of planning, acting, observing, and reflecting (Herr & Anderson, 2015). There are various action research studies in the field of science education. Laudonia et al. (2018) reported a meta-analysis of 149 journal articles/book chapters reporting on action research in science education. Additionally, Herr and Anderson (2015) refer to action research as a "transformational power" (p. 61) as it can be utilized as a means of professional development to promote institutional change.

The action research transformative epistemological approach was selected with the ambition to construct a scientific curriculum that reduces the underrepresentation of historically marginalized groups minority in STEM fields by eliminating unnecessary barriers to learning utilizing strategies from the UDL framework. Incorporating an action research approach allows for co-planning and collaboration with teachers, and the flexibility needed for our ever-evolving educational setting, as each class is composed of unique learners with needs that also change over time. Specifically, an action research approach to professional development and lesson implementation for a specified NYSSLS lesson can assist teachers with strategies to implement the UDL framework in future lessons to support students during science and engineering practices. Ultimately, triangulating the qualitative findings can offer a means of naturalistic generalization (Herr & Anderson, 2015; Stake, 1986). Practitioners can relate to naturalistic generalization, as the narrative accounts from teachers and their classrooms translate into vicarious experiences for other professionals in the education field (Herr & Anderson, 2015). The selected framework offers a means to explore how coaching teachers to utilize the Universal Design for Learning framework can support students during science and engineering practices.

**Participants and Setting**

This Action research study consisted of three cycles of research. Data included in this study was from cycles two and three. Cycle two included three participants that comprise of a fourth grade team of teachers in Creekside Elementary School, located in a suburban school district in New York State. All 3 participants were White females. The demographics of students in this district at the time was reported as 82% White, 12% Latinx, 3% Asian, 2% multiracial, and 1% Black. Gender was reported as 48% of female, and 52% male. 9.1% of students were eligible to participate in the federal free and reduced-price meal program. 1.1% of students were English language learners and 13.0% of students were classified with disabilities. Cycle three of this action research study was designed to include new teacher participants that were not familiar with professional development and lesson design. Cycle three participants consisted of four fourth grade teachers. Two teachers were white females and two were white males. The demographics of students in this district for cycle three was reported as 85% White, 10% Latinx, 3% Asian, 1% multiracial, and 1% Black. Gender was reported as 48% of female, and 52% male. 13% of students were eligible to participate in the federal free and reduced-price meal program. 2% of students were English language learners and 14.0% of students were classified with disabilities.

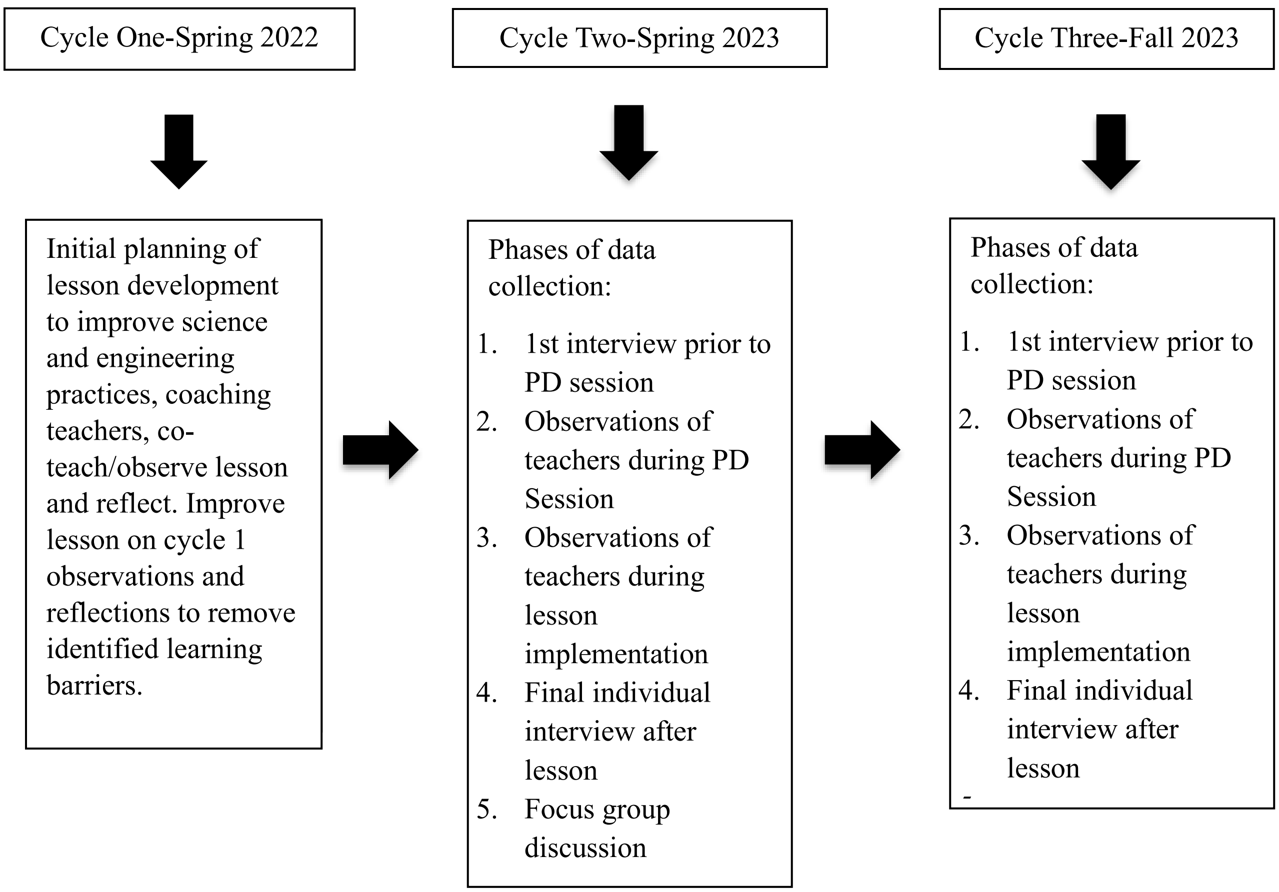
**Methods for Data Collection**

Action research is unique in that it does not necessarily have a clear beginning and end point. Rather, it constitutes a series of cycles and interventions throughout. The data collected for this dissertation constituted research from two of the three cycles. Figure 1 illustrates the action research cycles and context of data collection steps for this study. This study followed the structure of action research cycles, as outlined by Kemmis (1982). The researcher listed 4 main components of the action research cycle:

1. Develop a plan of action to improve what is already happening;
2. Act to implement the plan;
3. Observe the effects of action in the context in which it occurs; and
4. Reflect these effects as a basis for further planning, subsequent action and on, through a succession of cycles (p.7).

**Figure 1**

**Cycles of Action Research and Dissertation Data Collection**




## Overview of Three Cycles of Action Research

Cycle one consisted of identifying an area of need for professional development and coaching. Fourth grade teachers were supported to implement a new 5-E STEM lesson aligned with the NYSSLS via coaching and co-teaching. The second cycle applied UDL strategies to eliminate learning barriers identified during the first cycle. Based on teacher feedback from cycle two, professional development strategies and the UDL approach from cycle two were augmented, in addition to the incorporation of CRT strategies to eliminate any remaining learning barriers during the STEM lesson in cycle three.

***Cycle One***

The initial lesson design was created and implemented In the Spring of 2022. Thirteen fourth grade teachers participated in professional development and co-teaching sessions in four elementary schools within the Waterway School District on Long Island. As the lesson was implemented in each fourth-grade class, pedagogical strategies naturally evolved from classroom to classroom based on the observations of students' responses to the lesson, reflections from teachers, and reflections from the coaching perspective. At the culmination of all lessons, remaining learning barriers were identified. Subsequently, I identified specific UDL strategies applicable to each component of the 5E lesson design that could potentially eliminate the identified learning barriers. Additionally, explicit coaching strategies were added to the module utilized for the cycle two PD sessions.

***Cycle Two***

The new lesson, with UDL strategies was implemented during Cycle two in the spring of 2023. IRB approval (see Appendix A) for this cycle of action research was attained from Molloy's IRB committee on April 27$^{th}$ of 2023. A fourth-grade team in Creekside Elementary School in the Waterway School District, comprising of three teachers of the original 13 participants, were recruited via a purposeful sampling technique utilizing a recruitment letter. The three participants had 14, 20, and 22 years of teaching experience. The timeline for data collection for cycle two took place over a four-week period. Cycle two comprised of an initial ten-minute individual interview with each teacher, a professional development session, lesson implementation, a 20 minute post lesson individual interview, and a 30 minute focus group session. Prior to the initial interviews, participants signed the Informed Consent Form. Initial interviews with the teachers were semi-structured and conducted to attain background information on their teaching experience, views of STEM education, current class demographics, and knowledge, if any, on the UDL framework (see Appendix C). I facilitated the UDL professional development session. During this professional development session, the team of teachers discussed each component of the 5-E lesson design. The module was scripted to explicitly emphasize the UDL strategies applied to each component (see Appendix E). Since this group of teachers were familiar with the lesson from the prior action research cycle, the emphasis of the professional development session focused on the implementation of UDL strategies, rather than hands-on training. The teachers implemented the lesson on their own with me as an observer. After lesson implementation, another round of semi-structured interviews took place (see Appendix D). The fourth and final round of data collection was in the form of a focus group, to collectively reflect on the newly implemented UDL strategies.

***Cycle Three***

Based on participant feedback and data analysis from Cycle two, improvements were made to the lesson design and professional development session. Feedback from teachers during cycle two stressed the importance of going through the lesson through the eyes of the student in a hands-on manner during the professional development session. Additionally, feedback during the final interviews and focus group session included positive impressions with offering the students choice for the evaluation component.

IRB approval (See Appendix B) for cycle three was obtained from Molloy's IRB committee in the Fall of 2023. Four teachers from Dockside Elementary School participated in cycle three of this study during the Fall of 2023. Five teachers originally agreed to participate, with one participant dropping out of the study due to a personal situation. Each participant took part in a pre-interview before the professional development session, and a post-interview after lesson implementation. The four participants had 5, 5, 19, and 26 years of teaching experience. The timeline for data collection took place over a five-week period.

Cycle three comprised of an initial ten-minute individual interview with each teacher, a professional development session, lesson implementation, and a twenty-minute post lesson individual interview. Prior to the initial interviews, participants signed the Informed Consent Form. Initial interviews with the teachers were semi-structured and conducted to attain background information on their teaching experience, views of STEM education, current class demographics, and knowledge, if any, on the UDL framework. I facilitated the UDL professional development session. During this professional development session, teachers navigated the lesson, through the eyes of a student. After each component of the 5-E lesson, I verbally explained the UDL strategies implemented for that component of the lesson. After lesson implementation, I conducted a second round of interviews that focused on the teacher's perception of their ability to successfully carry out the lesson regarding the actual experimental apparatus and implementation of UDL procedures.

**Research Memos**

For each round of interviews, professional development sessions, and the focus group session, I documented my perceptions of the teachers' reactions to questions, the professional development session, and their reflections during the focus group. As I documented the teachers' perceptions to questions, I also noted any non-verbal communication that may shed light on the teachers' thoughts and feelings throughout the process. I took fieldnotes during the lesson implementation. During the lesson I focused on how closely the teachers followed the lesson module for cycle two, noted any deviations the teacher felt the need to implement, include my perceptions of nonverbal body language of the teacher, and overall, tried to document my own insight, thoughts, and feelings through both cycles two and three.

**Consent and Confidentiality**

To secure the confidentiality of the participants and their responses, all procedures for participant information and data collection were in accordance with IRB requirements. After IRB approval and just prior to the first interview, participants were asked to sign the consent form. The confidentiality of their responses was explained prior to the first interview. I also explained that they may drop out of the study at any point without any repercussions. Participants were asked to agree to electronically record their interview sessions. Additionally, all participants received a copy of their signed consent forms. The electronically recorded interviews transcribed via Rev.com. The transcribed interviews were stored on a password-protected computer. Throughout this dissertation, individual participants were given pseudonyms, along with the name of their specific schools and districts.

**Data Analysis**

Individual interviews were transcribed via Rev.com. The transcribed interviews and researcher's memos were uploaded onto the Dedoose platform. Dedoose was utilized to qualitatively analyze the transcripts and research memos for themes and patterns. As themes emerged throughout the study, descriptive codes were utilized to identify patterns until data saturation was reached. Patterns from the second round of interviews guided the focus group session of cycle two. Keeping an open mind about possible codes was important, as themes emerged that were not initially expected. Code emergence during cycle two resulted in suggestions to improve the PD session for cycle three. Additionally, analysis of cycle two shed light on remining barriers to learning, and resulted in the implementation of CRT practices in cycle three. Data from the PD sessions, field observations, cycle toe focus group, and interviews were triangulated.

**Authenticity Criteria**

While action research falls under the umbrella of qualitative studies, the validity criteria for such studies are different compared to other traditional qualitative research (Herr & Anderson, 2015). Guba and Lincoln (1989) described specific criteria for judging the trustworthiness of a qualitative research design. Reflecting on the dynamics of an action research design, the researchers' description of authenticity criteria aligns with the methodology of the cyclic nature of action research. They further explained that fairness and ontological, educative, catalytic, and tactical authenticity should be considered during the planning and implementation of action research. Similarly, Herr and Anderson (2015) correlated the following five goals of action research to validity criteria: generation of new knowledge (dialogic/process validity); achievement of action-oriented outcomes (outcome validity); education of both researcher and participants (catalytic validity); results that are relevant to the local setting (democratic validity); and a sound and appropriate research methodology (process validity).

In this study, new knowledge of learning barriers was generated via dialog and reflection of our experiences during the first cycle. Subsequently, action was taken to reduce learning barriers with the implementation of UDL strategies. As the researcher, I gained insight by examining various UDL strategies and selecting those that best aligned to the 5-E components of the lesson. Teachers gained knowledge when coached to teach this enhanced lesson with these UDL strategies during a professional development session in cycle two. Each fourth-grade teacher then carried out the UDL supported lesson in their own school settings with their fourth-grade classes. The implementation of UDL strategies during cycle two served as a means of change to promote an inclusive STEM learning environment and ensured a connection between theory and practice. Additionally, the feedback from teachers during cycle two resulted in a change in approach for the PD session offered to the new group of teachers during cycle three. Participants in cycle two suggested eliminating the scripted module and conducting the PD session through the eyes of a student. Further analysis of cycle two data also revealed patterns that initiated the implementation of CRT practices, in addition to UDL strategies, in cycle three to further eliminate barriers to learning.

**Ethical Implications of Action Research**

Action research is a collaborative research approach situated in real-world settings. In an educational setting, action research offers a means to investigate possible solutions to problems and implement changes in pedagogical practices to improve instruction and learning processes. When conducting action research, it is important to consider the ethical implications of insider status. Holian and Coghlan (2013) stated that those with insider status in action research face ethical issues due to their role duality, as the researcher holds a role in both the workplace with power relationships, in addition to the action research role. In this study, I held a position of power as compared to the teacher participants. Therefore, it was important to keep this in mind as it could influence the decisions of participation or possibly skew their perceptions throughout the process. Due to my insider status and hierarchical positionality, power relations and coercion were considered and mitigated.

**Limitations**

Limitations of a research study influence the outcomes and impact the conclusions of the researcher. Therefore, identifying potential limitations prior to a study can assist with design and positively impact the quality and validity of research. Galkiene and Monkeviciene (2021) explained that action research tends to be context-specific, and, therefore, one needs to utilize caution to not generalize results, as the resulting actions of one group may not necessarily be transferable to other settings. Specifically, the results of one study cannot be applied to making predictions about other groups in different settings (Galkiene & Monkeviciene, 2021). One limitation of my study is each teacher's perspective is unique, and therefore, these methodologies could be difficult to replicate. It is important to identify, limit, and reevaluate limitations throughout the action research process. I needed to continuously journal and reflect on the findings throughout each cycle research to illuminate the multiple perspectives of participants (democratic validity), identify ongoing changes in understanding (catalytic validity), and keep an open mind for limitations that might be more prevalent in one cycle as compared to cycle two and/or cycle three (Herr & Anderson, 2015). Due to the fluidity of action research, it was also important to be mindful of limiting factors that could arise within each cycle.

## Summary

This chapter presents the research design and methodology that was implemented for my dissertation study. I offered a detailed description of my qualitative action research study aimed to construct a science and engineering lesson that reduces the marginalization of historically marginalized groups in STEM fields. The components of three specific cycles of my action research were outlined. The methodology of this research was framed by a transformative epistemological worldview which aligns to action research in education. The rationale for this specific action research study was to address the gaps identified in the research with regards to supporting teachers to support their students while they carry out lessons as the students emulate scientists by engaging in the practices as outlined by the NYSSLS. The UDL framework is the foundation of this support, as specific UDL strategies were implemented to each of the 5-E components of the lesson. Ultimately, this research sought to understand how coaching teachers in with UDL strategies, can support the implementation of inclusive science and engineering lessons where all students can successfully carry out scientific practices and develop self-efficacy in STEM.

# Chapter 4

## Data Analysis and Findings

"*Science is not always my thing. I'm not always super comfortable with it, so I love that you really went through it all with us and we weren't going in blind with what the lesson was for the students. You pretended we were the students… We were students and I felt so much more comfortable when the kids did it. So, I thought the PD was awesome, and I felt so much more comfortable with science. I was like, oh, this is what it should be. This is so exciting. It makes me feel better about teaching it*."

~Cordelia, 4th grade teacher

The focus of this qualitative study was to explore how coaching teachers to utilize the Universal Design for Learning in conjunction with the 5-E lesson plan design can support teachers with the creation of inclusive STEM environments. As outlined in Chapter 1, the New York State Science Learning Standards do not offer teachers guidance on pedagogical practices to teach to the standards, nor a means of accessibility of scientific knowledge for all students. My study aimed to analyze teachers' perceptions of professional development and coaching strategies that were designed to support teachers when helping students learn during STEM lessons. The intention of this action research study was to work at the grassroots level, as an administrator, and to provide professional development group sessions, and one-to-one coaching sessions for teachers in their own classrooms. Specifically, I aimed to close the gap between theory and practice to promote inclusive STEM learning environments utilizing UDL asset-based pedagogies to eliminate learning barriers and provide equitable access to content and, ultimately, increase students' self-efficacy during scientific practices. As discussed in Chapter 2, there is an abundance of research that identifies historically marginalized groups in STEM fields (Canning et al., 2019; Falco & Summers, 2019; Legget-Robinson & Villa, 2020; Wood & Palmer, 2014);

however, studies that aim to understand pedagogical approaches in K-12 STEM education that can eliminate implicit biases for historically marginalized groups of students in STEM are lacking. This chapter provides the data from lesson observations from cycle two and three, a focus group session from cycle two, and pre- and post-lesson interviews conducted with the teacher participants from cycle two and cycle three.

## Research Questions

My research examined how fourth grade teachers perceived their effectiveness in reducing barriers to learning and supporting students throughout a constructivist-based 5-E STEM lesson. The analysis of data was guided through the lens of two asset-based pedagogies: Universal Design for learning (UDL) and Culturally Responsive Teaching (CRT), in addition to social cognitive and social constructivist theories, discussed in Chapters 1 and 2. The following research questions guided this study:

**Primary Research Question**: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices?

**Sub-Question 1**: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during each of the 5-E components of the lesson?

**Sub-Question 2**: What UDL strategies were perceived as effective in reducing or eliminating learning barriers within specific components of the 5-E lesson?

**Sub-Question** 3: What additional strategies do 4$^{th}$ grade teachers recommend to further reduce or eliminate barriers to learning?

## School District Comparisons

Pseudonyms were utilized for each school and all participants. This study consisted of three cycles of research and took place in two suburban school districts in New York, the Waterway School District and the Boatyard School District. The Waterway School District is comprised of four elementary schools, two middle schools, and one high school. Cycle one and cycle two took place in the Waterway School District. Cycle one consisted of observational data from 13 classrooms throughout the four different elementary schools within the Waterway School District.

Cycle two was conducted in Creekside Elementary School, one of the four elementary schools within the Waterway School District. Three teachers from Creekside Elementary school, out of the original 13 teachers, volunteered as participants for cycle two. Data from cycle two included pre-lesson interviews, observations from lesson implementation, post-lesson interviews, and a focus group session. Cycle three of this study was conducted in the Boatyard School District. The Boatyard School District consists of two elementary schools, one middle school, and one high school. Cycle three was conducted in the Dockside Elementary School, one of the two elementary schools within the Boatyard School District. Five participants originally volunteered to participate. One participant dropped out due to personal reasons. Data from cycle three consisted of pre-lesson interviews, observations from lesson implementation, and post-lesson interviews. The following sections offer a comparison between Creekside and Dockside Elementary Schools and their district's with regards to demographics, professional development opportunities, STEM resources, and cultural and pedagogical practices.

**School District Demographics**

As explained above, Creekside Elementary School and Dockside Elementary schools are located within two different suburban school districts in New York. The student demographics for each school are very similar. At the time of data collection, Creekside Elementary demographics was reported to be 82% White, 12% Latinx, 3% Asian, 1% Black, 2% Multiracial, 52% male, 48% female, 9.1% of students were eligible for free or reduced lunch, English language learners made up 1.1% of the population and 13% of students were students with special education accommodations. Comparatively, Dockside Elementary demographics was reported to be 85% White, 10% Latinx, 3% Asian, 1% Black, 1% Multiracial, 48% male, 52% female, 13% of students are eligible for free or reduced lunch, English language learners make up 2% of the population and 14% of students were students with special education accommodations. Table 1 offers a demographic comparison of both schools.

**Table 1**

*School Demographics*

| **Action Research Cycle Two: Creekside Elementary School Student Demographics** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | White | Latinx | Asian | Black | Multi-racial | Male | Female | Free/ Reduced Lunch | ELLs | Special Ed |
| Spring 2023 | 82% | 12% | 3% | 1% | 2% | 52% | 48% | 9.1% | 1.1% | 13% |
| **Action Research Cycle Three: Dockside Elementary School Student Demographics** | | | | | | | | | | |
| Year | White | Latinx | Asian | Black | Multi-racial | Male | Female | Free/ Reduced Lunch | ELLs | Special Ed |
| Fall 2024 | 85% | 10% | 3% | 1% | 1% | 48% | 52% | 13% | 2% | 14% |

## Participant Demographics

As explained in Chapter 3, IRB approval was obtained from Molloy's IRB committee to collect the data for cycles two and three of this dissertation study during the spring and fall of 2023, respectively. The participants in this study comprised of three fourth grade teachers from

Creekside Elementary School in the Waterway School District and four fourth grade teachers from Dockside Elementary School in the Boatyard School District.

Participants self-reported their demographics during their pre-lesson interviews. All seven teachers identified as White, and there were five females and two males. Their years of teaching experience ranged from 5-26 years. Half of the participants have taught 4th grade for more than 8 years, but the other half only taught 4th grade for only 1-3 years. One teacher in cycle three taught an ICT class. Table 2 depicts the details of participant demographics for cycle two and three of this study.

Although the demographics among teachers between the two schools in this study are similar, it is important to note that this is not representative of the overall teacher population in New York State. Garcia et al. (2023) reported that approximately 80% of teachers in New York State identified as White and the other 20% self-identify as American Indian /Alaska Native, Asian, Black, Native Hawaiian/Pacific Islander, multiracial, or of Latinx.

**Tabel 2**

*Participant Demographics*

| **Action Research Cycle Two: Creekside Elementary School** | | | | | |
|---|---|---|---|---|---|
| **Teacher Pseudonym** | **Years Teaching** | **Grades Taught** | **Number of Years in Grade 4** | **Race** | **Gender** |
| Sunny | 20 | 2,3,4,5,6,8 | 2 | White | Female |
| Christine | 14 | K,3,4,6 | 3 | White | Female |
| Clara | 18 | K,4 | 18 | White | Female |
| **Action Research Cycle Three: Dockside Elementary School** | | | | | |
| Cordelia (ICT) | 5 | 1,3,4 | 2 | White | Female |
| Augustus | 26 | 1,2,3,4 | 15 | White | Male |

| | | | | | |
|---|---|---|---|---|---|
| Paul | 19 | 4,5 | 8 | White | Male |
| Victoria | 5 | K,1,4 | 1 | White | Female |

**Professional Development**

Teacher participants from both schools were eager to volunteer for this study. Both schools have an established culture of professional development. The Waterway School District requires teachers to attend a minimum of 8-10 hours of professional development (PD) each year. If a teacher chooses to attend additional PD hours, this would be acknowledged in their end of the year written evaluation report, and the teacher would also receive a “highly effective” rating for the PD section on their evaluation rubric. The Boatyard School District also implements an 8-hour PD mandate. Teachers in this district must attend 4 hours of district-selected PD initiatives, and the other 4 hours are of choice. Teachers may attend additional PD hours once their 8 hours are met, yet there are no incentives to do so.

**STEM Resources**

The Waterway School District has a designated STEM lab in each of their four elementary schools. Teachers in each grade have specific days they can sign up and plan lessons in this space. Additionally, there is a STEM teacher assistant (TA) assigned to each STEM Lab to help with the setup of materials and assist the teachers throughout the lessons. The Boatyard school district does not have a designated STEM lab nor a STEM TA. Therefore, the library was booked to conduct the lesson in this study, as there were large collaborative tables and ample access to power outlets that were needed.

Due to the establishment of the STEM lab in the Waterway School district, teachers in Creekside Elementary School were in the routine of conducting STEM labs on a weekly basis.

Conversely, teachers in the Dockside Elementary School are more reliant on old fashioned pen and paper science lessons and conduct hands-on STEM experiments less frequently. They do have a storage closet with many Science "kits "that are aligned to their curriculum; however, it is infrequent to observe teachers utilize these materials, except for the state mandated laboratory exercises.

**School Culture and Pedagogical Practices**

The current culture and pedagogical practices within a school can influence the introduction of new asset-based frameworks. The pedagogical frameworks introduced in this study, UDL and CRT, are inclusive practices that embrace and address student differences. During the 2022-2023 school year, the Waterway School District began a district-wide Diversity, Equity, and Inclusion (DEI) initiative. A DEI committee was established in the fall of 2022 that included various stakeholders from within the schools and outside community. Students were finally heard outside of their "clubs" for the first time. I witnessed action being taken to make organizational changes that positively impacted students who were previously marginalized. As an example, some of these organizational changes included hanging up non-gender signs on bathrooms across the district and no longer forcing all high school students to take swimming classes, as they were expected to identify as a male or female, wear the "appropriate" swim uniform assigned to each sex, and change in the "appropriately" designated locker room. I have observed recent shifts in the Waterway School District's climate regarding DEI initiatives to begin to shift the overall culture toward a more inclusive feeling for all. This culture set the stage for the introduction of UDL practices within classrooms in the Waterway School District.

The Boatyard School District had a strong social emotional program infused into their elementary school curriculum. Creekside Elementary School is designated as an International

Habits of Mind Learning Community of Excellence (Institute for Habits of Mind, 2022). The Institute for habits of the mind list 16 characteristics of effective learners: thinking about your thinking, persisting, managing impulsivity, striving for accuracy, listening and understanding with empathy, thinking flexibility, questioning and posing problems, thinking independently, thinking and communicating with clarity and precision, applying past knowledge to new situations, gathering data through all senses, creating, imagining, and innovating, taking responsible risks, finding humor, responding with wonderment and awe, and remaining open to continuous learning. I have observed teachers infuse the "habits" into daily lessons and/or mindful moments throughout the day. I also observed the mindful characteristics hanging up in classrooms and on bulletin boards in the hallway. When these habits are infused in the classroom and throughout the building, it supports a culture of growth mindset that has the potential to fuel students' self-efficacy. From my observations, teachers and students in Creekside Elementary School have internalized the importance of these characteristics as part of being a young scholar. During the fall of 2023, the district started a K-12 scholar profile committee and incorporated the Habits of the Mind characteristics as a foundation to create their district scholar profile. This initiative offers a foundation to introduce asset-based pedagogies, such as UDL and CRT.

## Cycles of Action Research

### Rationale for Research: The Evolution of Cycle One

As mentioned in Chapter 3, cycle one of action research included the identification of a specific area of need for professional development and coaching. Cycle one was completed in the Spring of 2022. Thirteen fourth grade teachers within the Waterway School District were supported with professional development and coaching to implement a new 5-E STEM lesson aligned with the NYSSLS.

**Lesson Description**

The title of the 5-E lesson was 4th Grade Electrical Engineers. Students sat in groups of three or four. Students were preassigned by the teacher and heterogeneously grouped. The lesson began with the Engage portion where students were presented with a phenomenon. This phenomenon was an image of astronauts working on solar panels on the international space station. They observed the phenomenon and independently completed a T-chart, listing their observations and questions. Students then shared out their observations and questions to the class.

From there, the class transitioned into the Explore portion of the lesson. Students were told "Congratulations! You are all electrical engineers for NASA today!" Students were prompted to gather around one table for a demonstration on how to use the LightSpeed device that was on each of their group tables. After they gathered around, students were told that NASA has a conundrum, as they are having trouble with their solar panels on the international space station and on their Mars rover. Specifically, NASA scientists are not sure why their solar panels do not always run efficiently. Students were shown the piece of the solar panel they tested for NASA on the Lightspeed device. Students were asked to volunteer to participate in the class demonstration. As students took the roles of timekeeper, counter, recorder, start/stop person, and gel person, the class watched along as the teacher guided students on how to utilize the LightSpeed device. Students also learned that the LightSpeed device was designed and built by STEM students in the high school of the Waterway School District.

Students who volunteered for the demonstration did a practice run, collecting sample data while their peers watched. When the light was turned on and aimed at the solar panels, two disks would begin to spin. Students were to count the number of rotations in a 10 second period and record this on their charts. After the demonstration round, students were sent back to their groups with directions to select their group roles. Once selected, the students were to start once again with the control, counting the number of rotations in ten seconds. Once their data for the control was recorded, students experimented with gels. Each group of students tested a blue, green, and red gel. The gel was placed over the solar panel, and students repeated the collection method, recording the number of rotations in a ten second period. Students entered their data into a data table. Once complete, students then completed a second data table, ranking the control and colored gels from fastest to slowest. All groups shared their results to the class.

From there, the lesson transitioned into the Explain segment of the lesson and students were told they had to report back to NASA soon. It was explained that their report should include their data as well as how the LightSpeed device works. Students were presented with the lesson vocabulary: solar energy, electrical energy, mechanical energy, solar cells, and solar panel. Students were directed to describe how the Lightspeed device worked, while using the vocabulary. Students were given about 4 minutes to chat in their groups. After 4 minutes, the teacher selected one student per group to jigsaw with another group. Once these students switched groups, the group was to explain to the new member what they discussed, and similarly, the new student member shared out what their group discussed. They were tasked to complete this in just under 2 minutes. From there, students returned to their original group, and the group once again discussed how the device worked utilizing the vocabulary, incorporating what they learned from the new group members. After the group brainstorming session, each group shared their explanation one at a time to the whole class. All groups listened, their explanations would get more detailed as the description went from group to group. From there, students were then asked to brainstorm and come up with a definition for each vocabulary word. Each group shared out a definition of a term to the class.

The lesson then transitioned to the Elaborate portion of the lesson. Students were asked to ponder why solar panels on Mars, the International Space Station, and even on earth may not work efficiently at times. Students would offer sandstorms on Mars covering the panels, space debris damaging the panels or no sunlight shining on the international space station, and a variety of factors on Earth such as rain, leaves, snow, clouds, etc., blocking the sun's rays. Students then made the connection between the various color gels and these environmental factors. Students offered explanations such as darker clouds would represent the blue gel because the disks spun slower as compared to the red gel, which could be compared to light fluffy clouds.

The evaluation portion of the lesson occurred within a day of the lesson and included a refection page with a choice of prompts. Students were able to select one of the four following prompts:

1) Explain how solar energy is converted to electrical energy.
2) Describe how the LightSpeed devise works.
3) Explain how using the gels on the LightSpeed device simulates environmental conditions for real solar panels.
4) Describe with words and drawings what you learned during the activity.

Students were also given the lesson vocabulary as a checklist and directed to incorporate the vocabulary into their response.

**Professional Development and Lesson Implementation**

Fourth grade teachers attended a professional development session to learn how to set up and conduct the hands-on portion of the lesson. Teachers were then supported with co-teaching, as needed, during lesson implementation. I kept observational and reflective notes which included the teachers' reactions to the professional development sessions and lesson implementation, my observations of student responses to the lesson, and feedback from teachers after the lesson.

Overall, teachers and students were positive about the lesson. However, during cycle one, I felt that students struggled with specific aspects and noticed barriers to learning. Specifically, all students did not participate equally, as certain students seemed to dominate the group discussions. In a few classes, students were observed arguing over the roles they wanted to take during the hands-on portion of the lab. I observed students struggling with generating answers to the essential question and defining the vocabulary in their own words.

I also observed that teachers were quick to "rescue" students, as they jumped in to solve their quarrels or give away too much information as soon as they observed students struggling. Additionally, I observed that teachers seem to predict which students would struggle and would jump to assist those students too quickly, either by leading them to the correct answer or attempting to prevent/solve group disputes. These observations elucidate the need for different pedagogical approaches in which all students can gain equal access to the content and skills sets in this STEM lesson. It was my perception that students were stifled of their autonomy, and teachers appeared apprehensive about student success. As the lesson progressed from one fourth grade classroom to the next during cycle one, I attempted to implement new pedagogical strategies to reduce/eliminate observed learning barriers. One example of such a strategy included coaching teachers to allow students the time needed to work through the selection of group roles and problem solving. At the culmination of all lessons in the thirteen classrooms, I reviewed my reflections and identified common barriers to learning for this STEM lesson.

**Cycles Two and Three Overview**

To implement improvements to this lesson, UDL strategies were integrated within the 5-E lesson design to reduce/eliminate the identified barriers to learning. As stated in Chapter 3, IRB approval for cycle two was obtained from Molloy's IRB committee in the Spring of 2023. Out of the original 13 teachers in the waterway School District from cycle one, three teachers from Creekside Elementary school participated in cycle two of this study during the Spring of 2023. Each participant took part in a pre-interview before a professional development session, a post-interview after lesson implementation, and a focus group at the culmination of all individual interviews. The final three interviews were analyzed and drove the direction of the focus group for cycle two. During the final interviews of cycle two, the teachers indicated that they wanted more time to go through the student reflection pages. I felt a focus group was necessary to gather more data and gain clarity on the reflection portion of the lesson. During the focus group, teachers brough their student work with them and discussed their responses. The teachers unanimously felt that giving the students the page with both a space for illustration and writing is best, as it helped students to expand their written responses. During cycle two, students had a choice of the four prompts and the type of paper they could use for the reflection: plain, all lined, or mixed with a place to draw and write. For cycle three, the choice of the reflection prompts were the same, but all students received a reflection sheet with a blank space on top for an illustration and lines on the bottom and back for their written reflection. The interview and focus group data were analyzed through the lens of UDL framework and additional improvements were made to the lesson based on the analysis of teacher feedback. Additionally, aspects of the CRT as a framework were added to further reduce barriers to learning for cycle three.

As stated in Chapter 3, IRB approval for cycle three was obtained from Molloy's IRB committee in the Fall of 2023. Four teachers from Dockside Elementary School participated in cycle three of this study during the Fall of 2023. Five teachers originally agreed to participate, with one participant dropping out of the study before due to a personal situation. Each participant took part in a pre-interview before the professional development session, and a post-interview after lesson implementation. All interview transcripts were first analyzed through the lens of UDL and CRT, and codes were created for the initial analysis of cycle three. After in-depth analysis utilizing the Dedoose platform, followed by more hand-analysis, themes began to emerge. These themes will be described in detail later in this chapter.

## Chapter Overview

Chapter 4 is divided into two parts. In Part One I describe the generation of codes, coding analysis, theoretical analysis, and introduce the emergence of themes. Additionally, I offer a rationale for the specific way I organized the presentation of findings in Part Two. Throughout Part Two, I report the findings from cycle two and three of this study. The findings reported in this section are organized by theme, and the discussion describing the first theme is initially presented by timeline. Specifically, I discuss my thoughts for each theme for the three post-lesson interviews and focus group session for cycle two of this study, and the four post-lesson interviews for cycle three. Lastly, at the end of Part Two, I summarize the chapter based on the overall findings and introduce the final chapter of this dissertation.

## Part I Data Analysis

In this section I describe the evolution of data analysis through this study. Specifically, I describe the codes utilized to analyze the data, the emergence of themes from this analysis, and the findings of the study. Additionally, I provide a graphic representation of code and theme generation along with a detailed narrative of how I utilized theories previously described in Chapter One and Chapter Two to categorize codes and generate themes. Finally, I offer a description of the organization and content of Part Two.

**Generation of Codes**

Individual interview transcripts from cycle two of this study were initially hand coded before the cycle two focus group session. The focus group conversation was focused on the reflective portion of the lesson, as the teachers did not have enough time to look through the students' responses before the final interview. While hand-coding, I annotated my thoughts and looked for patterns and emerging themes. After reviewing the transcripts, I generated a list of codes. The initial list was very long, as was eventually collapsed after analysis of the cycle three data to eliminate repetitive codes. Herr and Anderson (2015) explain that initial cycles of action research are revisited when one analyzes the data set overall once all data collection is concluded.

Following data collection for cycle three, the interview transcripts were once again reviewed initially by hand. Following the same method as completed for the cycle two data, I hand annotated the data, making notes of patterns, listing all possible codes, and identified emerging themes. All interview transcripts from both cycle two and cycle three were then uploaded to the Dedoose platform and analyzed with the generated codes from cycle two and cycle three, collectively. After this first round of analysis utilizing the Dedoose platform, I once again collapsed some codes that overlapped. I was left with five parent codes and twenty child codes. Table 3 lists the parent codes, child codes, definitions, and frequency. Under the parent code of perceptions of PD session, the child code, script not real/too much, was only utilized during cycle two and another child code, hands-on/through the eyes of student, was only utilized for phase three. Table 3 summarizes the parent and child codes, in addition to offering a definition for each code and the frequency of occurrence. Additionally, the reporting indicators for the UDL guideline checklist are listed.

**Table 3**

*Codes, Definitions, and Frequency for Research Cycles Two and Three*

| Parent Code | Child Code | Definition | Frequency |
|---|---|---|---|
| Perceptions of PD Session | Script not real/too much (Phase 2 only) | Following script is not natural and too hard to follow during lesson | 6 |
| | Hands-On/Through Eyes of Student (Phase 3 only) | Teachers conduct lesson from students' perspective | 7 |
| | No suggestions to Improve PD | Teachers offered no suggestions to improve professional development | 4 |
| Perceived Challenges of Lesson | Defining vocabulary | Students generating their own definitions | 3 |
| | Setting up materials | Teachers setting up materials of students using materials | 3 |
| | Not saying too much | Not giving away any information during phenomena/ Not stating "good answer" or saying if an answer is correct/No teacher opinion on response | 5 |
| | Time restraints | Preparation/Class needing to go to a special at certain time/Interruptions | 4 |
| Perceived proficiency of UDL | Engage | Teacher identified transferable UDL strategies to future lessons: Phenomena/Prior knowledge/Where students are coming from (own thoughts/experiences) | 7 |
| | Explore | Hands-On component | 2 |
| | Explain | Brainstorming /Vocab defining | 6 |
| | Elaborate | Real-world connections | 1 |
| | Evaluate | Reflection with student choice | 5 |

| | | | |
|---|---|---|---|
| *Reduce/Eliminate barriers | Engage | *G1, C1.1; G3, C3.1; G3, C3.3; G5, C5.1 G7, C7.2 | 3;2;1;3;4;1 |
| | Explore | *G3, C3.3; G6, C6.2; G6, C6.3; G8, C8.3; G9, C9.1 | 2;2;2;2,2 |
| | Explain | *G3,C3.3; G8,C8.3; G8,C8.4 | 3;3;3 |
| | Elaborate | *G3,C3.4 | 2 |
| | Evaluate | *G6,C6.2; G7,C7.1 | 3;5 |
| Perception of Collaboration | Brainstorming Sessions | Students engaged in discourse/Problem solving | 12 |
| | Defining Vocabulary | Students generating their own definitions | 15 |

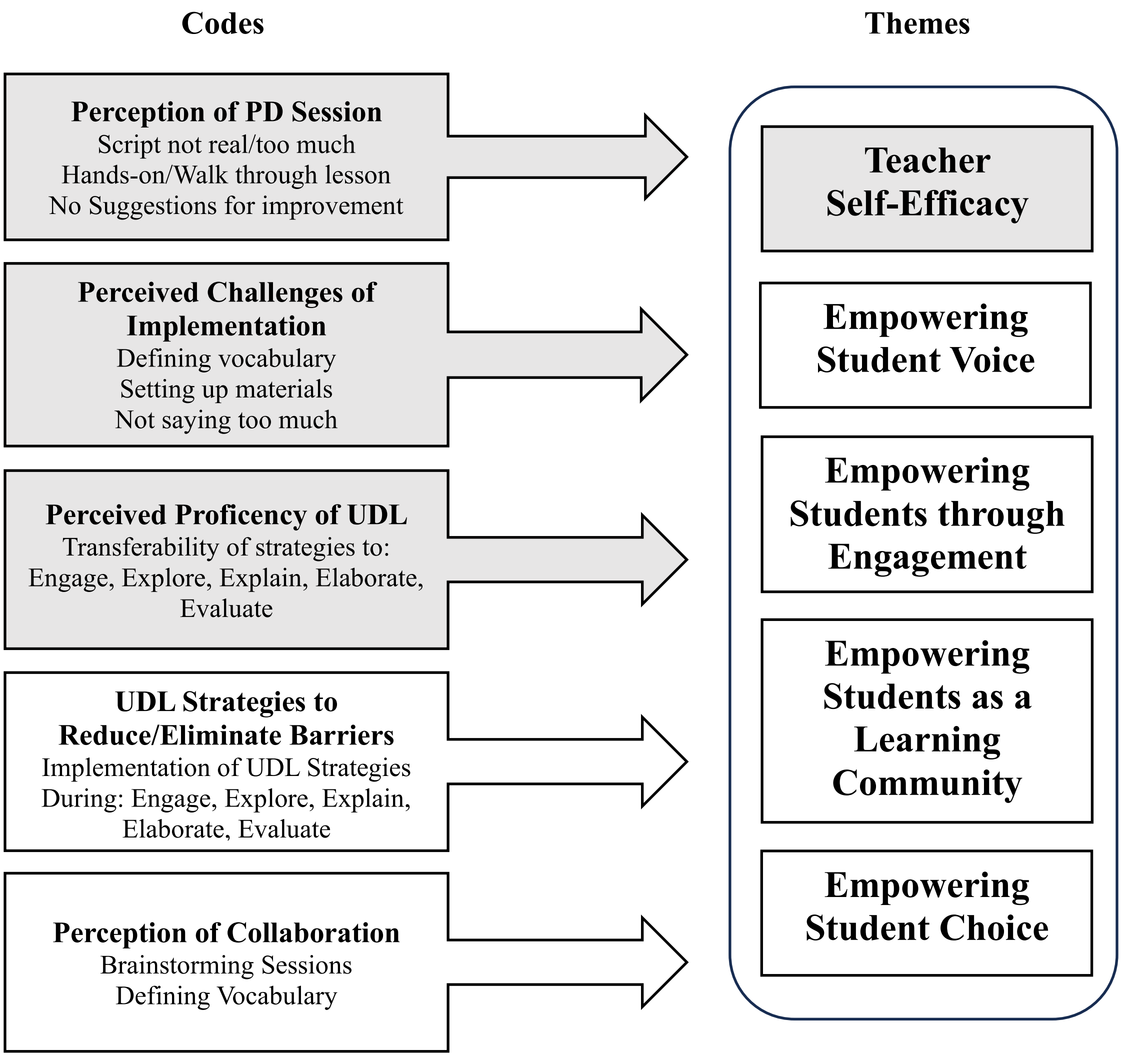
**Note*. Indicators are from the UDL Guideline checklist.: UDL Guideline Checklist CAST. (2018) *UDL Guidelines version 2.2*. *Research evidence* [webpage]. Retrieved from https://udlguidelines.cast.org/

**Theoretical Analysis of Codes to Themes- A Brief Overview**

After two rounds of in-depth coding on the Dedoose platform, I dove back into the theories that grounded this research and analyzed the codes and excerpts through a theoretical lens. This in-depth analysis led to the emergence of five themes: teacher self-efficacy, empowering student voice, empowering students through engagement, empowering students as a learning community, and empowering student choice. Figure 1 depicts a visual representation of codes to themes.

**Figure 1**

*Codes to Themes*




The first theme, teacher self-efficacy, encompassed three parent codes and 12 child codes. I utilized the lens of self-efficacy (Bandura, 1994) along with the construct of teaching self-efficacy (Tschannen-Moran et al.,1998) to identify these related codes and theme. Teacher self-efficacy aligns with the primary research question for this study: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices? During the final interviews of cycle two and cycle three of this study, teachers reflected on the professional development session, offering their perspectives on the aspects that were helpful or suggestions for change. It was insightful to hear their feedback, such as cycle two, teachers not wanting the lesson written out as a detailed script, but rather a focus on just the hands-on coaching and having the lesson modeled to view it through the eyes of a student. Their feedback caused me to shift gears and change up the professional development session to better support the teachers during cycle three. Throughout the third cycle of research, teachers voiced more confidence about going into the lesson with students, which shed more light on the nature of the professional development session and teacher's self-efficacy.

Cycles two and three teachers also reflected on their perceived challenges of lesson implementation. Their feedback both supported certain aspects of the professional development that enhanced teacher self-efficacy, as well as elucidated areas needing additional coaching and support. Lastly, teachers reported on their perceived proficiency with regards to specific UDL strategies by offering which strategies utilized in this lesson they feel they could transfer to future STEM lessons they will teach. Their responses offered insight into the sub-research question 1: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during each of the 5-E components of the lesson? Collectively the excerpts pertaining to these three parent codes and 12 child codes offered insight to the teachers' self-efficacy regarding the implementation of this STEM lesson and utilization of UDL strategies. The specific analysis with support of excerpts will be covered in more detail in Part Two of this chapter.

The remaining four themes, empowering student voice, empowering students through engagement, empowering students as a learning community, and empowering student choice emerged primarily from two parent codes and seven child codes. Five of the seven child codes were further broken down into 17 UDL guidelines from CAST (2018), as depicted in Table 3. As

I reviewed the teachers' reflections on strategies that reduced or eliminated barriers to learning, many patterns began to emerge. I was particularly intrigued by the repeated comments of how "impressed" or "surprised" teachers were at student responses when the teachers held back and did not offer praise to students nor allude if students were giving the correct response. One teacher reported that a shy student who never speaks up offered answers, because in their perspective, there was no right or wrong. Teachers also reflected on the engagement portion of the lesson and how they liked that it tapped into prior knowledge and allowed the students to all offer their own individual thoughts and prior experiences without any judgement. These comments together with the lens of UDL and CRT resulted in the emergence of the theme empowering student voice.

Similarly, teachers reflected on the hands-on component of the lesson, the brainstorming sessions, and student reflections. Patterns emerged such as: students figuring problems out on their own through brainstorming together, choosing their own roles for the hands-on portion, choosing their own direction for the evaluation portion, etc. With all this, the teachers reflected on how surprised they were with the level of student engagement and quality of students' responses. The teachers' reflective responses incorporated terms such as freedom, unbelievable, impressed, would never have thought, and it's just natural for a teacher to intervene and explain. Their responses in conjunction with CRT led me to the themes of empowering students, resulting from teachers "holding back" during the lesson. A deeper analysis of these themes, supported by excerpts from interviews will be described in Part Two of this chapter.

As described by Creswell and Poth (2016), three types of quotations are utilized as sources of evidence to support interpretations and presented explanations: short quotations, embedded quotations, and longer quotations. Additionally, as previously discussed in Chapter 3, Guba and Lincoln's (1989) trustworthiness criteria of credibility, dependability, confirmability and transferability are considered with regards to the organization of this chapter and presentation of data. Credibility of this research study is addressed through the triangulation of data from two different participant cycles of research in two different settings, the evolution of methodology based on participants feedback from cycle two to cycle three, and theories to back methodological decisions and interpretations of data. The order of presented data is also strategically planned to allow for an audit trial, as the presented data and interpretations are grounded in an actual timeline of events and evolution of themes. Finally, transferability is apparent from the evolution of methods from cycle two to cycle three, between two different groups of teachers in two different settings, in addition to being supported by evidence from teachers' responses to interview questions regarding the applicability of UDL strategies to other lessons.

## Part II Themes

As discussed in Chapter 3, an action research study allows for the flexibility needed for evolving educational settings. Additionally, every classroom, school building, and school district consists of unique individuals and circumstances, and therefore, has its own unique environment. Action research also allows for co-planning and collaboration at the grassroots level, offering educators the possibility of transferring naturalistic generalizations (Stake, 1986) into vicarious experiences (Herr & Anderson, 2015). Furthermore, as discussed in Chapter 1, my positionality for this study placed me as both an outsider and insider, as I had a hierarchical position, yet could deeply root myself alongside teachers to work toward the common goal of supporting students. Accordingly, for the reader to capture the natural evolution of practices from cycle two to cycle three of this study, I offer a detailed description organized by interview questions, codes, themes, and for teacher self-efficacy, by cycle, as this is how the practices and themes natural emerged and evolved in this study.

This section offers a detailed discussion of the following themes: teacher self-efficacy, empowering student voice, empowering students through engagement, empowering students as a learning community, and empowering student choice. Thematic development for each of the five emergent themes will be supported with data from participant interviews. To introduce each participant and gain a perspective of their experience with professional development and lesson implementation, the first self-efficacy theme section includes my impression of each participants confidence during the lesson implementation based on field observations and analysis of transcripts, in addition to transcript excerpts from all participants regarding their personal reflections of the professional development session. I feel the evolution of the professional development session based on my observations and participant feedback from analysis of transcripts, was an important component to the evolution of this study from cycle two to cycle three. At the conclusion of this section, I offer a summary of the chapter.

## Self-Efficacy

The theme of teacher self-efficacy is related to the primary research question for this study: How do $4^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices? As discussed earlier in this chapter, four teachers from Creekside Elementary School offered to participate in this action research study in the spring of 2023. These three teachers were among the thirteen who received the initial professional development session in cycle one during the spring of 2022.

### Perceptions of Professional Development

The initial professional development session in the spring of 2022 was carried out as a hands-on workshop where teachers were presented with the 5-E lesson plan and were able to "play" with the devise to become familiar with the lesson materials. As described earlier, my reflections of the initial professional development session called for stronger pedagogical practices that would support students' persistence, autonomy, problem solving skills, and allow for the voice and participation of all students.

Cycle two of professional development included the incorporation of UDL strategies. My goal was to support teachers to support their students to be more autonomous in their learning and to create a more inclusive environment for all students to access the content and skills within the lesson. To coach teachers with UDL strategies, I created a Lesson Module Guide (See Appendix E). This module included the original 5-E lesson design and included UDL and CRT strategies. For example, for the Engage component of the lesson, the script specifically directed teachers how to present the phenomena. Written directions included, "do not say anything about the lesson prior to the phenomena" and when students generate their questions not to state "that's a good question" to individual students. The specific UDL strategies were also listed. My thinking was that if I offered the teachers this script in an organized way with information listing UDL strategies and specific examples of what to say to create an inclusive environment, they would then feel more confident to incorporate the new strategies. One apparatus was set up, but the focus on the professional development session was on the scripted lesson.

I found the teachers to be excited when they entered the PD session. They chatted about their recollections of the lesson the previous year and how they looked forward to conducting the lesson again. It was already established that I would take more of a back seat during the lesson implementation unless they really needed my assistance during the lesson. Teachers looked through the scripted lesson, talking and remembering the different components of the 5-E lesson. I observed them discussing the challenging aspects, such as not saying too much during the phenomena piece, and how they initially made those mistakes the previous year. After we finished reviewing the entire lesson module, the teachers asked if the devices could stay in the STEM lab over the next week so they can "play with them" and run through the lesson during their free periods or common planning time as a refresher. I left enough setups with the teachers, and they had a week before lesson implementation.

For the lesson implementation, I stepped back as much as possible unless a teacher asked for help or was obviously flustered and needed assistance. It was insightful to observe the three teachers, Christine, Clara, and Sunny, and how they each carried out the lesson, described next.

***Christine***

I observed Christine start the lesson with confidence. She smiled at me while she did not "give away the punch line" to the phenomena, and she asked students to list their observations and questions, telling them there is no right or wrong answer. Christine's smile and clear directions to students demonstrated her self-efficacy in implementing the UDL strategies for the phenomena during the Engage portion of the lesson. Additionally, during the post-lesson interview, Christine offered that she "always loves the phenomena" and that she uses it "throughout the day in all her lessons." Christine's confidence to support students during this part of the lesson was observed by me and reflected in her responses during the post-lesson interview.

As Christine was about to shift to the next component of the lesson, I noticed she had a sheet of paper with bullet points that she glanced at before moving on. Christine continued to refer to this sheet throughout the lesson as she transitioned from one 5-E component of the lesson to the next. I did not notice her look at her notes at the start of the lesson, which further demonstrated her confidence with implementing the phenomena. Christine completed most of the lesson independently, incorporating UDL strategies into the directions for students.

She clearly listed the roles for the groups, showed the students the data tables to record their information on, explained they would discuss together how to interpret the directions for the second data tables, etc. She signaled for me to jump in after her directions for the group work, in a way of asking me if she forgot anything. Feeling she may not have explicitly stated how quickly the students should select roles without conflict, I just reiterated this aspect before the students were off and running on their own by telling them that they do not have time to argue over the roles because they need to report back to NASA in about 20 minutes. I also jumped in when one of the student's stop watches needed to be reset, or when one of the wheels on the devices was stuck, as students were told we would assist with those aspects if they asked for help. Overall, Christine seemed confident throughout the lesson. She felt the need to have some bullet points to refer to for the directions to students from the explore portion of the lesson to the end during the transitions.

During the post-lesson interview, Christine was asked to reflect on the professional development session and to give feedback on any aspect that could be improved to help support a new group of teachers who were not familiar with this lesson. Christine offered the following feedback:

> I love the booklet for the background information for the teachers. I really do. I think we were discussing that day [of the PD], something more bulleted, just for them [teachers] to just glance at. Not so much to have to follow the script during the lesson. Some things I was thinking about is even for us because it had been a whole year from just doing that

> one lesson that maybe just a quick hands-on play with the teacher themselves, play with that solar panel machine so that they could just see how it works. Because right after we did it, soon as we started working, it came back.

Christine offered that the script was a bit much, even though they taught the lesson the prior year. During the post-lesson interview, Christine reflected about the script and stated, "You become so focused on what you're supposed to say that you almost lose sights of what they're (students) supposed to do." Christine also emphasized the importance of the teachers having the opportunity to run through and practice the hands-on component of the lesson before implementation.

***Clara***

Clara entered the room and placed the module on the teacher's side desk as her students scurried to their seats. The module remained there unopened until she exited the room with the students at the end of the lesson. As I watched her body language, Clara seemed happy, a bit carefree, and confident enough for her own liking. She smiled at me as she was about to kick off the lesson, asked her students to say good morning to me, and offered me to join in whenever I wanted to.

Clara smoothly transitioned from one aspect of the lesson to the next. Like Christine, Clara also looked toward me for feedback right after she finished the directions for students to conduct the hands-on component. I once again emphasized the importance of the roles and explicitly told the students they do not have time to argue over their roles because they need to report back to NASA in about 20 minutes. Clara seemed to lack the confidence to direct her students to select their roles and begin the hands-on portion of the lesson. I found it telling that I found a pattern regarding the teachers' apprehension to explicitly tell students they need to select roles quickly and do not have time to argue over the roles. During the post-lesson interview, Clara mentioned that she was "surprised how quickly they picked their roles… they did it quickly and without incident." From my observations and this feedback, Clara seemed unconfident with directing students to select roles. During the brainstorming portion of the lesson, Clara also seemed insecure about having the students jigsaw their responses. After their initial conversation, she questioned how to rotate the students, so I jumped in and modeled this component of the lesson.

During the post-lesson interview, Clara was asked to reflect on the professional development session and to give feedback on any aspect that could be improved to help support a new group of teachers who were not familiar with this lesson. Clara only offered:

> I know with the first time you did it with us, there was a demo, there was... I remember how to spin the wheels and... just little caveats or troubleshooting, what to watch out for. I think just the hands-on was really meaningful.

Clara did not even mention the module. Her thoughts about it appeared to be left with the unused module booklet, on the teacher's desk in the STEM lab. The module did not seem to be of importance to Clara during the lesson or during the post-lesson interview, as she did not reflect on it at all. However, she was observed using UDL strategies in her directions for the phenomena, role selection (although I reinforced the expectations), data collection, and brainstorming (with coaching support for the jig-sawing component). Overall, Clara was observed utilizing UDL strategies, but was hesitant and lacked confidence about offering explicit directions to students for the group work and brainstorming portion of the lessons.

***Sunny***

Sunny entered the STEM lab with the module in hand opened to the first page. As her students were instructed to enter the room and take their seats, Sunny was reading the first page. She appeared nervous to me. Sunny began the lesson literally reading from the script. After the first couple of minutes, I could not take the look of panic and apprehension on her face, so I walked over to her as her students were writing their questions. She started to flip the page and asked me questions about the next section. I smiled at her, and we both started laughing. I literally took the book and said, “OK, let me assist” as I tossed the module on the side table. We tried not to laugh too hard, as students were busy generating questions about the phenomena, seemingly oblivious of us laughing and literally embracing each other’s arms. I offered to co-teach with her, realizing she did not display the same confidence as Christine and Clara. She graciously accepted as we still laughed. Just before each transition to the next component of the lesson, while students were busy and engaged, I chatted with Sunny and offered a quick synopsis of what will transpire next. I then asked, do you want to jump in and take the lead or do it together? Certain aspects of the lesson she felt comfortable enough to do, such as the analysis of data collection, instructions for group brainstorming, and reporting back to NASA. Sunny did ask me to go over the directions for the apparatus and group roles.

During the post-lesson interview, Sunny was asked to reflect on the professional development session and to give feedback on any aspect that could be improved to help support a new group of teachers who were not familiar with this lesson. Sunny initially offered the following feedback:

> So, I feel, yes, we were very fortunate to have had the lesson last year, but I would definitely encourage to do that. Just do a run through exactly what you would do, that demo with the kids, to do that with the new teachers, because I think that's the most

useful tool. And just go through the slides. 'Okay, this is what you're going to do.' And all those little tidbits like, 'All right, don't say those words, just stand back and let them go with it, and try to close your mouth.' And not do what we always try to do with them.

From there Sunny was initially hesitant to offer her additional thoughts. I prompted her to feel comfortable with sharing. The beginning portion of this interview correspondence is below:

Sunny:

Yeah, definitely going through it. The only suggest, and please don't, whatever, but-

Interviewer:
No, no, please, honestly.

Suny:
... It's very difficult.

Interviewer
Go ahead (as I smile)

Sunny:
For the color pattern on here….

Her analysis and feedback of the scripted module was over seven pages long in the transcribed interview. All was focused on *how* everything was written. None of her reflections were about the students' reaction to the lesson. Both my observations of Sunny and her reflections during the post-lesson interview indicated she was not confident to carry out this lesson alone. I recall my thoughts and emotions that I was trying hard to hide as she was speaking.

**Reflections of Cycle Two**

After all of the lessons were completed, I reflected in my field notes about how to improve the PD and lesson for Cycle three. Between Sunny's feedback and the observations with the other teachers, I came to the realization that the module was not the way to go. What I initially thought would help teachers to feel more confident, turned out to be minimized or tossed aside by the more confident teachers, Christine, and Clara, and seemingly obsessed over by Sunny, who appeared insecure throughout the lesson.

I knew that for teachers to be able to support students through the lesson, they themselves need to feel confident and proficient with the lesson. Specifically, teachers need to be self-efficacious about teaching STEM lessons before they can support the growth of their students' self-efficacy in STEM. As I reflected, I came to the realization that the scripted module was a barrier to teachers' confidence. I allowed my observations, and the teachers' interview responses to guide me, and I adjusted the approach to the professional development session for cycle three. Additionally, I realized a pattern that teachers were hesitant when it came to directing students to self-select their own roles and confidently explain role selection and group directions. My observations of hesitation from both Clara and Kristen were confirmed by their comments during the post-lesson interviews. As described above, Clara expressed her surprise about how fast the students selected their own roles without incident. Kristen offered her reflection that "allowing students to have their own jobs sets boundaries for them to work well together." For students to be self-directed in their own selection of group roles, teachers need to feel confident in the students first.

I needed to further support teachers to help students feel they are in control of their decisions and actions. This pattern helped to elucidate that additional asset-based strategies should be explicitly stated during the PD session. I dove back into research on culturally responsive teaching and made a point to explicitly add strategies into the PD session for cycle three, especially having higher expectations for students. As teachers' self-efficacy began to emerge as a theme with this analysis of cycle two data, I looked at the PD session through this lens, and thought of UDL and CRT strategies that I can emphasize during cycle three.

**Action Research Cycle Three: Perception of Professional Development**

In cycle three, four participants from Dockside Elementary School participated in the professional development session during the fall of 2023. As discussed in the above section, based upon reflection from participant feedback and initial analysis of transcripts from cycle two, I decided to not use the scripted module. The four participants, Cordelia, Augustus, Paul, and Victoria had never experienced the lesson, nor did they know what the lesson was going to be about as they entered the professional development session. As we began, I stated that they were going to experience the lesson through the eyes of a student. I presented the phenomena to them, asking them to generate their observations and questions. As they shared out, I modeled exactly how they should respond to the students.

After the first component of the 5-E lesson, Engage, I discussed how it was implemented and what I explicitly stated or did not state to students. I also shared the UDL strategies that should be utilized. I highlighted CRT strategies, such as being curious about where students are coming from, their prior knowledge, and holding high expectations for not only the science content, but actions as well. I then continued with each portion of the 5-E lesson, through the eyes of a student, and then reviewing teacher directions after they experienced each component, with explicit emphasis on UDL strategies implemented.

At the conclusion of the professional development session. I gave each teacher a copy of the 5-E lesson plan originally utilized in cycle one, the PowerPoint slides for the lesson, student handouts, and the UDL guidelines checklist (See Appendix F). Because these teachers have never conducted the lesson before, I offered to jump in when they felt they needed support during the lesson.

***Cordelia***

Cordelia entered the room with her students with observed excitement and energy. Cordelia teaches an integrated co-teaching class. Her co-teacher walked in the room first, directing certain students to specific tables. Once the students were seated in their assigned groups, Cordelia stated the instructions for the engagement component, presenting the phenomena to the class. She didn't give anything away, yet forgot to mention that there was no right or wrong answer, so I just piggybacked off her directions and added that in. The Co-teacher was observed walking around and watching students, but she appeared to take a 'back-seat" and allow the students to work through the lesson. I also noted that the co-teacher did not appear to linger in one specific area, nor hover over specific students.

After the demonstration when students were directed to go back to their tables and select their roles, I observed Cordelia beeline towards one of the back tables. I quickly followed and observed the students engaged in deciding their roles. Cordelia was about to interject, in obvious anticipation of an issue, and I jumped in and asked for her help with something else, whisking her away from the group. We laughed as we walked away, and she turned to watch them. They managed to work through their decision making without incident. Cordelia later disclosed that one student in that group is diagnosed with oppositional defiant disorder (ODD) and often has outbursts that "catches the attention of the whole class." However, out of the four students in the group, I could not discern which student she was concerned about from my observations. When I could not guess which student it was, Cordelia shared that he was "good" throughout the lesson and enjoys both hands-on science lessons and social studies. Both Cordelia's action to jump in and prevent a behavioral disruption in addition to referring to this child as being “good” throughout this lesson, displays a deficit ideology and exemplifies the oppressive normativity in special education. It is revealing that such actions and ideologies unveil themselves as the actual barriers to learning for students. Besides Cordelia feeling the need to prevent an anticipated problem that never occurred with one student with special education accommodations, she appeared confident throughout the lesson.

During the post-lesson interview, Cordelia offered her impressions of the professional development session:

> I loved the professional development. Science is not always my thing. I'm not always super comfortable with it, so I love that you really went through it all with us and we weren't going in blind with what the lesson was for the students. So, you pretended we were the students, you did everything. Like today, you're NASA Electrical Engineers, and I thought that was awesome. So, I love that we really took a role in what we were doing. I was one of the counters, And I was like, oh my gosh, I'm a little nervous, but you were totally teaching us, no, this is what the kids are going to experience. Feel it out. And me and Victoria [another teacher], who I was doing the counting with, we both got different numbers and it was just funny that it worked out that way. I really just love that you took it through with us. We were students and I felt so much more comfortable when the kids did it. So, I thought the PD was awesome, and I felt so much more comfortable with science. I was like, oh, this is what it should be. This is so exciting. It makes me feel better about teaching it. So, I thought it was awesome. Awesome.

Cordelia explicitly shared her feelings of self-efficacy and how experiencing the lesson through the eyes of a student helped her to gain confidence with teaching the lesson. She even mentions how her moment of struggle, with counting the disk as it spun fast, helped her to understand how the students would feel and made her more confident to teach the lesson. For teachers to be confident enough to support students with productive struggle, the teachers need to understand how the students feel, and believe that they can persevere. When further prompted for suggestions to improve the professional development session to support teachers Cordelia stated “No. I thought the professional development was awesome. Exactly what you did with us was what the kids did, and it was just, no, I wouldn't add anything.”

***Augustus***

Augustus entered the room with students while carrying a calm demeanor. Once the students were settled, Augustus jumped into the Engage portion, prompting students to write their observations and generate questions. He stressed that there are no right or wrong answers. Overall, Augustus seemed confident, but I noticed a bit of apprehension as students went back to their seats after the demo directions on how to use the device. Augustus was quick to run to each group, seemingly anxious that they may need assistance getting started with the explore component of the lesson. By now I was accustomed to this reaction from teachers. I recall wondering if this is something that can be “taught” from one PD session, or needed to be modeled through coaching within the classroom.  I went over to him and nodded for him to follow me. I just smiled and said “watch… just wait and watch.” He did, as his students selected their role within the given timeframe.

When prompted to reflect on the professional development session regarding what was helpful and suggestions for future PDs, Augustus offered:

> Well, I think that was important, just to wrap my head around what was the whole experiment going to be and just understand the whole concept and stuff. And to be able to

> interact, because we don’t get a chance to work together too much, except for some PD. Yeah, no, you covered everything that I needed to understand the lesson and stuff like that. I can't think of anything to improve upon.

I observed Augustus as confident with the scientific implementation; however, as previously mentioned, he seemed apprehensive when students went back to their seats to select their own roles. Like many participants, Augustus did not display self-efficacy with regards to supporting his students to select their own roles, as he was observed going from table to table to make sure they didn’t need help with choosing their roles. After the post-lesson interview, we discussed wait time, stepping back and watching the students as they select their roles. I reiterated the tactics of clear expectations and time frame for role selection, which reduced student conflict during the role selection process.

***Paul***

Paul appeared excited and confident from the start. Once his students were settled, he jumped into the lesson. I interjected after the introduction to the phenomena to add an explicit statement that there are not any right or wrong responses for their observations or question generation. Paul later repeated the same explicit statement when the groups shared out after the Explain portion of the lesson. I was happy that modeling this approach was successful, as he successfully implemented this CRT method into another portion of the lesson. For students to have a voice and know that their responses will not be dismissed as a ‘wrong response’ teachers need to explicitly state that all their thoughts are meaningful. Paul also seemed confident about allowing students to self-select their roles.

When asked for a reflection on the professional development session, Paul offered:

I thought it was very helpful. I really enjoyed the fact that we walked through the experiment step-by-step. We were able to see exactly what the kids would see from their perspective. I think that was beneficial for us because it gave us an insight into what questions they might have or what issues might arise. So, I think it was very beneficial to be able to walk through it step-by-step.

Interviewer: Is there anything else that you would suggest for the professional development that you would change?

Paul: No, I wouldn't. Like I said, it was perfect. And when I got down there, I felt completely comfortable, because I had seen it and I had been a part of it.

Overall, Paul appeared confident throughout, and more importantly, when I noticed he forgot to explicitly include an important direction, he learned from the modeling and then confidently incorporated the tactic on his own during other components of the 5-E lesson.

***Victoria***

Victoria stepped into the lesson a bit apprehensive. Both the teacher and I found out there was going to be a lockdown drill in the middle of the lesson. We briefly chatted about and discussed the plan. I offered to pick up after the drill, to speed the end of the lesson, if necessary, as the class had lunch after and we did not have the option of running over timewise.
Lockdown drills always add an element of nervousness to both teachers and students. The teacher of the fourth-grade class is challenged with not showing any fear; however, needing the students to follow directions seriously and keep quiet. I offered to assist throughout the drill, as we scoped out the section of the room we would utilize for the students to hide. This event was certainly a limitation to the study, as I could not really read too much into any apprehension the teacher displayed and attribute it to the lesson experience. The drill was called just after students

collected their data and before the explanation and brainstorming session of the lesson. Overall, about 10 minutes of lesson time was lost.

When asked to reflect on the lesson professional development session, Victoria responded like Cordelia did by saying that she appreciated how I treated them like the students during the PD:

> I thought it was really cool, just how you went through it, just like you would have with the kids. We experienced it all to understand why we were doing the things that we were doing the way that we did them, especially the beginning prompts when we were like, we weren't supposed to say anything, and just specifically the feedback that you gave us about making sure that we weren't really giving them a response, like, 'Oh, good answer,' or, 'Good thought.' It was more just like, 'Okay, I see what you're saying.' That way we're not really directing them any which way. So, I think that was really cool and just I think having us all together to do it first really just made it so much easier to do it with the kids.
>
> Interviewer: Is there anything about the PD that you would offer suggestions for me to make it better for another group of teachers next time?
>
> Victoria: No, I think everything really was ... It went really well.

It was difficult for me to get a read on how Victoria felt while conducting the lesson due to the anticipated lockdown drill, but her final interview did help to shed more light on her feelings. I strategically involved myself a bit more than with the other teachers, guiding the timing of the remainder of the lesson so the students could get to the brainstorming portion. They had less time to brainstorm than the other classes but did manage to complete both the brainstorming of the essential question and the vocabulary component. Ideally, the extra 10 minutes would have given all students more time to interact and engage in discourse. This is a reminder of organizational barriers and roadblocks that teachers and students face within the construct of a school day. Nonetheless, I feel Victoria's reflection about not giving them too much positive praise such as "good answer" is important. Victoria recalled the CRT strategies shared during the PD session, specifically regarding allowing all students to feel their responses in class are important and to not implicitly intimidate students by telling others that their responses are "good or great." Additionally, it does not direct student thoughts in one direction. During the PD it was stressed that all responses are important (despite our personal opinions), and I modeled this for the teachers by responding without opinion, to their comments.

**Summary of Professional Development Feedback in Cycles Two and Three**

My observations from cycle two lesson implementation were that Clara, who placed the module script on the teacher's desk before the lesson, appeared to be the most confident, followed by Christine who bulleted a few items for each component of the 5-E lesson plan. Sunny was observed to be the least prepared and most nervous about the lesson implementation. Feedback from the participants in cycle two supported my observations, as they indicated that hands-on practice with the lab setup, and not relying on a scripted module, was the best way to support teachers during the professional development session. Additionally, I realized a pattern during cycle two that teachers were hesitant when it came to directing students to self-select their own roles and confidently explain role selection and group directions to the students. My observations of lessons and teacher reactions during cycle two shed light on the teachers' self-efficacy to conduct the lesson. I learned that I would have to support teachers during the PD session without a scripted module. Additionally, I need to find a way to have teachers hold students to higher expectations for student self-directed actions during group work. Therefore, based on my observations and teacher feedback from cycle two, I decided to have the teachers conduct the lesson through the eyes of the students, as I verbally explained the UDL and CRT strategies after each component of the 5-E lesson.

Participants in cycle three offered no suggestions to improve upon supporting teachers during the professional development session, even after an additional prompt to respond to this question during the post-lesson interview. They indicated that they felt prepared for the lesson because they walked through the lesson through the lens of a student during the PD. They were not offered the scripted module at all, yet I did identify all the UDL and CRT strategies after running through each component of the lesson. My observations and teacher reflections of cycle three indicate that teachers feel more self-efficacious about conducting a hands-on lesson with students if they can conduct the lesson themselves during a PD session. Additionally, through my observations of cycle one with no UDL strategies compared to observations of cycles two and three with UDL strategies, teachers were more likely to step back during the lesson, although at times, reminders were needed, and/or I observed them catch themselves and pull back. Teachers during cycle three still hesitated once students started to select their own roles and were caught trying to rescue their students. This makes me wonder if CRT strategies, such as having high expectations for students' self-directed actions (not the curriculum content), need to be modeled and coached, as discussing this during the PD session was not enough. Additionally, these findings also suggest that teachers most likely exhibit the same actions in other content areas and indicate that UDL and CRT strategies may be needed across the curriculum.

**Perceived Challenges of Lesson**

To elicit teachers' perceived challenges of this lesson, they were asked: Were there any components of the lesson that were a challenge to implement? If so, what suggestions can you offer? Teachers' perceived challenges to a lesson can indicate what strategies they are still not confident with and offer insight with regards to further support teachers. Additionally, teachers' reflections of challenging portions of the lesson also shed light on remaining barriers to learning that need to be addressed. Data obtained from this interview question were utilized to answer the primary research question and sub-question number 3, What additional strategies do 4th-grade teachers recommend to further eliminate or reduce barriers to learning? Data from cycle two and three are presented together, as no divergent patterns between cycles were identified, nor specific evolution of challenges from one cycle to another. Patterns that emerged regarding teachers' identified challenges of the lesson included, setting up/using the materials, the students defining the vocabulary, and not saying too much feedback to the students.

### *Setting Up/Using the Materials*

Christine from cycle two, and Paul and Augustus from cycle three all reflected on the setup and use of materials as a challenge. Paul offered feedback regarding the materials from the eyes of the teachers and students:

> I think the biggest challenge was for the person doing the lesson, the setup, all of that stuff. There's a lot of things as far as you organizing a lesson, it's a lot of work, but once it got going I don't think there was and I don't think there was anything I saw that was too complicated, too difficult for them to kind of interact with.

Paul's feedback caused me to reflect and realize that offering time at the end of the PD session for teachers to practice setting up the device and testing it could enhance their confidence with the materials and setup.

Similarly, Augustus identified the device as a challenge, however, his reflection was from the perspective of students as he offered:

> Just sometimes the device itself, the kids just felt nervous about the wheel and stuff like that. But that's just a function of how it's put together and stuff, and just the sensitivity of it. But that's an easy thing to solve, is just go over and just gently get it going and stuff.

It is hard to determine if Augustus felt a bit insecure but then he found that it was easy to assist students, as the device is not too difficult to manage. Once again, allowing the teachers more time to setup and mock troubleshoot could potentially eliminate their perception of the materials being an identifiable challenge.

Christine identified the device as a challenge but with the perspective that cycle two teachers did not get to utilize the machine hands-on during the PD. She suggested "letting them run through it, how to do it" to eliminate this challenge.

***Students Defining the Vocabulary***

Both Victoria and Cordelia from cycle two identified having the students define the vocabulary on their own as a challenge. Victoria stated:

> I think it's hard to not give them the background on the vocabulary because they look at it, they're like, 'I have no idea what that means.' And, your natural instinct is to explain it to them or give them examples.

However, Victoria did express how she was impressed with the student responses. In my opinion, teachers are so used to giving students vocabulary definitions or having students copy the definition, word for word, from a resource. Her perception reminds me of how often I observe teachers as a vehicle of knowledge and they feel they need to deliver this knowledge to students, rather than have students generate their own knowledge based on their learning experiences.

Cordelia also reflected on the vocabulary but focused on one of her students with special education accommodations, who she observed struggle with this component of the lesson. She stated that this student offered responses, but they were very short. To assist the student to elaborate on her responses, Cordelia suggested utilizing a sentence starter for this student or having her label the parts of the machine first, then try to generate the vocabulary.

***Not Saying Too Much Feedback to the Students***

Clara stated that she did not find anything challenging but offered her perception of what aspects new teachers may find as a challenge:

> I don't think I found anything particularly challenging, maybe because it was my second time around. I think though, where some teachers would get hung up is that, 'Oh, great answer.' I think, I can see where that could be a problem… That might have been easy for me, but then again, I can definitely see, especially a new teacher, wanting to please and wanting to... you want to say, 'Ooh, fabulous. Yay, you did it.'

Based on Clara's feedback, I was sure to explicitly emphasize this during the cycle three PD session, and make sure students were told there were no right or wrong answers for the phenomena component. After observing the teachers from cycle three, all were great not to give the positive praise, yet some forgot to state there were no right or wrong answers, so I jumped in and modeled that component.

**Perceived Proficiency of UDL**

One of the final interview questions asked teachers: Are there any strategies from this lesson that you feel can be transferred to other 5E STEM lessons? Eliciting a response to this question can shed light on strategies implemented in the lesson that teachers feel comfortable enough to incorporate in future planning. Their responses to this were used to answer the primary research question and the 1$^{st}$ research sub-question: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during each of the 5-E components I the lesson? Table Four summarizes the specific components of the lesson that teachers felt they could transfer to other 5-E STEM lessons. Five out of seven teachers mentioned the Engage component, two mentioned Explore, and three mentioned Evaluation. Three out of the seven teachers cited two different strategies they would transfer to other lessons. Indeed, all four teachers from cycle three cited the Engage portion as a strategy they feel they can transfer to a future STEM lesson. I found this noteworthy because the teachers in cycle three were less familiar with the phenomena as compared to the teachers in cycle two. Student choice for evaluation came in second, and engaging students with experimentation and problem-solving third.

**Table Four**

*Teacher Identified strategies that can be transferred to other STEM Lessons*

| Teacher/Cycle of Research | 5-E Component(s) of Lesson | Strategy/Strategies Discussed |
|---|---|---|
| Sunny/Cycle Two | Evaluation | Student Choice |
| Christine/Cycle Two | Evaluation | Student Choice/ prompts/checklist |
| Clara/Cycle Two | Engage | Anchor instruction w/phenomena/activate prior knowledge/advanced organizers (teacher stated transferable to all subject areas) |
| Cordelia/Cycle Three | Engage<br>Explore | Anchor instruction w/phenomena/activate prior knowledge/advanced organizers<br>Active participation/ exploration/experimentation |
| Augustus/Cycle Three | Engage<br>Evaluation | Anchor instruction w/phenomena/activate prior knowledge/advanced organizers<br>Student Choice |
| Paul/Cycle Three | Engage | Anchor instruction w/phenomena/activate prior |

| | | |
|---|---|---|
| | | knowledge/advanced organizers |
| Victoria/Cycle Three | Engage<br>Explore | Anchor instruction w/phenomena/activate prior knowledge/advanced organizers(teacher stated transferable to all subject areas)<br>Active participation/ exploration/experimentation |

Clara, Augustus, Paul, Cordelia, and Victoria all stated strategies from the Engage component of the lesson could be transferred to other lessons, detailing information about the strategies utilized to present the phenomena to students. During the phenomena, students were presented with pictures and asked to generate observations and questions. Teachers were directed to allow students to complete this component individually before they share out. Teachers were also coached to explicitly state that there are no right or wrong answers, and when students share not to state something like "Oh that's a good question" because all student ideas are equally as important and can contribute to the discussion.

Clara stated that starting any lesson with a phenomenon is great, and that this strategy can be utilized for other subjects in addition to STEM. Victoria also mentioned phenomena and how it can be utilized in other subjects as well. While reflecting on the phenomena, Victoria stated:

> That's something that we could use probably across the board in any topic. So, I think that's something I'm going to look to incorporate in my lessons. I think it's cool to just see where they're coming from, what they already know, and where their thinking is taking them.

I was happy to hear Clara state that she felt comfortable enough with the phenomena that it was transferable to additional subjects other than science.

Paul and Cordelia reflected on the phenomena piece and stated how they may have used this strategy in the past, but how they gave away too much information. They both expanded on the strategies utilized when presenting phenomena. Paul shared "I need to step back a little bit and give them the opportunity to figure it out. Let it click in their own brains rather than me giving it to them." Similarly, Cordelia also reflected on the specific strategies utilized and discussed how she will change her practices with presenting phenomena. Cordelia shared "I've tried that before…We have to think about it, write it down first, and then chime in and expand on each other." Augustus reflected on how he sometimes rushed the beginning and how it is important to slow down with the notice and wondering aspect of the phenomena. Since the phenomena is considered the anchoring component of the lesson, I was pleasantly surprised to hear that all four teachers felt they could utilize this strategy in future lessons.

**Summary of Self-Efficacy Theme**

Analyzing the data from the parent codes, Perception of PD, Perceived challenges of lesson, and Perceived proficiency of UDL, it became apparent that teachers need to feel self-efficacious with the materials and asset-based pedagogical strategies to support the students during STEM lessons. Teachers need to feel confident walking out of the professional development session. Changing the PD session based on the teachers' feedback during cycle two resulted in teachers feeling more confident with the lesson implementation during cycle three.

Scripting the lesson actually created a barrier to pedagogy for teachers. Allowing the teachers to walk through the lesson through the eyes of the students led them to feel they could support students through the lesson. I even observed teachers become more comfortable throughout the lesson implementation. Some teachers began to implement UDL strategies after I modeled them, and others seemed visibly more comfortable as they observed their students as self-regulated learners. It seems hard to determine if the implementation of CRT strategies during the PD session is enough to support teachers. I felt they still struggled with having the confidence to give students the directions for group work and role selections, and I still observed teachers running over to be sure the students were selecting their roles during cycle three.

During the post-lesson interviews, teachers expressed their surprise with their students' quick role selection. I wonder if the teachers would now transfer this to another lesson and feel more confident to step back and allow their students to select their roles without teacher interference. After analyzing data from cycles two and three, I noticed that teachers need to be self-efficacious to hold high expectations of content, in addition to high expectations of self-directed behaviors during group work. Overall, teacher self-efficacy and their perceived effectiveness in supporting students evolved from cycle two to cycle three with regards to feeling supported during PD sessions and their perceived preparedness to carry out the lesson.

## Empowering Students

When teachers are self-efficacious with asset-based pedagogical practices, they have the power to empower students. As depicted in Figure 1, the remainder of the themes, empowering student voice, empowering students through engagement, empowering students as a learning community, and empowering student choice, emerged through the analysis of two-parent codes: Reducing/Eliminating Barriers and Perception of Collaboration. The following two sections elucidate the development of the final four themes related to empowering students through voice, engagement, community, and choice.

### Reduce or Eliminate Barriers to Learning

One of the post-lesson interview questions asked teachers to reflect on how they felt the UDL lesson went overall. More specifically, the subcomponent of this question asked teachers if they felt there were any UDL strategies that reduced or eliminated barriers to learning. The data from these questions were utilized to answer research sub-question number 2: What UDL strategies were perceived as effective in reducing or eliminating barriers within specific components of the 5-E lesson? Child codes were generated based on the 5-E components of the lesson, as this pattern emerged when teachers offered the component of the lesson, followed by an elaboration on a particular UDL strategy. For reporting purposes, as per CAST (2018) UDL reporting guidelines, Child codes were further organized into the UDL Checklist guidelines, as indicated previously in Table 3. Therefore, this section is organized into the 5E components, with the teachers' perceptions of identified strategies that reduced or eliminated barriers to learning in this lesson.

***Engage***

All seven participants identified UDL strategies utilized during the Engage portion of the lesson that reduced or eliminated barriers to learning. Sunny, Victoria, and Cordelia each identified strategies from G1, C1.1: Provide options for perception. This strategy offers ways of customizing the display of information for students. During the engage portion of the lesson, the phenomena was a set of two, color pictures presented concurrently. The pictures were displayed on the smart board in front of the room in addition to each student having an 8 ½ x 11" laminated copy of the picture on their desk. Sunny stated that she liked the laminated pictures because some of her students were glasses for distance and she felt it was very helpful to have the pictures on the tables as well. Victoria mentioned that everyone having their own copy allowed students to "get into it themselves and see it closely." Marina mentioned the visuals and how students "knew what they were looking at on the board" in addition to students "noticing and wondering and making observations all on their own." Student responses to the phenomena was the only component of this lesson completed independently without any influence from peers or the teacher. It offered students the opportunity to tap into prior knowledge and generate their own thoughts and ideas in the form of questions. Based on the teachers' perspectives, having their own copy supported students' individual thoughts and voice as they listed their observations based on their prior experiences and generated questions as they engaged on the metacognitive level while viewing the pictures and connecting their observations to prior experiences.

Christine and Nicole identified a strategy from G3, C3.1: Provide options for comprehension. This strategy supports students by either activating or supplying background knowledge using instructional anchors that link to and activate relevant prior knowledge. Christine offered that she likes the phenomena portion because she likes knowing "where they are coming from, what they are thinking before we jump in, I think it's amazing." Nicole stated that "I think it's cool just to see where they're coming from and what they know already, and where their thinking is taking them." Christine and Nicole's perspectives support CRT and embracing students' personal experiences and incorporating them into the lesson as an anchor. This also supports student voice, as their own perspectives and unique questions are embraced.

Paul identified a strategy from G3, C3.3: Guide information processing, visualization, and manipulation through explicit prompts for each step in a sequential process. Paul reflected on the presentation of the phenomena and stated:

> I just think the prompting was very beneficial for the kids. The prompting, but not giving away anything, just kind of alluding to things and letting the kids figure it out. I liked that we didn't tell them a lot. You basically gave an overview, it was up to them to kind of make decisions on the picture or make decisions on what they notice or wondered without leading them too far into it.

Clara, Paul, and Augustus identified a strategy from G7, C7.2: Optimize relevance, value, and authenticity by inviting personal response. The three teachers discussed the students writing about their own thoughts. Clara mentioned "accepting any answer, accepting anything," and Paul, as quoted above, expressed how students could make their own decisions. Again, in addition to UDL, these comments support CRT, and show the teachers' support to empower students' individual perceptions and ideas. Accepting any answer empowers student "voice" as there is no wrong response. One can empower student voice by simply removing judgment.

***Explore***

Cordelia and Victoria identified strategies from G6, 6.2: Support planning and strategy development by providing checklists, templates, sequences, etc. Additionally, their reflections included strategies from G6, G6.3: Facilitate managing information and resources through templates for data collection, prompts for systematizing. Cordelia mentioned that she has an integrated co-teaching (ICT) classroom, and her students often need explicit directions. She commented on how students were gathered around for the demonstration, how they were a part of the demonstration, with step-by-step directions, and how the provided checklist supported her students' needs. Victoria mentioned the worksheet for recording was clear for all students, as no one seemed to have any confusion, and they all were able to list all their data and move on to the next component of the lesson. These UDL strategies supported self-directed learning, as instruction was appropriately scaffolded, and students were engaged in the scientific practices without constant assistance from the teacher.

Clara and Christine identified strategies from G8, C8.3 and G9, C9.1: Fostering collaboration and community through the creation of cooperative learning groups with clear goals, roles and responsibilities and providing options for self-regulation such as reducing the frequency of outbursts in response to frustration through prompts and guides. Clara stated that "Giving the kids ownership with picking their roles was key. And they did that. I was really surprised how quickly my class did it…quickly and without incident." Similarly, Christine reported that "just having each person have their own jobs, I think just sets those boundaries for them to be working well." These UDL strategies allowed students to form an effective, self-directed learning community.

***Explain***

Sunny, Cordelia, and Clara identified strategies utilized during the Explain portion of the lesson. Sunny and Cordelia noted strategies from G3, C3.3: Guide information processing through graduated scaffolds that support information processing strategies and progressively releasing information, such as sequential highlighting; G8, C8.3: Foster collaboration and community through prompts that guide learners in when and how to communicate; G8, C8.4: Increase mastery-oriented feedback through the emphasis of effort, improvement, and achieving a standard rather than on relative performance. Specifically, Sunny discussed how the partners worked collaboratively within the group, jig-sawing the information by switching a partner from each group, reporting back to their original group, and then further building upon that new information. Cordelia also commented on the jig-sawing portion during the Explain portion of the lesson. Clara identified the graduated scaffolds as she recalled how they piggybacked off each other and were given a little bit to focus on, had them elaborate on it, and prompting them by saying "Okay, so what can you say about that specifically?" Scaffolding the conversations via these UDL strategies allowed for continuous discourse engagement, as students collaborated within their learning community. This resulted in student voice, which will be explored and supported further in a later section.

***Elaborate***

Augustus and Victoria reported on the Elaborate portion of the lesson. They provided examples to support G3; C3.4: Maximize transfer and generalization by providing scaffolds for new information to prior knowledge and generalizations to new situations. Augustus shared how students "were able to come up with the connection between gels and what was real-life application." Similarly, Victoria discussed how a student compared the gels to "clouds in the sky." These UDL strategies allowed for students to take what they learned through the Engage portion of the lesson and emulate the practices of scientists as they transferred their learned knowledge and expressed how they relate to real-life situations.

***Evaluate***

Five of the seven teachers identified specific strategies from the Evaluate component of the lesson. Victoria, Augustus, and Christine all identified strategies from G6, C6.2: Support planning and strategy development by supporting with prompts to show and explain work, along with checklists. All three teachers mentioned the diagrams students were offered to include along with their written explanations. Augustus expressed his surprise with his students' diagrams. As he reflected on their evaluation pieces he stated: "They did a really nice job. Just a matter of some of them, especially some of them with the diagrams they drew, it was like unbelievable. They can rebuild it themselves, some of these kids." After analyzing the feedback from cycle two, teachers indicated that the refection paper should include a space for a diagram. Teachers indicated that when students drew a diagram of the machine they used, they then were able to elaborate on their written responses.

Sunny, Christine, Cordelia, Augustus, and Victoria identified strategies from G7, C7.1: Optimize individual choice and autonomy by providing options for recruiting interest and assessing skills. Sunny, Christine, Cordelia, and Augustus all referred to student "choice" when reflecting on UDL strategies that reduced or eliminated barriers to learning for the evaluation portion of the lesson. Sunny stated that "having the options for the reflection was dynamite." She explained that some students "drew pictures and responded in written format and that she felt they chose the way they could best express what was going on and reflected on it" and described the reflective portion as "dynamite." Christine expressed that she loved the choices given to the students for the reflection and also described her surprise when reviewing the students' reflections. Christine stated that "It's just very interesting to see what they chose to do for their reflection… I would've assumed somebody would've chosen a specific way, and they didn't choose that one." Nicole described why she was impressed with the students' reflections referring to their real-world connections and discussing the detail they put into it. As she showed me examples of the details in the students' diagrams, she stated "so you can tell they were really engaged in it." Cordelia reflected on her ICT class and stated that the choice options were awesome and that her students really did all their reflections on their own. The emerging themes continued to strengthen with the analysis of the last parent code, perception of collaboration.

**Perception of Collaboration: Brainstorming of Essential Question and Vocabulary**

To gain an understanding of the teachers' perception of student collaboration during the lesson, they were asked to reflect on the student brainstorming sessions during the explain component of the lesson. During the first brainstorming session, students were asked to collaborate and answer the lesson's essential question. During the post-lesson interview, teachers were asked: How did you feel when the students engaged in the brainstorming session to answer the essential question?

Teachers' responses to their observations of students answering the essential question were a mix of positivity and surprise. Christine offered that the students' responses "blew her away," as she described their engagement as having a "high road of thinking" going on. By empowering students to brainstorm together in a learning community, and stepping back as the teacher, the students can take their conversations to a higher level. Similarly, Augustus reflected on how he really didn't have to do much to draw answers out of the students, as they came up with the connections between the gels and real-life applications on their own. Victoria reflected on allowing the students to "be problem solvers on their own." She described how giving them "freedom" to figure it out and work through it on their own "helps them think like a scientist" rather them having the students "rely on us for answers." The students truly emulated scientific practices, as they brainstormed and edited their stories until they had the whole picture. From my observations and the teachers' reflections during the post-lesson interviews, when teachers step back and release their power, they empower students to self-direct their own learning. The "surprised" reactions from teachers indicate how they often overpower the learning process by constantly feeling the need to be in control and not believing in the students' abilities.

Allowing students to work as a community of learners by engaging in scientific practices empowers those who normally would take a back seat and not speak up. Clara described her reflection as "throwing them in" and allowing the students to "piggyback off one another" as being really helpful as their answer to the essential question became stronger and stronger as students jig sawed. Similarly, Paul described how he felt surprised and rewarded as he observed his students' work through a lesson and had it all come together at the end. During Paul's reflection he stated:

> I know the kids, I have such a relationship with them, to then see some of the shyer ones all of the sudden jump in and say a certain thing. You're like wow, they got that? They understood that? It was very, very rewarding for me to see.

Paul further commented on how some of his quietest kids jumped in to respond and offer answers and how he felt very proud to see that, because it indicated that they really got it. This made me ponder, what does it mean to be a "shy" student? What causes these students to be silenced? What aspects of the UDL and CRT strategies gave them voice? Was it that we encouraged all responses, purposely did not give positive feedback because we did not want students to think there were "great" and therefore not great responses? Was it this along with the scaffolding of student discourse? Somehow, these strategies, combined or alone, prompted students to have voice who did not normally speak up.

During the final interview, teachers were also asked: How did you feel when students were presented with the lesson vocabulary and asked to brainstorm their own definitions? Victoria commented on how she initially thought the students would have a bit more trouble with defining the vocabulary, especially when they first looked at the unknown words. Reflecting on the students' defining the vocabulary, Victoria stated that she was impressed and offered "I think they used a lot of knowledge from the actual experiment, and they were able to kind of piece some of those things together." Similarly, Paul also shared that he was a little nervous about the vocabulary because they have not learned a lot of background knowledge on energy. Paul also reflected on the hands-on component of the lesson and described how he felt the students utilized the components of the machine to figure out the vocabulary. During Paul's reflection he also offered "So I was a little nervous in the beginning, but I was very impressed with the way they were able to put it together through minimal prompting. They were able to put those sentences together and formulate cohesive ideas." Therefore, allowing students to engage in the hands-on component and engage in discourse as a community of learners allowed them to make the necessary connections to define the vocabulary on their own.

Christine stated that she felt the majority of the class did well with the vocabulary, there were a few that struggled. She further offered that they worked so well with their peers that they talked through it which really helped them, further supporting the notion of a learning community.

Cordelia reflected on her ICT class and shared how she was really surprised that they were able to come up with the responses on their own. Cordelia offered her perception and shared:

> It wasn't just my stronger students. I feel like they were all really involved, and they were trying to raise their hands and give feedback whether or not it was always the correct answer. They were all engaged and willing and felt like there was no wrong answer. So, I was actually really surprised in their responses.

Cordelia sheds light on how we can empower student voice by taking away the notion of right or wrong. Additionally, Cordelia was surprised by the level of her students' responses, which suggests that all students are not encouraged to participate on a regular basis. However, her use of labeling (e.g., stronger students) and her surprise that special education students could "come up with responses on their own" reflects deficit thinking and implicit biases. Based on her response, I feel it is important to address this in future PD sessions. Specifically, I feel it is important to conduct PD sessions where teachers walk away with the understanding that their students can access the knowledge within the curriculum, making connections between new material and their own prior knowledge, and combing their past personal and current experiences to generate novel thoughts that they can express. Ultimately, I feel that teachers need to understand the power they have if they “let go” and empower their students’ autonomous thoughts in the classroom.

Another important observation is that students and teachers are so accustomed to there being a right or wrong response to questions. This perception creates barriers to both pedagogy and learning. Clara stated that she thought the vocabulary was a little challenging for them because they are not used to putting things into their own words and that a lot of students just want to be correct. She also offered that she feels they do not trust themselves and don’t have the confidence. Hearing this response, I asked Clara what advice she would give new teachers to help students overcome this fear. Clara stated, “Just go with it, letting go and not being on top of them.” She further stated that their responses do not have to be perfect, or memorized, stating that “they’re good enough” and that “they actually know what they are doing, you just have to give them that confidence.” Clara completed her reflection with “It’s a release for the teacher. It’s a release for the kids.” To me, this further solidified the notion that barriers in lessons are synonymous to pedagogical practices. The barriers are not within students. The barriers are how lessons are implemented.

Conversely, Augustus stated that the vocabulary was a bit of a challenge for his students. He further shared that he felt the reflection helped his students with the vocabulary, as they had a list of term s to incorporate, and many students drew diagrams. This supports the use of multi modalities to eliminate barriers and reach all learners. He felt that “the picture was huge. It helped them to formulate the words.” Sunny also identified the vocabulary as difficult. She reflected on how rushed the end of the lesson was, and that the students had to get to their special. Sunny suggested that there was a time constraint at the end of class and if we gave them more time to collaborate, they would have more success defining the terms. This further supported the importance of allocating time for collaboration and discourse within STEM lessons.

Teachers' perception of student collaboration during the brainstorming components of the lesson included positive feedback in addition to many reported feelings of surprise. All seven participants responded positively to the interview questions regarding their perceptions of the students during the collaborative brainstorming sessions. Five of the seven participants expressed feelings of astonishment as they let go of their authoritative role and allowed students to take the lead of classroom discussions. Empowering students through voice and as a community of learners emerged as teachers stepped back during this component of the lesson.

## Conclusion

This chapter presented the major findings of this action research study that answered my primary research question: How do 4th-grade teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices? The participants' individual reflections of their students' response to the lesson elucidated two categories of themes: teacher self-efficacy and empowering students. As teachers were coached to step back throughout the lesson process and relinquish their usual authoritative approach towards teaching, they empowered their students to access content knowledge and express themselves through voice, engagement, learning communities, and their individualized choice to reflect on learning. As will be further discussed in Chapter 5, I argue that barriers to learning are not about barriers within students but rather organizational barriers with regards to power and authority, and how lessons can be crafted, one way or another, to channel the direction of this power as students engage in the practices within the NYSSLS. Collectively, these findings generate possible areas of future research and provide specific recommendations to the approach of STEM pedagogical practices, which are discussed in the next chapter.

# Chapter 5

# Conclusion

"*Just go with it. Let go and not be on top of them. It doesn't have to be perfect. It doesn't have to be memorized. They're good enough. They actually know what they are doing. You just have to work on giving them confidence. It's a release for the teacher. It's a release for the kids.*"

~Clara

The purpose of this action research study was to explore how coaching teachers to utilize the UDL and CRT frameworks in conjunction with the 5-E lesson plan design can support teachers in creating inclusive learning environments where all students develop self-efficacy in STEM. In this chapter, I offer a comprehensive overview of this study. I first offer an overall summary of this study including the purpose, research questions, and discussion of the findings. Next, I discuss the research findings in context with the literature and theoretical frameworks. I then offer the limitations of this research study, followed by a discussion on how this study contributes to the literature and implications of this research. Lastly, I close this chapter with final remarks.

## Summary of the Study

This action research study aimed to address the gaps identified in the research regarding supporting students as learners as they emulate scientists while engaging in the practices in the NYSSLS, and to eliminate barriers that prevent students from accessing knowledge-based content in the NYSSLS. I worked at the grassroots level, alongside teachers, through three cycles of research over the course of a three-year period. Data from cycles two and three were included in this dissertation study. Next, I offer a summative overview of each chapter of this dissertation.

Chapter 1 offered an overall summary of this dissertation study including a statement of the problem, brief overview of the theoretical frameworks, the research questions and methodology, my positionality as a researcher, significance of the study, and definitions of key words. The literature presented in Chapter 2 elucidated my understanding of the inequalities that exist in STEM fields and the necessity of pedagogical practices that support teachers to enhance student self-efficacy in STEM by eliminating the barriers to learning in STEM lessons. Moreover, Chapter 2 details the social cognitive and social constructivist theories, in addition to asset-based pedagogies that guided the development of my methodologies and offered a lens to analyze the data collected. Chapter 3 provided a detailed description of the methodology utilized for this study. I was guided by a transformative worldview that aligned to the social cognitive and social constructivist theories and selected an action research design to work alongside teachers during professional development and coaching sessions. When action research is utilized as a means of professional development, it has the potential to be transformative and promote institutional change (Herr & Anderson, 2015). Chapter 4 offered me a vehicle to dive deep into the data, identify patterns, recognize themes, and comprehend the importance of the participants views. Through each of the three cycles, the data guided transformation of methodologies, resulting in a deeper understanding of the participants and richer data.

## Research Questions

The following research questions guided this study:

**Primary Research Question**: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during science and engineering practices?

**Sub-Question 1**: How do 4$^{th}$ grade teachers coached in UDL strategies perceive their effectiveness in supporting students during each of the 5-E components of the lesson?

**Sub-Question 2**: What UDL strategies were perceived as effective in reducing or eliminating learning barriers within specific components of the 5-E lesson?

**Sub-Question** 3: What additional strategies do 4th grade teachers recommend to further reduce or eliminate barriers to learning?

## Summary of General Findings

As an educator in STEM fields for 30 years, I have first-hand experience of both national and state initiates regarding science reform. After decades of various reforms, there remain inequities and barriers to learning in STEM within our K-12 institutions. To address these inequities, the NGSS and NYSSLS shifted the focus from scientific content to the process of science. Yet, despite both documents claiming to be focused on equity, they are drafted with a deficit mindset as they explicitly refer to marginalized groups that need special attention to be successful in gaining access to the content within the standards. Furthermore, they do not offer specific pedagogical solutions to eliminate barriers, and the NGSS document acknowledges a dearth in research regarding how to support the marginalized groups that need special attention.

Working through the three cycles of action research described in this dissertation elucidated specific barriers to learning that prevent all students from accessing content and successfully navigating the practices embedded in NYSSLS designed STEM lessons. Gaining an understanding of the specific barriers offered clarity on how to shift pedagogical practices to eliminate these barriers. Both the NYSSLS and NGSS documents refer to marginalized groups of students who will have trouble accessing content within these State and National standards. However, based on my lesson observations and analysis of teachers' reflections, I argue that barriers to learning are not about barriers within students, but rather organizational barriers with regards to power and authority. This analysis offers a lens to flip the focus of the "issues" away from the students, and rather on the design of the lessons and pedagogical practices. Two major themes emerged during this study: Teacher self-efficacy and Empowering students. Findings of this study suggest that constructing lessons through the lens of asset-based pedagogies, such as UDL and CRT, suggest promise for eliminating barriers to learning in NYSSLS STEM lessons.

## Removing Organizational Barriers to Empower Students

Several personal and organizational barriers to empowering students during STEM lessons were found to have a negative impact on lesson implementation. These barriers include 1) low teacher self-efficacy in science, 2) teacher-directed instruction, 3) deficit-mindset and labeling of students, and 4) a lack of planning time with other teachers and coaching to develop and implement lessons, and such organizational barriers effectuate the racial and gender gaps prevalent in STEM fields.

### *Teachers' Self-Efficacy*

A lack of teacher's own self-efficacy presented as the first barrier to lesson implementation, as teachers were quick to jump in and rescue students, offering answers and solutions. If teachers themselves have low-self efficacy in scientific practices, they are less likely to relinquish control during lessons, as they tend to believe that the students cannot navigate STEM challenges on their own. Van Garderen et al. (2012) reported that teachers with low-self efficacy in science content tend to maintain control of content flow during lessons. When teachers were coached with UDL and CRT strategies to let go of their authoritative role and relinquish control, they empowered their students to access content knowledge and students expressed themselves through voice, engagement, collaboration, and their individualized choice to reflect on learning.

The professional development session prior to lesson implementation was found to be important with regards to the teachers' self-efficacy of teaching the STEM lessons. Teachers during cycle two reflected on a scripted module of the lesson with UDL strategies and felt the module was overwhelming, as it put the focus on what the teachers should be doing instead of what the students are supposed to do. As detailed as the module was, teachers were not confident on how to carry out the lesson and support students as they transitioned through each 5-E component. During the cycle two post-lesson interviews, teachers suggested that it would be beneficial to run through the lesson, through the eyes of the students, during the PD session. Zhou et al. (2023) conducted a meta-analysis on the effect of professional development on in-service STEM teachers' self-efficacy. The researchers reported that PD sessions with both content and pedagogical knowledge resulted in optimal gains in teachers' self-efficacy as compared to PD sessions without the pedagogical practices. Hence, based on data collected from this study and a review of the literature, the structure of the professional development session for cycle three was organized so teachers can work through the lesson through the eyes of a student.

Additionally, the incorporation of CRT, in addition to UDL strategies during cycle three was motivated by my observations of teachers having trouble stepping back and being quick to rescue students, along with their element of surprise of how students can navigate certain aspects of the lesson together without teacher intervention. Although my explicit explanations of both UDL and CRT strategies during the PD may not have reduced authoritative behavior overall during cycle three, when teachers were coached during the lesson and prompted to step back, they did so quickly and reflected on how the students were able to accomplish tasks without teacher intervention. However, data from cycle three indicated that all four teachers continued to offer evidence of a deficit mindset. Paul was surprised when "shy" students spoke up and offered their thoughts. Augustus offered that he thought some of his students' reflections were "unbelievable" as he described the details they included in their diagrams. Victoria also offered how she was "really impressed" with her students' reflections, in addition to being "impressed" with her students defining the vocabulary by themselves. Cordelia was "really surprised" how students were able to come up with definitions to the vocabulary on their own and it wasn't just her "stronger students" in her ICT class. She also was surprised that one of her "behavior students" was able to quickly select a role with his group. Therefore, even after the PD session that included UDL and CRT strategies, teachers still felt an element of surprise regarding the students' ability to brainstorm and generate thoughts and reflections on their own, indicating the teachers' low self-efficacy with regards to inclusive education.

Inclusive education refers to increases in both access to and participation within education institutions for all students by setting specific goals (Messiou, 2017). Weber and Greiner (2019) report on a cyclical pattern of the development of pre-service teacher self-efficacy with regards to their beliefs of inclusive education. Specifically, the researchers report that slightly high self-efficacy among pre-service teachers results in more inclusive teaching practices. However, the researchers also affirm that concurrent positive experiences are essential to foster a strong self-efficacy towards inclusive education. Therefore, the correlation between teachers' self-efficacy and their deficit mindset view of student's ability to access content and navigate practices independently with their peers are identified as two, co-dependent organizational barriers in this study.

***Teacher Directed Instruction***

Low teacher self-efficacy can influence teachers' perceptions regarding the ability of their students to successfully self-navigate STEM activities. As illustrated from the teachers' behaviors in this study, low self-efficacy prompted teachers to feel the need to step in and direct lessons or interfere with student self-selection of roles without giving the students a chance to self-regulate their own learning. Purposeful planning of student-directed lessons that incorporate scaffolds to support self-regulated learning, student choice, and cooperative peer-to-peer experiences can offer students the opportunity to successfully navigate STEM lessons and enhance their own self-efficacy in STEM related fields (Koes-H et al., 2021; Montgomery et al., 2023; Murphy, 2022). Findings from this study indicate that frameworks from both social cognitive and social constructivist theories can be infused within the constructs of STEM lesson-planning to shift the focus away from the teachers and put the students at the center of the learning process.

Data from this study supports the social cognitive frameworks of growth mindset, self-efficacy, and self-regulation and social constructivist frameworks, including Vygotsky's zone of proximal development, which are the foundational pedagogical frameworks for UDL. The incorporation of UDL strategies in this lesson offered various opportunities for students to exhibit self-regulated learning behaviors. Specifically, scaffolding supports were intentionally added to each component of the 5-E lesson design. Montgomery et al. (2023) incorporated intentional scaffolding as part of their UDL STEM lesson and found that students exhibited an increase in confidence in applying the scientific method and stronger skills to solve scientific problems. Data analysis for my study indicated how teachers felt students were able to generate their own thoughts as they listed their observations and questions on the T-chart because they each had their own laminated copy of the picture. Another example of lesson design that prompted self-directed behaviors was the format of the directions and data tables. Cordelia explained that her students in the ICT classroom often need explicit directions and how the step-by-step directions and checklists provided during the lesson guided all students and supported their needs.

Students' self-selecting of their roles was identified as a strategy to reduce frustration and options for self-regulation. Additionally, student choice and a provided check list was identified by five out of seven teachers as a self-directed scaffold that offered the students both choice and guidance. Koes-H et al. (2021) explain how students need scaffolding within a STEM lesson to navigate from the introduction and background to making real-world connections after the experimentation phase. UDL is designed to develop expert learners (Meyer et al., 2014) as they display self-regulation through their learning process. If students are to engage in the practices as they navigate content of the NYSSLS, they need to be supported with the scaffolds to guide them during their self-regulated learning as they emulate scientists.

In addition to scaffolding the independent practices and student direction, overall comprehension and meaning making needs to be scaffolded as well. Data from this study supports the bridge from social cognitive theory to social constructivist theory. When students were presented with their phenomena, they connected their prior knowledge to a new situation (Piaget, 1973). Additionally, Victoria offered that she felt the students used knowledge from the actual experiment to kind of piece everything together to make sense of how it worked. As students worked through problem-based cooperative learning, they generated their own ideas as then relied on each-other to learn (Murphy, 2022). Data from this study also illustrated the student generated knowledge that supports social constructivist theory. Christine reflected on her students' brainstorming sessions and felt that their engagement displayed a "high road of thinking" and that their responses "blew her away." Augustus reflected on how students were able to come up with the connection between the gels and real-life applications. Augustus' reflection illustrates how students utilized their prior knowledge (learned during this lesson) and generalized their thoughts to new situations. During Victoria's reflection of the brainstorming session, she offered that giving students "freedom" to figure it out and work it though on their own "helps them think like scientists" rather than students having to "rely on us for answers." Clara picked up on how students were able to scaffold their learning off each other's responses as she stated that having them "piggyback off one another" as being "really helpful to answer the essential question."

Various studies support STEM project-based learning utilizing social constructivist methods (Admawati et al., 2018; Aguilar, 2016; Hanson, 2020; MacDonald et al., 2020). Data analysis from this study elucidated the importance of social constructivism during STEM lessons. It offers a means for students to learn independent of the teacher, allows them to express their own voice and thoughts and sets the stage for a culturally responsive learning environment. However, as students collaborated and successfully generated their own knowledge, teachers in this study expressed their "surprise" with regards to certain students who offered well-constructed thoughts and responses. This elucidated a deficit mindset for certain groups of students, such as those with special education accommodations or students labeled as "shy" or "strong students" or "behavior students" by their teachers.

***Deficit Mindset and Labeling of Students***

Another organizational barrier identified from the data analysis of this study is teachers' deficit mindsets for specific groups of historically marginalized students. As described above, even after the PD session during cycle three, teachers still expressed their "surprise" regarding how well students navigated the practices or constructed their responses. This elucidates another organizational barrier, as teachers appear to need more than just a PD session to release their authoritative role. It appears necessary to coach teachers with UDL and CRT strategies, at the grassroots level within the classroom, as the coach needs to intervene during actual lessons and coach teachers to step back and observe how their students successfully navigate the 5-E components of a STEM lesson. Zhao (2016) stipulated the need to shift focus away from students' deficits and teachers to focus their efforts on allowing students to identify and utilize their strengths. Cordelia from cycle three had an ICT class. As described in Chapter 4, she displayed a deficit mindset with regard to stepping in to prevent a behavioral outburst from one of her students with an IEP accommodation. For another student with accommodation, she expected her to struggle with the vocabulary. Although Cordelia was surprised (deficit mindset) that her student was able to offer something for her own definitions, Cordelia offered utilizing sentence starters as a scaffold for this student to help her elevate the level of her responses.

Labeling students is an additional factor that perpetuates a deficit mindset. Once a teacher formulates a label for one student, they automatically construct an unexpressed label for another group. For example, calling a student "shy" insinuates there are students who are outgoing, referring to "behavior students" compares them to the well-behaved and referring to "strong students" means that there are students who are weak. In this study, Paul mentioned that he knows his students and has a good relationship with them and expressed how he was surprised to see some of the "shyer" students jump in and offer responses. Since changing the pedagogical practices with asset-based pedagogies, such as UDL and CRT, gave these students voice, then perhaps perceived shyness is not a trait of a student, but rather a sign of oppression because of teacher-directed lessons. Similarly, Cordelia anticipated that her "behavior student during role selection would not be able to self-regulate through this task is another example of how labeling puts the blame on the student rather than pedagogy. Labels are institutional and teacher-created barriers that oppress students. This study indicated that the incorporation of asset-based pedagogies, such as UDL and CRT, can shift not only the successful access to content and practices during STEM lessons for all students, but can also shift the dynamics of deficit mindsets and possibly reduce the perceived limitations of students that often causes the creation of such labels. It is important to note that teachers in this study gave no indication with regards to their understanding of the detrimental effect that labeling students can have on student self-efficacy. Moreover, the labeling of students perpetuated teachers to feel the need to act in a teacher-directed manner, as they felt their students needed rescuing throughout certain components of the lesson.

Data analyzed from this study suggests that when the teachers released their power, four themes of empowering students emerged: Empowering student voice, Empowering students through engagement, Empowering students as a learning community, and Empowering student choice. However, if I did not intervene during the teachers' lessons, I am not sure students' empowerment would have emerged to the extent that it did. Teachers were quick to jump in and rescue students during the lesson. As part of the coaching strategies during the lesson, I would interject and signal for teachers to step back and allow students to proceed independently. Zhou et al. (2023) reported on the importance of coaching with on-site support for STEM lessons to enhance teacher-self-efficacy. Therefore, according to the data analysis of this study in addition to evidence from the literature, to overcome this organizational barrier, schools need to provide teachers with grassroots coaching and continued training within their classrooms beyond initial PD sessions.

***Lack of Planning Time***

Analysis of participant data illustrated that grade level teachers do not get a chance to work together often, as they did in this study during the PD session, illuminating another organizational barrier: teachers often plan and carry out lessons in isolation. Allen and Heredia (2021) cited limiting planning time with colleagues as an organizational barrier to successfully carrying out science lessons. Data analysis from this study suggested that the ability to work together during the PD had a positive impact with regards to understanding how to carry out the lesson. During the cycle three PD session, teachers worked together to mimic the interaction of the students. As mentioned in Chapter 4, Augustus reflected on the PD session in cycle three and shared that his fourth-grade team often do not get a chance to interact with the curriculum together, except for a PD session like the one in this study. Navigating the lesson together gave a sense of how the students would feel and interact. Cordelia also shared that she was nervous when she selected to be a counter during the cycle three PD session, and after her and her partner got different numbers while counting the same disk in ten seconds, she realized that this is how the students would feel, so she and her partner tried again, and it all worked out. This experience of working together enhanced the teachers' self-efficacy, as they understood what the students would experience and feel during each component of the 5-E lesson. Therefore, the barrier of teachers not understanding how students feel throughout the hands-on portion of the lesson can be addressed by simulating the experiences of students and having teachers work together during PD sessions.

In summary, data analysis of this study elucidated that specific organizational barriers need to be addressed so that students can access content within the NYSSLS and engage in practices to emulate scientists. To reduce the long-standing deficit mindset patterns in our educational institutions, I argue that organizations need to flip the focus and look through a new lens: the deficits do not lie within groups of marginalized students, but rather, within the constructs of our K-12 organizations in the way we prepare and support teachers. Our efforts need to shift toward enhancing teacher-self efficacy in STEM, training teachers to step-back and release that need of control and embrace that every child with the understanding that each student has something to offer that will enrich learning experiences for all. Teachers suggest running PD sessions through the eyes of the students and offering teachers opportunities to interact with each other through the curriculum can support teachers to support students. Data from this study indicates that relinquishing teachers' authoritative role empowers students with voice to express their ideas, make connections to past experiences, enhance access to hands-on practices through engagement, initiative idea-building and comprehension through learning communities and offer personal reflection through choice. In the next section, I offer a bridge between these findings and the theoretical frameworks that guided this study.

**Relationship of Findings to Theoretical Frameworks**

This action research study utilized the UDL framework (CAST, 2018) to support teachers with strategies that eliminate barriers to learning and promote inclusive learning environments during STEM lessons. The UDL framework is based on the foundation of growth mindset, self-efficacy, and self-regulation theories (Meyer, et al., 2014). Dweck (2016) proposed the motivational theory of growth mindset, the belief that one's own qualities are developed through efforts and taking initiatives to utilize strategies and acquire assistance from others. Bandura (2007) describes self-efficacy as one's ability to perform a specific task and attain a goal. Bandura et al. (2003) explained the importance of self-efficacy for self-directed learning, the ability to regulate and manage one's academic development. Self-efficacy is one subset of Bandura's social cognitive theory. Social cognitive theory encompasses cognitive factors and motivational regulation mechanisms (Bandura et al., 2003; Caprara et al., 208, Thibaut et al., 2018). Zimmerman (2002) explained the importance of self-regulation to develop life-long learners. Additionally, this study applied the foundation of Vygotsky's (1978) social constructivist theory. Vygotsky explained that learners need to be engaged during the learning process and learning involves emotion and communicative interactions between their peers and teacher (Murphy, 2022). Finally, during the third cycle of this study, culturally responsive teaching (CRT) was added as an asset-based framework to further support UDL practices (Kieran & Anderson, 2019). In the following sections, I offer connections for each of these theories to the findings of this study.

**Social Cognitive Theory**

The findings from this study are aligned with social cognitive theory. Social cognitive theory emphasizes the importance of learning from the social environment (Schunk & Usher, 2012). Bandura's triadic reciprocality model is based on social cognitive theory and utilized as a lens to understand the uniqueness of individual learners as a product of their own interactions with the environment (Schunk, 2020). Triadic reciprocality is exemplified in the data from this study with regards to teachers' reactions to PD sessions.

Bandura et al. (2003) explained that Triadic reciprocality involves an interplay between an environmental process (what one is exposed to), behavioral process (one's response to the environment), and personal process (how one feels and internalizes the experiences). Huang and Yip (2021) employed the triadic reciprocity framework to explore how teachers can exercise agency over their teaching and professional development. Data from cycle two of this dissertation study indicated that the written scripted module was a barrier to pedagogical practices. The scripted module was the environmental process in triadic reciprocality. Sunny read directly from the script during the start of the lesson, and Christine referred to bulleted notes from the script. Christine had offered "You become so focused on what you're supposed to say that you almost lose sight of what they're (students) supposed to do." The teacher's behavior of leaning on the script was the behavioral process, and in turn, made some teachers feel insecure during their personal process of teaching. Overall, data from cycle two indicated that the script was a negative motivator that left teachers with feelings of insecurity to support students through the lesson. Additionally, data from cycle two indicated that teachers called for a change in the PD process. They all suggested that the training should be hands-on and conducted through the eyes of the student. The teachers' reflections initiated improvements in the environmental process to strengthen the behavioral outcomes and personal feelings for future teachers.

Data on the PD session from cycle three also supported Bandura's triadic reciprocality model. However, as compared to cycle two, data from cycle three supported a positive outcome of environmental, behavioral, and personal reflection. Data indicated that teachers felt supported during the PD session for cycle three. The cycle three PD session was hands-on and carried out through the eyes of the students. The environmental process of hands-on training supported teachers to act with more confidence while giving directions to utilize the materials and during the hands-on components of the lesson. The teachers' behavior of supporting the students then left the teachers with positive feelings about teaching STEM lessons. All four teachers during cycle three stated that they would not change anything with regard to the PD session. Cordelia's reflections summarize the personalization of the learning teaching cycle after the cycle three PD session and lesson implementation. Cordelia explained that "science is not always my thing" and that she felt nervous at the start of the PD session. She then stated "but you were totally teaching us, no, this is what the kids are going to experience…We were the students and I felt so much more comfortable when the kids did it…and I felt so much more comfortable with science.

The teachers in cycle two reflected on how to change future PD sessions to initiate positive outcomes for future teachers and students. Data analysis indicated that teachers in cycle three benefited from the proposed changes. Employing a qualitative analysis method through the lens of triadic reciprocity framework allowed for positive change from cycle two to cycle three of this action research study. Allowing teachers to reflect on the support provided to them in their work environment offers justification of their beliefs, improved support practices, and the feeling of agency as teachers have an active role in change (Huang & Yip, 2021). Both the data and supporting literature on social cognitive theory substantiates the utilization of triadic reciprocity as a lens for this study, and underpins other models of social cognition, such self-efficacy.

**Self-Efficacy Theme and Theory**

The explication of data in this study led to the theme of teacher-self-efficacy. Utilizing self-efficacy theory for analysis was supported from participants' feedback on the PD sessions, as described above. Teachers' reflections indicated lower self-efficacy after the PD session during cycle two, and increased levels of self-efficacy when teachers were able to experience what the students will be doing and during cycle three. However, according to the analysis, teachers still displayed low self-efficacy with regards to letting go of their authority and showing confidence in students to select their own roles for group work. When drawing upon the lens of the triadic reciprocity framework, one could argue that teachers did not get the chance to experience the role selection of students, only themselves, during the PD session, and did not have confidence that the students could select their roles without witnessing it for themselves.

Therefore, without this experience (environmental process) they have not yet formed behavioral processes and internalized the personal process.

Teachers seemed to internalize the PD experiences during the lesson as the first "environmental process" of this experience. As evidenced by post-lesson interviews, cycle two teachers reflected on their observations of their students and mentioned that they were "surprised how quickly they picked their roles…they did it quickly and without incident" and "allowing students to have their own jobs sets boundaries for them to work well together." Although cycle three teachers seemed to stop rescuing students a little bit more during the lesson, they still, at times felt the need to run to tables and check that role selection was going smoothly. Therefore, just talking about the CRT practices of setting high academic expectations for students during the PD sessions was not enough to increase teacher self-efficacy to release their power to students. Specifically, one teacher ran over to one table in anticipation that one student with a special education accommodation might "act out." As I interjected with coaching and guided the teacher away from the student, the teacher was able to observe that the students in that group, including the student she was concerned about, selected their roles just fine on their own.

Analysis of this study indicates that teachers need coaching at the grassroots level. Bradshaw et al. (2018) reported that coaching, in addition to PD sessions, was most effective for improving culturally responsive teaching practices. The researchers employed various teacher self-efficacy scales that measured the teacher's self-efficacy to provide culturally responsive instruction, connect with culturally diverse students, and manage classroom behavior and stress. Although the researchers found improvements with coaching sessions as compared to no coaching session, there was no significant difference in the teachers' reported self-efficacy between the PD and PD and coached groups. The theoretical framework of self-efficacy is certainly a critical lens for this study; however, analysis from my data in addition to current literature necessitates additional research in this area of teacher coaching.

**Culturally Responsive Teaching**

Culturally responsive teaching was added as a theoretical lens after the first two cycles of research. Data from this study supported the paradigm and importance of culturally responsive teaching. Teachers in this study were quick to rescue students and hinder their autonomy. Even during cycle three, teachers portrayed a deficit mindset with regards to students being able to select their own roles and come up with their own responses for the vocabulary terms and essential questions. I found the element of "surprise" as a pattern among teachers with regards to their students' responses. Victoria reflected and stated that she found it hard not to give the students the background to the vocabulary and how she felt her instinct was to explain it or give them examples as soon as they started to show any struggle. She also reported how she was impressed with their responses.

When students are not given the opportunity to productively struggle on their own, they become dependent learners (Hammond, 2015). To close achievement and opportunity gaps among historically marginalized groups in STEM fields, culturally responsive pedagogies need to be employed in STEM education (Cayton et al., 2024; Hypolite & Rogers, 2023; O'Leary et al., 2020). Hammond (2015) explains that there is a vicious cycle of dependency among marginalized students of color, and because teachers do not have confidence in the students' ability, their gaps increase throughout the years. Teachers in this study were explicitly coached to tell students there were no right or wrong answers when generating their observations and questions. Embracing students' personal experiences and prior knowledge is an important component of the CRT philosophy (Mburu, 2022). Teachers' reflections supported the positive results of this CRT strategy. Many teachers reflected on how students had freedom in their responses. Nicole stated that she thought it was "cool to just see where they're coming from, what they already know, and where their thinking is taking them." Implementing CRT and telling students there were no right or wrong answers as they tapped into their prior knowledge empowered student voice.

Student voice was also evident as they collaborated and brainstormed together. Students were encouraged to collaborate and share ideas, and once again told there was no right or wrong answers, as they learned from each other. As students were empowered to brainstorm in their learning community, teachers reflected on the level of students' responses, as they took the "high road of thinking."

Culturally responsive teaching also encompasses holding high expectations of students (Hammond, 2015). This was accomplished by offering students the "freedom" to work it out on their own as they learned to "think like a scientist" rather than having students "rely on us for answers." Cultivating a culturally responsive learning environment took the teachers by surprise as their "shy" students or "weaker students" were verbally engaged. Through the lens of culturally response teaching, students were empowered through engagement, their learning communities, and voice. Additionally, teachers were impressed with student responses to the evaluation component when students were given choice of the prompt to respond to. Teachers mentioned the "choice" and that "having options for the reflection" was incredible. CRT is supported as an asset-based pedagogy from both data from this study and in the literature.

## Limitations

In Chapter 3, I addressed limitations imminent within the construct of action research studies. Firstly, my positionality was that of both insider and outsider status. I had insider status, as I worked alongside teachers with the common goal of supporting students. However, as a supervisor of these teachers I also had an outsider status, as I held a position with a different level of power within the workplace. At times, I felt both positionalities came out in the study. As mentioned in Chapter 3, Sunny and I embraced arms and were laughing together when I tossed the script to the side during the lesson. I felt my insider status allowed us to connect and laugh while we shifted gears and moved on together. At other times I wonder if their signaling to me to jump in and assist was their view of my authoritative, outsider status. My unique life experiences, positionality in this study, and interactions with the participants cannot be replicated and poses a limitation in this study.

The specific participants and classes utilized for this study can also result in limitations. The teachers' life experiences and perspectives are also unique. This study was also conducted with only fourth grade teachers and students. The transferability to other age groups cannot be guaranteed. In addition to participants unique life experiences and positionalities, the demographics of both the teachers and students making up the two districts included in the study are very similar and do not reflect the racially, socio-economically, linguistically, and academically diverse demographics of all schools across New York state. Conducting this study in schools with different demographics, such as a teacher or student population that was more diverse, or a school with different socioeconomics, could potentially result in different findings. Therefore, although this study carried over from one district into another, generalization, and transferability of findings to a different district will be up to the reader to decide.

## Implications of Study

As a summation of the analysis above, for teachers to successfully support students during a 5-E NYSSLS STEM lesson, teachers need to be supported with PD sessions to understand the content of STEM lessons. Specifically, they benefit when offered hands-on training, through the eyes of the students, and vicarious experiences while working with their colleagues during the PD sessions. Analysis from cycle three data indicates that the hands-on experience during the sessions increases teacher self-efficacy. However, even after the improvements to the cycle three PD session, teachers still displayed a deficit mindset as evidenced by trying to jump in to assist students, or by their reactions to students self-directed learning and high-level thinking. Teachers also tended to label students and explicitly utilized these labels in their reflections of the students with regards to how they engaged with the lesson. When teachers did let go of their authoritative power, barriers to learning were eliminated and students were empowered through voice, engagement, learning communities and choice. Empowering students' access to the content and successfully navigating the practices are possible when organizational barriers are addressed and eliminated. Therefore, it is important to consider these results when designing courses for pre-service teachers and the continued professional development of educators. Asset based pedagogies, such as UDL and CRT, should be the foundation of teacher training programs and infused across curricula in all subject areas.

Chapter 1 identified three main problems with the NYSSLS. Firstly, the standards do not offer teachers pedagogical practices, or the "how" with regards to implementation of the standards into lessons. Second, the language of the recently implemented NYSSLS shifted the focus away from inquiry and introduced the practices that students are to engage in as they emulate scientists. Thirdly, the standards exemplify a deficit mindset by placing the blame of content accessibility on marginalized groups of students. Additionally, it is important to note that the adaptation of the NYSSLS, as opposed to the NGSS directly, was a result of conforming to the alignment of the NYS Regents exams. Standardized testing often drives the structure of standards and pedagogical practices; however, this study elucidated that asset-based pedagogies should be driving the evaluation of students, such as offering student choice with regards to them expressing the content and practices they learned. Therefore, I suggest the following strategies:

1. The introduction of the NYSSLS and appendix of the NGSS should be re-written to eliminate the deficit mindset surrounded historically marginalized groups. Instead, the focus should flip from student deficits to eliminating deficits in pedagogical practices and lesson design.
2. The hybridization of asset-based pedagogies, such as UDL and CRT should be implemented to eliminate learning barriers that prevent students from accessing the content and engaging in the practices of the NYSSLS and NGSS. These asset-based practices should also drive the structure of student evaluations, offering students choice with regards to how they express what they learned.
3. Teachers need to be provided with PD sessions and coaching within the classroom to successfully support students during STEM lessons. To enhance teacher self-efficacy, they need hands-on PD sessions to navigate the lesson through the eyes of the student. These PD sessions should also incorporate the negative effect of labeling students, and explicitly train teachers that barriers to learning are within the construct of the lesson, and not within students. Additionally, since PD sessions cannot offer the opportunity for teachers to implement CRT strategies, they need to be offered coaching during lesson implementation for support, where the behavioral process is modeled so they can observe student responses, reflect, and personalize the process to increase their self-efficacy and take a step back. Teacher training and coaching on asset-based pedagogies, such as UDL and CRT, should be incorporated in pre-service teacher programs.

**Final Remarks…Just Let Go**

Teachers need to let go of their authoritative role in the classroom before students can be empowered to learn. According to this dissertation study, the gender and racial gaps that are prevalent in STEM fields can be a result of organizational barriers such as low teacher self-efficacy, teacher-directed instruction, deficit mindsets and labeling of students, and a lack of PD, coaching, and professional planning time for teachers. Future studies should explore ways to implement asset-based pedagogies to eliminate each of these organizational barriers and transfer the power of learning from teachers to their students. Clara could not have summarized the findings of this study any better:

> Just go with it. Let go and not be on top of them. It doesn't have to be perfect. It doesn't have to be memorized. They're good enough. They actually know what they are doing. You just have to work on giving them confidence. It's a release for the teacher. It's a release for the kids.

As I had started this dissertation with my evocation of The Power of an Offer, we need to give teachers the Power to Empower students. I offer the following POWER acronym for both coaches and teachers:

**P**ause Pedagogy
**O**bserve Open-mindedly
**W**ait and Wonder
**E**ngage and Empower
**R**efrain and Reflect

During the Engage component of the lesson, teachers should Pause Pedagogy and allow students to tap into their prior knowledge and unique experiences while making their own connections to phenomena presented. As students navigate through the Explore components of the lesson, teachers should Wait and Wonder. Teachers should be coached to "step back" and not jump in to rescue students. Students need to productively struggle to attain a higher level of thinking. Students should form communities of learners as they navigate the Explain portion of the lesson and offer their own definitions of the lesson vocabulary. Teachers should be coached to Wait and Wonder about the information students will generate and not give into their desire to assist students with the vocabulary. As students enter the Elaborate portion of the lesson, teachers should Engage and Empower with scaffolds that can prompt students to bridge what they have learned to real-world scenarios. Finally, for the Evaluation component of the lesson, teachers should Refrain and Reflect, as they do not insist on only one way to assess student learning but rather offer choice and reflect on the student responses.

It's time to reform the cycle of educational reform itself. It's time to reduce the racial and gender gaps in STEM fields by changing written policy in standards and eliminating the deficit mindset in the verbiage of the NYSSLS and NGSS. We also need to close the gap between theory and practice and support teachers through professional development and coaching with asset-based strategies during STEM lessons. It's time to empower all of our students.

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# Appendix A
# IRB Approval Letter 1

MOLLOY UNIVERSITY

1000 Hempstead Ave., PO Box 5002, Rockville Center, NY 11571-5002
www.molloy.edu

**Patricia A. Eckardt, PhD, RN, FAAN**
**Chair, Molloy University Institutional Review Board**
**Professor, Barbara H. Hagan School of Nursing and Health Sciences**

**E:** peckardt@molloy.edu
**T:** 516.323.3711

| | |
|---|---|
| **DATE:** | April 27, 2023 |
| **TO:** | Debbie Langone |
| **FROM:** | Molloy University IRB |
| **PROJECT TITLE:** | [2046587-1] Closing the Gap between Theory and Practice to Promote Inclusive Learning Environments in STEM: Coaching Teachers with UDL Strategies for Science and Engineering Lessons |
| **REFERENCE #:** | |
| **SUBMISSION TYPE:** | New Project |
| **ACTION:** | DETERMINATION OF ACTION RESEARCH: NOT HUMAN SUBJECT RESEARCH |
| **DECISION DATE:** | April 27, 2023 |

Thank you for your submission of New Project materials for this project. The Molloy University IRB has determined this project does not meet the definition of human subject research under the purview of the IRB according to Department of Health and Human Services (DHHS) regulations for the research as defined in 45CFR§46.101.

**You may proceed with your project.**

We will retain a copy of this correspondence within our records.

If there is a proposed change to the project, it is the responsibility of the Principal Investigator to inform the Molloy University IRB of any requested changes before implementation. A change in the activities may change the project from not human subject research status and requires prior communication with the IRB.

The finding of the project may be published if NO individual level or identifiable data are used. An example of text for publication in a journal could read: "This activity was acknowledged by the Molloy University IRB and deemed to not be human subject research as defined the Common Rule 45 CFR part 46, subpart A."

Projects that do not meet the definition of research (as defined the Common Rule 45 CFR part 46, subpart A) still require an annual ongoing report of the project if the project extends beyond a year (see Annual Non-Research Ongoing Project Report Form).

If you have any questions, please contact Patricia Eckardt at 516-323-3711 or peckardt@molloy.edu. Please include your project title and reference number in all correspondence with this committee.

Sincerely,



Patricia Eckardt, Ph.D., RN, FAAN
Chair, Molloy University Institutional Review Board

This letter has been issued in accordance with all applicable regulations, and a copy is retained within Molloy University IRB's records

# Appendix B
# IRB Approval Letter 2

1000 Hempstead Ave., PO Box 5002, Rockville Center, NY 11571-5002
www.molloy.edu

MOLLOY UNIVERSITY

**Patricia A. Eckardt, PhD, RN, FAAN**
**Chair, Molloy University Institutional Review Board**
**Professor, Barbara H. Hagan School of Nursing and Health Sciences**
**E:** peckardt@molloy.edu
**T:** 516.323.3711

| | |
|---|---|
| **DATE:** | October 19, 2023 |
| **TO:** | Debbie Langone |
| **FROM:** | Molloy University IRB |
| **PROJECT TITLE:** | [2046587-2] Closing the Gap between Theory and Practice to Promote Inclusive Learning Environments in STEM: Coaching Teachers with UDL Strategies for Science and Engineering Lessons |
| **REFERENCE #:** | 2046587-1 |
| **SUBMISSION TYPE:** | Amendment/Modification |
| **ACTION:** | ACKNOWLEDGED: NOT HUMAN SUBJECT RESEARCH |
| **EFFECTIVE DATE:** | October 18, 2023 |
| **EXPIRATION DATE:** | April 26, 2024 |

Thank you for submitting the Amendment/Modification materials for this project. The Molloy University IRB has ACKNOWLEDGED your submission. No further action on submission 2046587-2 is required at this time.

**You may continue with your project.**

The following items are acknowledged in this submission:

- Abstract/Summary - UPDATED IRB Executive Summary of Action Research.docx (stamped).pdf (UPDATED: 10/10/2023)
- Advertisement - UPDATEDParticipant Recruitment Letter.pdf (UPDATED: 10/10/2023)
- Amendment/Modification - Amendment_Revision_Application_pdf_10_2022 .pdf (UPDATED: 10/10/2023)
- Letter - UPDATED Superintendent Approval-Seaford UFSD.jpg (UPDATED: 10/10/2023)

Please refer to Molloy University IRB Policies and Procedures for required submission process if any changes to this project.

If you have any questions, please contact Patricia Eckardt at 516-323-3711 or peckardt@molloy.edu. Please include your project title and reference number in all correspondence with this committee.

Sincerely,

Patricia Eckardt, Ph.D., RN, FAAN



Chair, Molloy University Institutional Review Board

This letter has been issued in accordance with all applicable regulations, and a copy is retained within Molloy University IRB's records.

# Appendix C
# Interview Protocol 1

Molloy University IRB
Approval Date: April 27, 2023
Expiration Date: April 26, 2024

## Semi-Structured 4th Grade Teacher Interview # 1
## (Pre-Professional Development Session)

**Before turning on the Audio recording:**
I would like to audio record this interview to ensure I accurately capture our conversation. Is that ok with you?

It is (date) and this is Debbie and I am here with (insert T name).

-----------------------------------------------------------------------------------------------------------------

- Can you please tell me about your teaching experience, how many years you have been teaching and which grades?
  - -How long have you been in the 4th grade (if not already stated above?)
- What subjects or content areas are you responsible for teaching your 4th graders this year?
- Tell me about your planning process for curriculum and instruction in your classroom.
  - -Can you describe how you reflect on the effectiveness of your lessons?
- How would you describe your outlook on teaching STEM lessons?
  - -Describe what a typical STEM lesson looks like. ○ How do you plan for a new STEM lesson?

We will shift our discussion towards your students' learning needs in your current class.

- Tell me about your current students.
  - -What are the demographics?
  - -Are their students with specific learning needs?
- When you are planning instruction, do you consider the various needs of all students collectively? How?
  - −Do you consider the needs of individual students? How?

For the last part of this interview, I would like to ask few questions about a framework called Universal Design for Learning.

- Have you ever head of Universal Design for learning before?
  - -If yes, in what capacity? (If utilized in past) Can you describe your experience with this framework?
  - -From the name, what do you think Universal Design for Learning means?

# Appendix D
# Interview Protocol 2

Molloy University IRB
Approval Date: April 27, 2023
Expiration Date: April 26, 2024

## Semi-Structured 4th Grade Teacher Interview # 2
## (Post-Professional Development Session and Implementation of Lesson)

**Before turning on the Audio recording:**
I would like to audio record this interview to ensure I accurately capture our conversation. Is that ok with you?

It is (date) and this is Debbie and I am here with (insert T name).

---

First I would like to reflect on the professional development session for this lesson.

- Can you share your overall impressions of the professional development session?
    - What do you feel was helpful?
    - What suggestions can you offer?

Ok Let's shift to reflect on the lesson implementation.

- How do you feel the UDL lesson went overall?
    - Do feel there were specific UDL strategies within the lesson design that reduced or eliminated potential barriers to learning? If so, can you offer a specific example?
- Were there any components of the lesson that were a challenge to implement?
    - If so, what suggestions can you offer?
    - Did students ask any questions for clarification during the lesson? If so, what did they ask?
    - Did you feel the need to deviate from the lesson plan at any point to further scaffold or guide the students in more detail? If so, what component? Any suggestions to offer?
- How did you feel the students responded to the lesson?
    - How did you feel when the students engaged in the brainstorming session to answer the essential question?
    - How did you feel when the students were presented with the lesson vocabulary and asked to brainstorm their own definitions?
- Are there any strategies from this lesson that you feel can be transferred to other 5E STEM lessons?
- Is there anything else you feel is important from this experience that you would like to share?

# Appendix E
# Teacher Module Guide

## Engage → Phenomena

Have student packets at their desks as they walk into the STEM lab. They should be seated in groups of 4 (or 3).

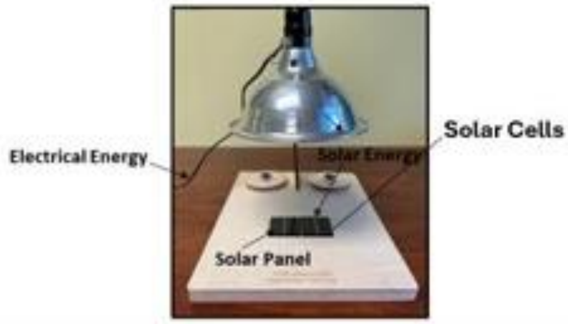
Do not state *anything* about the lesson. You can say something to the effect that *we have a fun activity planned today* ☺

Strategies:

1) The phenomena will be completed by students ***individually***
2) Direct students to view the images and list their observations and questions.
3) Present image on smartboard to students without giving away *any* background on the lesson. You can state there are no right or wrong answers. All observations and any questions you generate are good ones. List as many as possible for both.
4) Encourage students to list observations of the pictures. Walk around to check that students are listing observations.
5) Encourage students to generate questions. Wait Time!
6) Have students share out observations first, by table then share out questions.

# Solar Power Electrical Engineers
## Space Lesson Teacher Directions

**Engage:** Opening Activity → Access Prior Knowledge
**Phenomena** Presented → Students Generate Observations & Questions




**Writing Alternatives:**
Students can create illustrations or use a speech-to-text app to record their observations and questions.

**Question generation scaffold for a struggling student:**
"Look at your observations. Take one and turn it into a question."
** Note: This ***should not be stated out loud to all students***, as it will *lower the level of question generation for most students*. This can be a starting point for students who struggle to write or draw at least one question.

**Coaching toward higher level questions without diminishing student's self-efficacy:**
***Don't say***: "That's a good question."
***Say*** "Oh! That question is directly related to what we will be learning today."
The latter illustrates how a student related their skillful observations to the question without making any student feel as if their question is not good.

| UDL Guidelines (G) & Checkpoints (C) | Intervention or Practice (Engage) |
|---|---|
| G3; C3.1 | Anchor instruction with phenomena/activate prior knowledge; advanced organizers (KW) |
| G3; C3.3 | Guide information processing; explicit prompts for each step sequentially |
| G5; C5.1 | Options for expression & communication; drawing |

## Explore

Teacher acts as the ***facilitator*** during student-centered cooperative activity.
Strategies:

1) Present the slide and read the text: "Today you are Electrical Engineers, and you work for NASA!!
Using the LightSpeed Solar apparatus designed by high school students, you are going to determine the efficiency of the solar panels in various environmental conditions. NASA is having problems with their solar panels, and they need your help! After your experiment, you will report back to NASA with the results."

2) Have all students gather around one table for demonstration.

3) State safety- Lamp gets hot, watch your hands.

4) Choose one timer, one counter, one "Go" starter

5) Practice with the stopwatch. State: There will be times you will have to re-do. Be kind to yourselves and others because science & Engineering take practice trails"

6) Do a trail run...two if necessary, until it goes smoothly. Show the gels, but do not practice these as a class.

**Explore:** Students actively explore new concepts. Students are given hands-on experience before any formal explanation of terms, definitions, or concepts.

## Explore

**Today, you are electrical engineers and you work for NASA! Using the LightSpeed Solar apparatus designed by high school students, you will determine the efficiency of solar panels in various environmental conditions. After your experiment, you will report back to NASA with the results.**


| DATA TABLE 1 | |
|---|---|
| **Variable** | # of Full Rotations in 10 seconds |
| No Gel (control) | |
| Blue Gel | |
| Green Gel | |
| Red Gel | |

• Remember to ***facilitate.*** You may be tempted to jump to one table when you think they will argue over the roles. Step back and observe, giving them time. Give a "30 seconds" indicator to complete role selection (because we need to report back to NASA soon). Circulate around the room and be sure they are using the same disk for all trials.

| UDL Guidelines (G) & Checkpoints (C) | Intervention or Practice (Explore) |
|---|---|
| G7; C7.2 | Active participation, exploration, experimentation; activate imagination to solve problems/make sense in creative ways |
| G8; C8.3 | Create cooperative groups w/clear goals, roles, responsibilities, & expectations. |
| G9; C9.1 | Self-regulatory goals to reduce frequency of outbursts in response to frustration |
| G6; C6.2 | Support planning and strategy development; provide a checklist, and sequence of steps |
| G6; C6.3 | Facilitate management of information; Graphic organizers for data collection and organizing information. |

7) Before students return to their tables, State: "See which wheel seems to work best and use that side for the ENTIRE experiment so your results are accurate. When you return to your tables you choose your roles: "Go" person, stopwatch person, counter, recorder, start person. I strongly suggest you stick to that role. Switching will cause you to lose time and may not give you accurate results. I know you each may want the same role, but we are going to practice being engineers that have to work together as a team, even though we may want certain jobs as an individual. I will give you a minute and 30 seconds to choose tour roles once you get back. O.K. carefully walk back and decide on roles.
8) After all groups have their results recorded in data table 1, instruct them to complete data table 2. Have students report out, by table, fastest (most turns) to slowest.
9) Discuss "outliers" if one group has unexpected results. There is no need to justify the "right" answer.

PROCEDURE

| Place a ✓ | STEPS 1-8 |
|---|---|
| | 1. Make sure the disks start turning. (It may need a gentle push). |
| | 2. Have one partner set a timer for 10 seconds. One partner should count the number of full rotations in a ten second period. |
| | 3. Record this number in the "No Gel" column in the data table. |
| | 5. Place the blue gel over the solar panel. |
| | 6. Count the number of full rotations for 10 seconds with the gel on and record data in the table. |
| | 7. Repeat steps 5 and 6 with the green gel and then the Red Gel. Write down the number of full rotations for each of the gels in the Data Table |
| | 8. List the Variables, Gel Colors, from fastest (highest number of rotations), to slowest (Least number of rotations). |

➢ ***Describe*** the relationship between the intensity of the light on a solar cell and speed at which a disk turns

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

| DATA TABLE 2 | |
|---|---|
| **Rank Fastest to Slowest** | **Variable (No Gel of Specific Color Gel)** |
| **1** | |
| **2** | |
| **3** | |
| **4** | |

## Explain

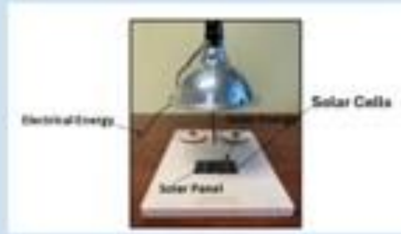
1) State: "Now we need to collaborate to prepare our report for NASA.
2) State: "You have ***two minutes*** to discuss the essential question with your group: Explain how solar energy is converted into electrical energy. Use the LightSpeed device to answer this question. Incorporate the vocabulary words listed: solar energy, electrical energy, mechanical energy, solar cells and solar panel in their explanation. ***GO!***"
3) After 2-3 minutes, get the students' attention and swap one member from each group to another group (select someone you feel will quickly collaborate). Do this quickly, you do not need to explain until after students move.
4) State: "Now you each have a new group member. You have a ***minute and a half*** to have them explain what their group came up with and then to report to them what your group came up with…***GO!***"
5) After about 1 ½-2 min, tell groups to go back to original seats.

## Explore

**Explain how solar energy is converted into electrical energy.**

**Use the terms below to explain how the lightspeed device works:**

- **Solar energy**
- **Electrical energy**
- **Mechanical energy**
- **Solar cells**
- **Solar panel**




**Teacher Challenge:** *Walk around and listen, but don't interject or comment during this time.*

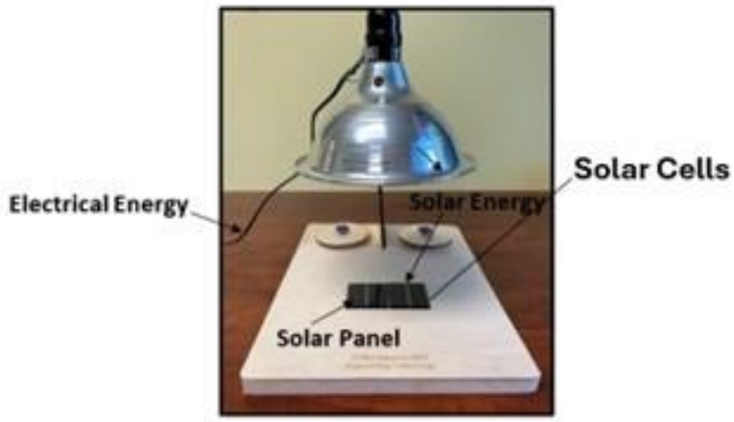
This should be *fast* paced collaborations. It will engage all and motive the students to communicate quickly and efficiently. Emphasize the timing ☺ When students share out, it is not necessary to tell students if they are correct or not (*another teacher challenge*). Let the story build and let them come to their own conclusions, as engineers would in a brainstorming session.

| UDL Guidelines (G) & Checkpoints (C) | Intervention or Practice (Explain) |
|---|---|
| G3; C3.3 | Guide information processing; explicit prompts for each step sequentially, interactive models, graduated scaffolds supporting information processing strategies |
| G3; C3.4 | Maximize transfer and generalization; incorporate explicit opportunities for review and practice, provide scaffolds that connect new information to prior knowledge, revisit key ideas and linkages between ideas |
| G2; C 2.1 | Clarify vocabulary; connection to prior knowledge |
| G8; C.8.3 | Foster collaboration and community; encourage and support peer interactions, communities of learners engaged in common interest |
| G9; C8.4 | Increase mastery-oriented feedback; encourage perseverance, efficacy, improvement |

6) Explain we will now go around the room to each table to put our information all together to form a logical sequence on how the LightSpeed device works. Tell all to listen carefully to each group so our story gets more detailed as we go around.
7) Have groups share out.
8) Use one device to point to each part of their story until accurate. Let students guide this discussion.
9) Give students 1-2 minutes to define each term in their groups now.
10) Have students share out until each term is defined. Students can use the LightSpeed device to point and explain.

**Explain:** During the explanation component of the lesson, students connect prior knowledge to the new discoveries and communicate their understanding. The teacher encourages students to communicate their understandings in their own words, while defining vocabulary. Students provide explanations to essential questions using previous observations and findings.

## Energy Conversion




Electrical Energy ➡ Solar Energy ➡ Solar Panel ➡ Solar Cells ➡ Electrical Energy ➡ Mechanical Energy

- ***Explain*** how solar energy is converted into electrical energy utilizing
- ***Describe*** the flow of energy conversion in the LightSpeed Device

4-PS3-2 Make observations to provide evidence that energy is conserved as it is transferred and/or converted from one form to another.
4-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment

## Elaborate

Pose these questions:

1) What environmental conditions can affect solar panels on Earth?
2) What environmental conditions can affect solar panels on Mars?
3) What environmental conditions can affect solar panels on the International Space Station (ISS)?

- Lesson enrichment extensions: Videos, books, new experiments designed by the students to test different variables, etc. See lesson plan for extension resources.

**Elaborate:**

1) What can affect solar panels on **Earth: Leaves, snow, rain, cloud cover, physical damage to solar panel, etc.**

2) What can affect solar panels on **Mars: Dust storms**

3) What can affect solar panels on the **ISS: Not in line with the sun, meteorites/physical damage.**

| UDL Guidelines (G) & Checkpoints (C) | Intervention or Practice (Elaborate) |
|---|---|
| G3; C3.2 | Highlight patterns, big ideas and relationships; previously learned skills to unfamiliar problems. |
| G3; C3.4 | Maximize transfer and generalization; provide scaffolds for new information to prior knowledge, generalize to new situations. |

- ***Describe*** some potential obstacles that reduce efficiency of solar panels on Mars, the International Space Station, and Earth

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
3-5-ETS1-1 Define a simple design problem reflecting a need or want that includes specified criteria for success and constraints on materials, time, or cost
3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

## Evaluate

Evaluation: Measurement of the evolution of students' learning:

- Observations and conversations between students and when reporting out to class/teacher
- Student Reflective Journals:

→ Choice of journal format, 3 different paper options (or digital?)

→ Choice of reflective prompt

→ Includes checklist

### Student Reflective Journal

**Choice of reflective prompts:**

1. Explain how solar energy is converted to electrical energy.
2. Describe how the LightSpeed device works.
3. Explain how using the gels on the LightSpeed device simulates environmental conditions for real solar panels.
4. Describe with words and drawings what you learned during the activity.

### Student Reflective Journal Format Options:

| UDL Guidelines (G) & Checkpoints (C) | Intervention or Practice (Evaluate) |
|---|---|
| G6; C6.2 | Support planning and strategy development; prompts to "show and explain," provide a checklist. |
| G7; C7.1 | Provide options for recruiting interest, assessing skills |

# Appendix F
# UDL Guidelines 2.2 (CAST, 2018)

**Principle I. Provide Multiple Means of Representation**
**Guideline 1: Perception**

**Checkpoint 1.1 – Offer ways of customizing the display of information:**

- The size of text, images, graphs, tables, or other visual content
- The contrast between background and text or image
- The color used for information or emphasis
- The volume or rate of speech or sound
- The speed or timing of video, animation, sound, simulations, etc.
- The layout of visual or other elements
- The font used for print materials

**Checkpoint 1.2 - Offer alternatives for auditory information**

- Use text equivalents in the form of captions or automated speech-to-text (voice recognition) for spoken language
- Provide visual diagrams, charts, notations of music or sound
- Provide written transcripts for videos or auditory clips
- Provide American Sign Language (ASL) for spoken English
- Use visual analogues to represent emphasis and prosody (e.g., emoticons, symbols, or images)
- Provide visual or tactile (e.g., vibrations) equivalents for sound effects or alerts
- Provide visual and/or emotional description for musical interpretation

**Checkpoint 1.3 - Offer alternatives for visual information**

- Provide descriptions (text or spoken) for all images, graphics, video, or animations
- Use touch equivalents (tactile graphics or objects of reference) for key visuals that represent concepts
- Provide physical objects and spatial models to convey perspective or interaction
- Provide auditory cues for key concepts and transitions in visual information
- Follow accessibility standards (NIMAS, DAISY, etc.) when creating digital text
- Allow for a competent aide, partner, or "intervener" to read text aloud
- Provide access to text-to-Speech software

**Guideline 2: Language and Symbols**

**Checkpoint 2.1 - Clarify vocabulary and symbols**

- Pre-teach vocabulary and symbols, especially in ways that promote connection to the learners' experience and prior knowledge
- Provide graphic symbols with alternative text descriptions
- Highlight how complex terms, expressions, or equations are composed of simpler words or symbols
- Embed support for vocabulary and symbols within the text (e.g., hyperlinks or footnotes to definitions, explanations, illustrations, previous coverage, translations)
- Embed support for unfamiliar references within the text (e.g., domain specific notation, lesser known properties and theorems, idioms, academic language, figurative language, mathematical language, jargon, archaic language,

colloquialism, and dialect)

**Checkpoint 2.2 - Clarify syntax and structure**

- Clarify unfamiliar syntax (in language or in math formulas) or underlying structure (in diagrams, graphs, illustrations, extended expositions or narratives) through alternatives that:
- Highlight structural relations or make them more explicit
- Make connections to previously learned structures
- Make relationships between elements explicit (e.g., highlighting the transition words in an essay, links between ideas in a concept map, etc.)

**Checkpoint 2.3 - Support decoding of text, mathematical notation, and symbols**

- Allow the use of Text-to-Speech
- Use automatic voicing with digital mathematical notation (Math ML)
- Use digital text with an accompanying human voice recording (e.g., Daisy Talking Books)
- Allow for flexibility and easy access to multiple representations of notation where appropriate (e.g., formulas, word problems, graphs)
- Offer clarification of notation through lists of key terms

**Checkpoint 2.4 - Promote understanding across languages**

- Make all key information in the dominant language (e.g., English) also available in first languages (e.g., Spanish) for learners with limited-English proficiency and in ASL for learners who are deaf
- Link key vocabulary words to definitions and pronunciations in both dominant and heritage languages
- Define domain-specific vocabulary (e.g., "map key" in social studies) using both domain-specific and common terms
- Provide electronic translation tools or links to multilingual glossaries on the web
- Embed visual, non-linguistic supports for vocabulary clarification (pictures, videos, etc)

**Checkpoint 2.5 - Illustrate through multiple media**

- Present key concepts in one form of symbolic representation (e.g., an expository text or a math equation) with an alternative form (e.g., an illustration, dance/movement, diagram, table, model, video, comic strip, storyboard, photograph, animation, physical or virtual manipulative)
- Make explicit links between information provided in texts and any accompanying representation of that information in illustrations, equations, charts, or diagrams

**Guideline 3: Comprehension**

**Checkpoint 3.1 - Activate or supply background knowledge**

- Anchor instruction by linking to and activating relevant prior knowledge (e.g., using visual imagery, concept anchoring, or concept mastery routines)
- Use advanced organizers (e.g., KWL methods, concept maps)
- Pre-teach critical prerequisite concepts through demonstration or models
- Bridge concepts with relevant analogies and metaphors
- Make explicit cross-curricular connections (e.g., teaching literacy strategies in the social studies classroom)

**Checkpoint 3.2 - Highlight patterns, critical features, big ideas, and relationships**

- Highlight or emphasize key elements in text, graphics, diagrams, formulas
- Use outlines, graphic organizers, unit organizer routines, concept organizer routines, and concept mastery routines to emphasize key ideas and relationships
- Use multiple examples and non-examples to emphasize critical features
- Use cues and prompts to draw attention to critical features
- Highlight previously learned skills that can be used to solve unfamiliar problems

**Checkpoint 3.3 - Guide information processing and visualization**

- Give explicit prompts for each step in a sequential process
- Provide options for organizational methods and approaches (tables and algorithms for processing mathematical operations)
- Provide interactive models that guide exploration and new understandings
- Introduce graduated scaffolds that support information processing strategies
- Provide multiple entry points to a lesson and optional pathways through content (e.g., exploring big ideas through dramatic works, arts and literature, film and media)
- "Chunk" information into smaller elements
- Progressively release information (e.g., sequential highlighting)
- Remove unnecessary distractions unless they are essential to the instructional goal

**Checkpoint 3.4 - Maximize transfer and generalization**

- Provide checklists, organizers, sticky notes, electronic reminders
- Prompt the use of mnemonic strategies and devices (e.g., visual imagery, paraphrasing strategies, method of loci, etc.)
- Incorporate explicit opportunities for review and practice
- Provide templates, graphic organizers, concept maps to support note-taking
- Provide scaffolds that connect new information to prior knowledge (e.g., word webs, half-full concept maps)
- Embed new ideas in familiar ideas and contexts (e.g., use of analogy, metaphor, drama, music, film, etc.)
- Provide explicit, supported opportunities to generalize learning to new situations (e.g., different types of problems that can be solved with linear equations, using physics principles to build a playground)
- Offer opportunities over time to revisit key ideas and linkages between ideas

**Principle II. Provide Multiple Means of Action and Expression**

**Guideline 4: Physical Action**

**Checkpoint 4.1 - Vary the methods for response and navigation**

- Provide alternatives in the requirements for rate, timing, speed, and range of motor action required to interact with instructional materials, physical manipulatives, and technologies
- Provide alternatives for physically responding or indicating selections (e.g., alternatives to marking with pen and pencil, alternatives to mouse control)
- Provide alternatives for physically interacting with materials by hand, voice, single switch, joystick, keyboard, or adapted keyboard

**Checkpoint 4.2 - Optimize access to tools and assistive technologies**

- Provide alternate keyboard commands for mouse action
- Build switch and scanning options for increased independent access and keyboard alternatives
- Provide access to alternative keyboards
- Customize overlays for touch screens and keyboards
- Select software that works seamlessly with keyboard alternatives and alt keys

**Guideline 5: Expression and Communication**

**Checkpoint 5.1 - Use multiple media for communication**

- Compose in multiple media such as text, speech, drawing, illustration, design, film, music, dance/movement, visual art, sculpture or video
- Use physical manipulatives (e.g., blocks, 3D models, base-ten blocks)
- Use social media and interactive web tools (e.g., discussion forums, chats, web design, annotation tools, storyboards, comic strips, animation presentations)
- Solve problems using a variety of strategies

**Checkpoint 5.2 - Use multiple tools for construction and composition**

- Provide spellcheckers, grammar checkers, word prediction software
- Provide Text-To-Speech software (voice recognition), human dictation, recording
- Provide calculators, graphing calculators, geometric sketchpads, or pre-formatted graph paper
- Provide sentence starters or sentence strips
- Use story webs, outlining tools, or concept mapping tools
- Provide Computer-Aided-Design (CAD), music notation (writing) software, or mathematical notation software
- Provide virtual or concrete mathematics manipulatives (e.g., base-10 blocks, algebra blocks)
- Use web applications (e.g., wikis, animation, presentation)

**Checkpoint 5.3 - Build fluencies with graduated levels of support for practice and performance**

- Provide differentiated models to emulate (i.e. models that demonstrate the same outcomes but use differing approaches, strategies, skills, etc.)
- Provide differentiated mentors (i.e., teachers/tutors who use different approaches to motivate, guide, feedback or inform)
- Provide scaffolds that can be gradually released with increasing independence and skills (e.g., embedded into digital reading and writing software)
- Provide differentiated feedback (e.g., feedback that is accessible because it can be customized to individual learners)
- Provide multiple examples of novel solutions to authentic problems

**Guideline 6: Executive Functions**

**Checkpoint 6.1 - Guide appropriate goal-setting**

- Provide prompts and scaffolds to estimate effort, resources, and difficulty
- Provide models or examples of the process and product of goal-setting
- Provide guides and checklists for scaffolding goal-setting
- Post goals, objectives, and schedules in an obvious place

**Checkpoint 6.2 - Support planning and strategy development**

- Embed prompts to “stop and think” before acting as well as adequate space

- Embed prompts to "show and explain your work" (e.g., portfolio review, art critiques)
- Provide checklists and project planning templates for understanding the problem, setting up prioritization, sequences, and schedules of steps
- Embed coaches or mentors that model think-alouds of the process
- Provide guides for breaking long-term goals into reachable short-term objectives

**Checkpoint 6.3 - Facilitate managing information and resources**

- Provide graphic organizers and templates for data collection and organizing information
- Embed prompts for categorizing and systematizing
  Provide checklists and guides for note-taking

**Checkpoint 6.4 - Enhance capacity for monitoring progress**

- Ask questions to guide self-monitoring and reflection
- Show representations of progress (e.g., before and after photos, graphs and charts showing progress over time, process portfolios)
- Prompt learners to identify the type of feedback or advice that they are seeking
- Use templates that guide self-reflection on quality and completeness
- Provide differentiated models of self-assessment strategies (e.g., role-playing, video reviews, peer feedback)
- Use of assessment checklists, scoring rubrics, and multiple examples of annotated student work/performance examples

**Provide III. Multiple Means of Engagement**
**Guideline 7: Recruiting Interest**

**Checkpoint 7.1 - Optimize individual choice and autonomy**

- Provide learners with as much discretion and autonomy as possible by providing choices in such things as:
    - The level of perceived challenge
    - The type of rewards or recognition available
    - The context or content used for practicing and assessing skills
    - The tools used for information gathering or production
    - The color, design, or graphics of layouts, etc.
    - The sequence or timing for completion of subcomponents of tasks
- Allow learners to participate in the design of classroom activities and academic tasks
- Involve learners, where and whenever possible, in setting their own personal academic and behavioral goals

**Checkpoint 7.2 - Optimize relevance, value, and authenticity**

- Vary activities and sources of information so that they can be:
    - Personalized and contextualized to learners' lives
    - Culturally relevant and responsive
    - Socially relevant
    - Age and ability appropriate
    - Appropriate for different racial, cultural, ethnic, and gender groups
- Design activities so that learning outcomes are authentic, communicate to real audiences, and reflect a purpose that is clear to the participants
- Provide tasks that allow for active participation, exploration and experimentation

- Invite personal response, evaluation and self-reflection to content and activities
- Include activities that foster the use of imagination to solve novel and relevant problems, or make sense of complex ideas in creative ways

**Checkpoint 7.3 - Minimize threats and distractions**

- Create an accepting and supportive classroom climate
- Vary the level of novelty or risk
    - Charts, calendars, schedules, visible timers, cues, etc. that can increase the predictability of daily activities and transitions
    - Creation of class routines
    - Alerts and previews that can help learners anticipate and prepare for changes in activities, schedules, and novel events
    - Options that can, in contrast to the above, maximize the unexpected, surprising, or novel in highly routinized activities
- Vary the level of sensory stimulation
    - Variation in the presence of background noise or visual stimulation, noise buffers, number of features or items presented at a time
    - Variation in pace of work, length of work sessions, availability of breaks or time-outs, or timing or sequence of activities
- Vary the social demands required for learning or performance, the perceived level of support and protection and the requirements for public display and evaluation
- Involve all participants in whole class discussions

**Guideline 8: Sustaining Effort and Persistence**

**Checkpoint 8.1 - Heighten salience of goals and objectives**

- Prompt or require learners to explicitly formulate or restate goal
- Display the goal in multiple ways
- Encourage division of long-term goals into short-term objectives
- Demonstrate the use of hand-held or computer-based scheduling tools
- Use prompts or scaffolds for visualizing desired outcome
- Engage learners in assessment discussions of what constitutes excellence and generate relevant examples that connect to their cultural background and interests

**Checkpoint 8.2 - Vary demands and resources to optimize challenge**

- Differentiate the degree of difficulty or complexity within which core activities can be completed
- Provide alternatives in the permissible tools and scaffolds
- Vary the degrees of freedom for acceptable performance
- Emphasize process, effort, improvement in meeting standards as alternatives to external evaluation and competition

**Checkpoint 8.3 - Foster collaboration and community**

- Create cooperative learning groups with clear goals, roles, and responsibilities
- Create school-wide programs of positive behavior support with differentiated objectives and supports
- Provide prompts that guide learners in when and how to ask peers and/or teachers for help
- Encourage and support opportunities for peer interactions and supports (e.g.,

peer-tutors)

- Construct communities of learners engaged in common interests or activities
- Create expectations for group work (e.g., rubrics, norms, etc.)

**Checkpoint 8.4 - Increase mastery-oriented feedback**

- Provide feedback that encourages perseverance, focuses on development of efficacy and self- awareness, and encourages the use of specific supports and strategies in the face of challenge
- Provide feedback that emphasizes effort, improvement, and achieving a standard rather than on relative performance
- Provide feedback that is frequent, timely, and specific
- Provide feedback that is substantive and informative rather than comparative or competitive
- Provide feedback that models how to incorporate evaluation, including identifying patterns of errors and wrong answers, into positive strategies for future success

**Guideline 9: Self-Regulation**

**Checkpoint 9.1 - Promote expectations and beliefs that optimize motivation**

- Provide prompts, reminders, guides, rubrics, checklists that focus on:
    - Self-regulatory goals like reducing the frequency of aggressive outbursts in response to frustration
    - Increasing the length of on-task orientation in the face of distractions
    - Elevating the frequency of self-reflection and self-reinforcements
- Provide coaches, mentors, or agents that model the process of setting personally appropriate goals that take into account both strengths and weaknesses
- Support activities that encourage self-reflection and identification of personal goals

**Checkpoint 9.2 - Facilitate personal coping skills and strategies**

- Provide differentiated models, scaffolds and feedback for:
    - Managing frustration
    - Seeking external emotional support
    - Developing internal controls and coping skills
    - Appropriately handling subject specific phobias and judgments of “natural” aptitude (e.g., “how can I improve on the areas I am struggling in?” rather than “I am not good at math”)
    - Use real life situations or simulations to demonstrate coping skills

**Checkpoint 9.3 - Develop self-assessment and reflection**

- Offer devices, aids, or charts to assist individuals in learning to collect, chart and display data from their own behavior for the purpose of monitoring changes in those behaviors
- Use activities that include a means by which learners get feedback and have access to alternative scaffolds (e.g., charts, templates, feedback displays) that support understanding progress in a manner that is understandable and timely

Adopted from: CAST (2018). Universal Design for Learning Guidelines Version 2.2
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