PROJECT-BASED LEARNING: A CASE STUDY INCORPORATING PROJECT-BASED LEARNING INTO A THIRD GRADE CLASSROOM

A Dissertation
by
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Abstract

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This exploratory case study focuses on using Project Based Learning (PBL) in a third-grade classroom. The research questions created for this study included: What is the impact of a science project-based learning unit on: student motivation, academic performance (reading, writing, and science) and student perceptions about STEM careers? Data collection consisted of focus group interviews (student), documents (test scores, writing samples, student observation sheets), and observational field notes.

A teacher created student motivation inventory was created by the teacher/researcher. Results from this study indicated PBL had a positive impact on student motivation and demonstrated that PBL had a positive impact on student motivation. Results were mixed in terms of PBL's impact on student academic performance. Future recommendations for research includes: conducting a PBL unit in the third-grade (without modifications to the

unit) and expand implementation to fourth grade, conduct a study to implement a series of PBL units, modified to the state standards.

Acknowledgments

"Education is not preparation for life; Education is life itself." – John Dewey

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Dedication

“Start where you are. Use what you have. Do what you can.” —Arthur Ashe

This is dedicated to my mom and dad. Thank you for your love and support during my educational journey.

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Chapter 1: Introduction

Background

In elementary education, there is a strong emphasis on high-stakes testing. High-stakes testing affects how teachers approach teaching lessons. Quite often, time becomes a factor in how the curriculum is presented to students. In North Carolina, End of Grade testing for students begins in third-grade for reading and math. The Read to Achieve legislation emphasizes the need for students to master reading comprehension skills. The push to master reading comprehension tends to move other core subjects to the side, as they are not considered high priority. A variety of programs from mClass to iStation have been used to measure reading comprehension, while taking a considerable amount of time from the teacher and preventing the creation and implementation of strong inquiry-based lessons in reading, math, social studies, and science. While there is a need to reduce the amount of testing in elementary school, the focus should be to incorporate student-centered learning experiences in areas such as science and social studies.

Project-Based vs. Problem-Based Learning

Project-Based (PBL) and Problem-Based Learning (PjBl) have distinguishing components which offer students time to develop skills and synthesize understanding of topics. Both are instructional methods that can increase the rigor of the topics being studied. A 2017 study conducted by Merritt and colleagues highlighted the use of Project and Problem Based Learning strategies in a K-8 classroom. The results indicated "PBL being an effective method for improving K-8 students' science academic achievement, including knowledge retention, conceptual development, and attitudes" (Merritt et al., 2017, para.1). Commonalities exist with both methods including the inquiry-based approach and the opportunity to examine topics deeply. Both methods pose real-world, authentic problems and promote student-centered learning (Dole et al., 2017). Problems that may be posed include recent and current events. Situations that are presented to students are typically relevant and do not have a current solution. Galvan and Coronado (2014) explained the differences between PjBL and PBL:

> Project-based learning is an instructional strategy in which students work cooperatively over time to create a concrete, substantial product…Problem-based learning is an instructional tactic which allows students to work communally in order to investigate and resolve an ill-structured problem based on real world issues. (p. 40)

These terms have been used interchangeably in the literature reviewed, as will be further explored in chapter two. PBL was introduced as an instructional approach in medical school in 1958. Students were given an "authentic, ill-structured problem" (Dole et al., 2017, p. 2). Dole et al. (2017) suggested that a limited amount of PBL research has been conducted with elementary students; however, the studies that have been conducted revealed positive results.

Many effective studies in PBL and PjBL have occurred from the middle school level through the university level. Hall and Miro's study (2016) explored evaluating the effectiveness of PBL and STEM education in high school, while a study conducted by Oh et. al. (2020) assessed the impact of design students' e-portfolios and social media use. While these studies are not connected to the elementary level, they inform and contribute to the gap in the PBL literature for third-grade which shows a need for more research in K-6 to be conducted.

Research Problem

This research will explore the use of PBL as an instructional strategy for student motivation, academic performance, and perceptions of STEM career options. Most of the research that has been conducted on this instructional practice are at the secondary level, leaving the elementary level underexplored in terms of how PBL can be implemented and the effect that

PBL has on student populations. This is particularly important in relation to science as a content area, as that content focuses so strongly on solving problems.

The purpose of this study is to explore the use of PBL as an instructional strategy for improving student motivation, academic performance, and perceptions of future career options. The Universal Design for Learning (UDL) framework incorporates components which customize student learning and promote equity for ensuring the student has strategies for being successful. A constructivist approach promotes inquiry-based learning, which can be used to motivate students to be engaged in their learning. Experiences gained from participating in a PBL unit encourages students to write about what they know.

Theoretical Framework

Project-Based Learning is based on constructivist theory. Xu and Shi (2018) stated that "The constructivist learning theory states that through consultation in the community, learning can be the process of construction and cognition of knowledge" (p. 883). The constructivist theory focuses on making sense of a topic or a question using the environment the students and teachers are in. Xu and Shi (2018) stated, "the constructivist learning environment includes four elements: situation, cooperation, conversation, and meaning construction" (p. 884). These four elements are essential to student-centered learning. Each element is important to the process; however, the situation is crucial to constructing and assimilating knowledge (Xu & Shi, 2018). In the next section, the foundations of constructivism (social vs. psychological) are discussed. The implications and influences from constructivism are also examined.

Social vs. Psychological Constructivism

Richardson (2003) suggested that the lenses of constructivism may differ and focused on two distinct categories of constructivism: social constructivism and psychological constructivism. These two categories were formed due to the distinct differences in their views. Social constructivism is viewed through the lens of understanding experiences are constructed by the environment. The environment may include "politics, ideologies, values, the exertion of power and the preservation of status, religious beliefs, and economic self-interest" (Richardson, 2003, p. 1624). The second category is psychological constructivism. During psychological constructivism, the learner is actively constructing meaning, and depends on the background knowledge of the learner. As a result, using the psychological constructivism lens is most commonly used in education.

Social and psychological constructivism have distinct differences in their meaning. Social constructivism focuses on the development of formal knowledge and psychological constructivism focuses on ways meaning is created and shared. Richardson (2003) stated, "psychological constructivism are individual contributions, which are used to create a shared meaning" (p. 1625). Critical issues such as politics, status, power, and ideologies are more commonly used in the social constructivist approach.

Richardson (2003) indicated that being an effective constructivist teacher is grounded in learning theory and not teaching theory. Misconceptions of self-proclaimed constructivist teachers include not utilizing teaching strategies such as direct instruction or basal texts; this is due to the idea that these strategies are not within the boundaries of constructivism. The lack of a strong constructivist learning theory often leads to a weaker constructivist teacher. Richardson (2003) described the range of teachers aligned with constructivist teaching as, "laissez-faire nonteaching to typical homogenous reading groups" (p. 1630). Using this approach to teaching is neither grounded in constructivist teaching nor learning theory. A laissez-faire approach creates an unstructured learning experience for the student. The outcome of this approach may superficially indicate that students are not disciplined enough to manage their learning experience. For example, before beginning a third-grade math project with fractions, the student must achieve concrete (manipulatives) and representational (pictures and models) skill development in equivalent fractions, part to whole, etc. Reaching the concrete and representational level ensures that the learner is ready to transition to more independent tasks within project-based learning. To master foundational skills, direct instruction must be provided leading up to independent inquiry-based learning.

Giving students total control to explore a topic before mastery is counter-productive to a student's success. Students may formulate incorrect conclusions if basic content is not mastered. Providing direct instruction to the student is not aligned with constructivist theory; however, it can be beneficial for allowing students to have the opportunity to explore their topic to provide direction. This reveals that lack of a true constructivist teaching process prevents opportunities for PBL to be an effective strategy. For the purposes of this study, foundational work from the constructivist theory/approach will be used. Limitations from the study will connect back to the psychological and social constructivist frameworks, which will also help to inform improvements needed in teaching.

Developmental and Cognitive Theory Influences

Fusing psychological constructivism with foundational constructivist ideas are key for a strong PBL foundation. Influences from Vygotsky (1978) and Dewey grounded PBL in developmental and cognitive theory. Studies conducted by these theorists have shown significant contributions to education. One of the key concepts in Lev Vygotsky's work is the Zone of Proximal Development (ZPD). The ZPD is a range that shows students at their actual and potential developmental levels. The potential developmental level suggests the track that students could travel on developmentally. Instruction that is delivered to the student, who has already reached their ZPD level, does not benefit the student. This is due to the instruction not shifting students towards a new level of development (Vygotsky, 1978). Vygotsky focused on the process of learning and development. One of the main principles of his theory included understanding how a child's social environment contributes to his or her development.

ZPD could be an important concept to PBL, because it reinforces the idea that a student does not need to only work at their developmental level. Table 1 below shows how the suggested ZPD range correlates with the Lexile measure.

Table 1

Lexile Measure Aligned With Suggested ZPD Measure

Lexile Measure (L)	Suggested ZPD
BR400L	BR350L-BR500L
BR260L	BR210L-BR360L
BR35L	BR135L-15L
185L	85L-235L
345L	245L-395L
470L	370L-520L
560L	460L-610L
660L	560L-710L
745L	645L-795L
840L	740L-890L
925L	825L-975L
1000L	900L-1050L
1055L	955L-1105L
1110L	1010L-1160L
1185L	1085L-1235L

Note. Table 1 adapted from Renaissance Learning. (2022).

The Lexile measure is utilized in North Carolina for reading. There are a variety of sources which approximate the Lexile range for students. North Carolina utilizes the program mClass DIBELS Next. This program incorporates the DIBELS composite score and the Lexile measure to generate the range of appropriate reading materials for the student. The higher end of the Lexile/ZPD range could be used for more challenging reading materials. These materials may be Adult Directed (AD) which could require additional support from the teacher. Without teacher support, this could lead to frustrational reading, and will not support the learner. When the frustrational reading level is reached, the student often stops becoming engaged with the text. The goal for finding the correct reading range for each student is crucial and meant to personalize reading for students. Thinking about the role of ZPD and Lexile's in PBL is important because personalized learning experiences occur. The PBL lesson is on-going with choice board activities, etc. Active-learning is taking place, with the additional supplemental reading activities which help to build background knowledge for the student.

Vygotsky and PBL

Vygotsky (1978) believed, "learning gives direction to development through social interaction" (p. 115). PBL promotes social interaction through the use of critical thinking and collaborative learning with peers. Students are encouraged to explore topics through inquiry-based learning and research. Vygotsky (1978) noted the following conversation during a clinical observation:

> When a five-year-old is asked, "why doesn't the sun fall?" it is assumed that the child does not have the ability to generate an answer or is able to answer the question. The point of asking questions that are so far beyond the reach of a child's intellectual skills is to eliminate the influence of previous experience and knowledge. (p. 80)

This reflection encourages students to shift into a new range within the ZPD. PBL seeks to have students think critically and to explore topics. By not using the influence of previous experience and knowledge, this encourages the student to dig deep into a topic and to use their inquiry skills to further explore a topic. This clinical example illustrates the intention of PBL. During the process of PBL, the student is encouraged to explore a topic, make discoveries, connections, and synthesize topics.

Vygotsky (1978) described play as a way for children to be more advanced than their age or behavior. Games that are played are based on rules and instructions, previously given. Children use their imagination to achieve an elementary mastery of abstract thought. Vygotsky suggested that there is a parallel between play and school instruction. PBL encourages students to examine new strategies or topics and to seek out new ways of understanding a topic or question that is to be explored. While PBL is not necessarily delivered in a game-like approach, the driving questions help students to explore topics in new and different ways.

Dewey and Experiential Learning

John Dewey, an American educational theorist, and philosopher, coined the term experiential learning. Experiential learning first evolved in the 1930s from Dewey's work and is still used today. Dewey's original work in 1918 is regarded as the gold standard for inquiry-based learning, long before the trend of utilizing PBL in the classroom. Much of Dewey's work focused on experiential learning. Matriano (2020) shared that experiential learning is defined as making meaning from direct experience. Kolb, a student of Dewey's, applied experiential learning theory and further developed the concept. Matriano (2020) explained that Kolb's theory proposed, "the assumptions that learning is a process and not as an outcome, driven by experience in a more holistic and integrative manner" (p. 214) while Kolb's take on experiential learning concluded that experiential learning makes the learner interact with the environment, which creates knowledge. While both defined experiential learning differently, they are both connected to constructivism which includes hands-on direct experience as the crucial element.

Growth and change are two recurring themes in Dewey's learning theory and are foundational concepts in learning. He believed in the concepts of plasticity, habit, and growth as part of the working habits. Plasticity was described as something that a person experiences from past and present. If these experiences do not change the way a person behaves, then a routine is established. The idea of plasticity is rooted in Dewey's idea of immaturity and maturity (Desforges, 2018). Within this idea, immaturity is linked to childhood, while maturity signals the end of immaturity. Desforges further explained that immaturity is dependence and need for others while plasticity enables the individual to grow and learn from experience. Growth is cyclical; if plasticity disappears, then there is no growth. Growth occurs when an experience changes the way an individual thinks or behaves (Sutinen, 2013).

A part of developing critical thinking skills is from making mistakes and understanding how to learn from their experiences, which contributes to the idea of plasticity. Growth is a skill that promotes problem-solving and signifies maturity in thinking. A strong classroom community empowers students and can change the way students approach learning. Students feel safe with making mistakes and can develop a growth mindset, which is conducive to problem-solving and higher-order thinking skills.

Reflective thinking is another key concept in Dewey's work. Dewey categorized thinking into the following five phases. The first phase is to recognize a problem exists. The second phase is understanding the problem and its meaning. The third phase is brainstorming ways to solve the problem. The fourth phase is solving the problem using reasoning. The last phase is observing the solution and its effectiveness (Sutinen, 2013). These phases of thinking encourage an individual to make connections and reflect on their reasoning and thinking. Reflective thinking leads to synthesis of a topic. Dewey's concept of reflective thinking is the embodiment of constructivism. Constructivism requires that the learner make meaning of a topic, which contribute to synthesis of a topic and material learned.

Kilpatrick, Dewey's student, developed his process for engaging learning experiences. Larmer et al. (2015) noted Kilpatrick's contribution to PBL, writing that "the goal of projects was to foster student motivation by encouraging students to freely decide the 'purposes' they wanted to pursue" (p. 27). This statement justifies and further solidifies the rationale behind PBL. Students may become more motivated by choosing projects they are most interested in, which can contribute to the student's success with the learning outcome.

PBL requires the student to interact with a variety of resources. Boss (2011) noted that Dewey "challenged the traditional view of the student as the passive recipient of knowledge (and the teacher as the transmitter of a static body of facts)" (para. 3). Boss further explained that Dewey sought to give students learning opportunities with authentic and practical applications.

Critique of Constructivist Theory

While the constructivist framework is crucial to student-centered and inquiry-based learning, one downside is that the learner may have too much freedom when choosing or developing their PBL topic. For this reason, the teacher should provide a strong foundation, prior to giving students the opportunity to explore a topic. Constructivist theory relies on the learner to construct meaning from their experiences and through inquiry. One key component of a strong foundation of skills includes ensuring students have a good grasp of a topic. Krahenbuhl (2016) also suggested that "constructing meaning that does not correspond with reality goes directly against a major purpose of learning – to correctly know that which corresponds with reality and that which does not" (p. 102). Teachers should carefully plan and activate prior knowledge of student learning before shifting to PBL. Activating prior knowledge leads to deep understanding, which is the goal of constructivism. Active learning is not always the key to ensuring constructivism is effective. In fact, success with constructivism occurs when the teacher provides learning experiences connected to the inquiry lesson. Krahenbuhl (2016) explained that a variety of teaching methods should always be incorporated with the understanding that some may not be aligned with constructivist theory. Adjusting teaching methods and instruction ensures the student has more opportunities to be successful with PBL. There are misconceptions that teachers believe they align with constructivist thinking yet may steer clear of using basal texts or direct instruction. These resources should be used if they promote rigor within the curriculum and PBL. A strong constructivist learning theory foundation should guide the learner into an inquiry-based learning experience. PBL demands that the teacher guide student learning yet allow the process to be discovery or inquiry based. Synthesis of content is evident by the results of the products created from PBL. Fully grasping constructivist learning theory is key to understanding how to empower students to construct their knowledge. The research questions were developed based on this foundational work in constructivism, to further understand student learning.

Research Questions

As stated earlier in this document, the purpose of this study is to explore the use of PBL as an instructional strategy for improving student motivation, academic performance, and perceptions of future career options. With that in mind, and based on the literature reviewed and my teaching experiences, the following question was proposed for this study:

What is the impact of a science project-based learning unit on:

1) student motivation?
2) academic performance (reading, writing, and science)?
3) student perceptions about STEM careers?

With this research question, I explored the impact of PBL in a third-grade classroom within the context of a science unit. The Universal Design for Learning (UDL) is a framework which is incorporated to support student learning, through the use of strategies for incorporating multiple modalities.

Learning Framework

Universal Design for Learning (UDL) is a framework which focuses on three regions of how the brain processes information. These regions are identified as the recognition, affective, and strategic networks (UDL & the Learning Brain, n.d.). These three networks have formed the why, what, and how of learning. Each category provides options for learning strategies which are implemented to accommodate the learner. From this research the organization noted "the UDL guidelines are not meant to be a prescription but a set of suggestions that can be applied to reduce barriers and maximize learning opportunities for all learners" (UDL: About the Graphic Organizer, n.d.). Elements from the Multiple Means of Representation category are present throughout the classroom community and PBL unit.

Components of PBL

PBL presents an opportunity for the teacher to create academically rigorous projects, which lead to acquiring deep content knowledge and understanding of their topic (Boss et al., 2018). In addition to using higher order thinking skills, students are given ownership of their learning. Ownership for learning can be concrete, like a final product, or more abstract like boosting a student's self-esteem and motivation towards learning. Utilizing a framework for PBL is important to ensure student learning is successful. Boss & Larmer (2018) generated the following seven criteria in the framework for high quality PBL. The seven criteria are as follows: "Intellectual challenge, accomplishment, collaboration, reflection, authenticity, public product, and project management" (p. 3).

Each of these components contributes to the process of PBL, however, not all of them are pertinent to the research proposed in this dissertation. Personalized learning and student-centered instructional practices tend to overlap with PBL. Personalized learning emphasizes, "more of a premium on students' individual interests, skills, and developmental needs" (Boss & Larmer, 2018, p. 4). PBL is aligned with enabling students to have choices and opportunities to choose the direction of learning. The Driving Question (DQ) of PBL is crucial to designing an effective project. The driving question of a project "helps to initiate and focus the inquiry" (Miller, 2011, n.p.). The overarching driving question generates discussion with the topic, while additional DQ's are presented for each learning set, which consists of a series of lessons.

Exploring components of a successful PBL classroom are also important. Two key components to building an effective PBL classroom include building a strong classroom culture and community and incorporating differentiation strategies with projects. The following section explores discussion on incorporating the UDL guidelines within the classroom community and as a tool for differentiation.

Classroom Culture and Community

From the UDL guidelines, classroom culture and community are present in the Multiple Means of Representation category, which emphasizes the need to foster collaboration and community. Evidence of incorporation includes guiding students to protocols for how to ask for help and support peer interactions (UDL: Foster Collaboration and Community, n.d.). Fostering collaboration happens in the classroom during morning meetings, class discussions, and while working in groups. The building of these skills provides support and promotes confidence within the classroom setting. The goal is to have these skills transfer to PBL lessons to better support students. Students are often working together to create products and find solutions for tasks. UDL guidelines support students by scaffolding instructions and tasks so that all students may be successful.

When considering the importance of building a classroom culture, it should be noted that a strong classroom culture gives students an environment to learn to take risks and to learn how to build a growth mindset. The culture of the classroom sets the tone and creates a sense of empowerment and safety. Students learn how to share their ideas and how to give feedback in a constructive manner. Classroom culture also involves making sure the social and emotional needs of students are met. One strategy that can be used to build community in the classroom is morning meetings. Morning meetings can range from discussions to incorporating literature. Lopez-Robinson and Haney (2017) conducted a study on building a classroom community through the use of multicultural literature. The researchers shared, "educational processes can be greatly enhanced when teachers learn about the everyday lived contexts of their students' lives and strengths that they bring to school" (p. 49). Building connections with students encourages them to share their ideas and thoughts in a productive manner.

Differentiation in PBL

Project-Based Learning contributes to the teacher's ability to differentiate lessons for students. Teachers should scaffold projects from the Multiple Means of Representation with options from the language and symbols or comprehension. Strategies for this category include:

illustrate through multiple media, activate, or supply background knowledge, and maximizing transfer and generalization. Figure 1 includes examples for each of the learning strategies from UDL to be used, while Table 2 shows specific examples from the Multiple Means of Representation category.

Figure 1

The Universal Design for Learning Guidelines

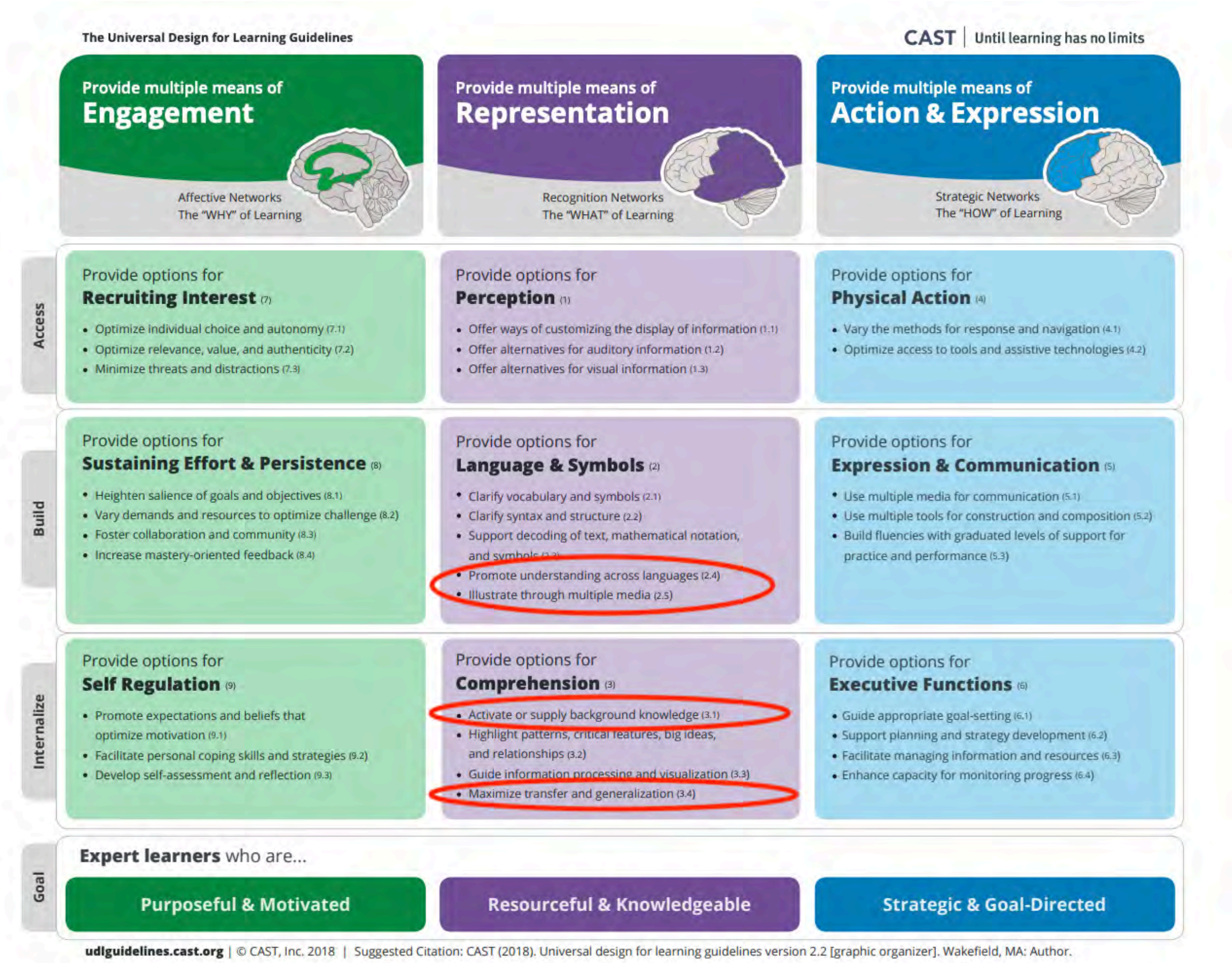


Table 2

Examples for Multiple Means of Representation

Provide Multiple Means of Representation	Examples
Provide options for Language and Symbols • Illustrate through multiple media	• Provide symbolic representation (text) with an additional visual (illustration)
Provide options for Comprehension • Activate or supply background knowledge	• Use advanced organizers • Bridge concepts • Cross-curricular connections (literacy strategies in science)
• Maximize transfer and generalization	• Provide checklists/organizers • Provide templates, graphic organizers, concept maps • Provide scaffolds that connect new information to prior knowledge

Note. From the UDL Guidelines. Adapted from (UDL: Activate or Supply Background Knowledge, n.d., UDL: Illustrate through Multiple Media, n.d., UDL: Maximize Transfer and Generalization, n.d.) Copyright 2018 CAST, Inc.

Scaffolding projects may take place prior to beginning a project, or the teacher may need to adjust the project as the student makes progress with the project. Boss et al. (2018) noted, "In an equitable classroom, students' prior learning experiences, language fluency, or reading levels are not barriers to success" (p. 129). Scaffolding a project gives students an equitable opportunity to approach learning in a different way than a classmate and boosts confidence of learning and mastering content. While the student guides the project, the teacher should continue to monitor the progress of student learning. Providing ongoing feedback ensures the student is staying on track with their project and gives students an opportunity to modify or adjust, as needed. Scaffolding projects may be necessary, if the student struggles with project completion or has not mastered basic concepts.

Researcher Positionality/Relationship to Topic

My relationship to my dissertation topic includes being a National Board-Certified teacher in Middle Childhood, with the majority of my teaching experience in third and fourth grade. My interest in PBL began when I taught fourth grade and worked on my National Board Certification. I created a PBL Social Studies Economics unit incorporating supply, demand, and opportunity cost. Students created items from playdough and learned how to barter and trade for items that were “worth” more. A PBL approach to the Economics unit provided opportunities for students to use critical thinking and higher order thinking skills. Students were actively engaged in their learning and were able to make better connections to abstract concepts, like opportunity cost. Based on this classroom experience, there is a lot of value in student created products which develop critical thinking skills needed for standardized testing. Incorporating a science and literacy focused PBL unit in third-grade, will keep students energized with learning.

The research took place during fall of 2022. As part of this dissertation, a tested PBL unit developed by Michigan State University and the University at Michigan was implemented into the teacher and researcher’s third-grade classroom. The teacher will also be the researcher in this study, since the research conducted was in the teacher/researcher’s school.

Summary

Differentiating between Project and Problem Based learning is crucial to understanding the specific purposes of each. While both have similar characteristics, problem-based learning focuses on a solution for a problem, whereas project-based learning is constructed around DQ’s for each lesson or unit. PBL is rooted in the constructivist framework and follows elements from John Dewey and Lev Vygotsky’s foundational work. An important contribution to PBL from Dewey’s work is his experiential learning theory. Experiential learning uses personal experiences, which are applied to make sense of a topic. Lev Vygotsky's key contributions to PBL include the development of ZPD, which seeks to challenge students in their learning. There is not a standardized test for PBL, to indicate the ZPD range that a student should work in. Reading programs such as Renaissance Learning show the ZPD for a student. If a project is reading focused, a program such as Renaissance Learning could help a teacher plan for the higher range of PBL. Renaissance Learning includes a ZPD measure. This data can help to incorporate higher order thinking skills into learning. Another tool that could be used to measure ability is the CogAT test. In North Carolina, students are first given the reading comprehension test in third-grade. The breakdown of this test can indicate strength areas for a student. Analyzing these areas could also help a teacher to plan projects with areas that may need more strengthening. For example, a student may be strong in quantitative skills, but weaker in verbal skills. The project could be designed to enrich verbal skills in the higher range of the ZPD to encourage growth. According to Dewey, this is where real growth occurs in student learning. To further ensure equity and access for all students and English Language Learners, the Naglieri Nonverbal Ability Test could be administered. The Naglieri test is reflective of problem-solving skills and nonverbal reasoning, which indicate student strengths. Based on the results, teachers could design projects based on processes.

Richardson (2003) noted that psychological constructivism is most commonly used in education, due to the learner actively constructing meaning during the learning process. Becoming an effective constructivist teacher relies on having a solid foundation for learning theory, which contributes to the process of being a teacher who can implement PBL.

Chapter 2: Literature Reviewed

The literature reviewed is inclusive of PreK – university level, to show the range and depth of Project-Based Learning (PBL). Varying trends and themes within the area of Project Based Learning emerged from the literature reviewed. Including studies from Pre-K through university level shows the range of PBL and the variety of application. PBL at the university level could be applied to the secondary level or be modified and incorporated at the primary level, with the driving question. The literature reviewed suggested a positive impact on student learning and achievement, while revealing the shift from teacher-directed assignments to student-centered, inquiry-based learning experiences. Group work dynamics and status ordering are explored as an instructional technique for PBL; while the following themes were reviewed in literature: Self-efficacy, motivation, diverse learners and equity. The synthesis of the literature reviewed contributes to the gap in PBL. These themes are supportive in seeking answers to the research question:

What is the impact of a science project-based learning unit on:

1. student motivation?
2. academic performance (reading, writing, and science)?
3. student perceptions about STEM careers?

Michigan State University and The University of Michigan found the need for curriculum to be developed for elementary science students. Researchers and teachers created the Multiple Literacies Project Based Learning (ML-PBL) units for grades 3 and 4. The university developed ML-PBL units while incorporating the Next Generation Science Standards and the Framework for K-12 Science Education (Krajcik, et al, 2023). Alvermann (2017) defined multiple literacies as a practice that is used in everyday settings and is applied in the real world. Standards within guiding documents such as Common Core and North Carolina Standard Course of Study are aligned with promoting real world application of literacy. Literacy should be interacted with in a way that supports practicality, such as reading recipes or developing ‘how to’ writing pieces. Traditional materials in reading, writing, and digital content with the ML-PBL unit will be encountered throughout the study. The Toys unit is housed in the Sprocket (Sprocket, n.d.) portal.

Educational Underpinnings of PBL

Bandura’s self-efficacy and motivation concept (Shin, 2018) is a crucial component to PBL. To be successful with PBL, a student must show self-motivation and drive to be successful. Another theorist, Montessori, a child development expert began working with children in 1900. Montessori’s work focused on “individualization and the use of manipulative materials” (Demirbaga, 2018, p. 115). The focus on individualization and use of manipulative materials gives the student options for tailoring PBL through the use of inquiry-based learning. In the following sections, Bandura, Montessori, and the Universal Design for Learning (UDL) guidelines will be reviewed to show concepts that are foundational and contribute to PBL.

Albert Bandura

Student efficacy and motivation are important factors when considering the impact of PBL. Motivation can impact academic performance, which is important how these concepts are and how they are connected to PBL. Bandura defined self-efficacy as, “a belief in one’s ability to organize and perform the activities required to achieve a certain goal” (as cited in Shin, 2018, p. 100). The ability to organize and perform activities is important for Project-Based Learning. These skills contribute to student motivation. Student motivation drives the desire to find out the why for the topic being studied. Larmer et al. (2015) revealed that students were motivated by the same conditions that adults are motivated by. Upon further explanation, the authors explained how motivating jobs involve a variety of skills, are engaging, and provide opportunities for workers to be successful in the task at hand. When these concepts are fused together, student efficacy and motivation drive the success of PBL. These concepts are what drive student instruction and are crucial for student learning.

For this reason, a study conducted by Dole et al. (2017) regarding cognitive load theory, becomes essential for recognizing whether or not tasks are supportive of student learning and should be a factor when considering the importance of direct instruction. Cognitive load theory was first introduced by Sweller in 1988. Sweller (as cited in Dole et al., 2017, para. 8) explained that the "working memory has limited capacity and should not be overloaded" by introducing activities not related to the learning objective or topic. One option is to guide students with direct instruction so they are not left to discover information on their own (Dole, 2017). This may benefit students who require building more schema before diving in to explore topics. Concepts are easier to scaffold, when there is a reduction of overload.

Maria Montessori

Montessori worked with children considered to have special needs, on basic skills such as reading and writing. As a result, these students passed the state exams with above-average scores. Montessori had a second opportunity to work with children ages 3-6. During this time, the children who were part of the study were low-income. One reason Montessori was allowed to work with these children is because they were considered not educable (Thayer-Bacon, 2012). Children who were considered not educable were not given challenging tasks. Montessori sought to change how instruction can happen for these students.

Montessori supported the idea that education happens, “not by listening to words, but by experience upon the environment” (Boss, 2011, para. 4). In a Montessori classroom, students are given control of their learning. The teacher is considered an observer and guides the student toward their developmental learning level for a topic. One of the differing components of Montessori’s approach to the regular classroom is that the student determines the evaluation of projects, as there are “no common evaluation criteria” (Demirbaga, 2018, p. 119). In this instance, the teacher did not create a standard grading system for students. Montessori chose to let students evaluate their own work. Characteristics from Montessori’s approach parallel some of the elements in PBL. PBL is supportive of a student-centered learning approach and gives students an inquiry-based learning experience. Montessori’s developmental work influences PBL with key components such as the teacher accepting the observer role in the environment, which is consistent with Inquiry-based learning. Students are provided avenues to success based on their developmental learning levels.

Group Work Dynamics

PBL often requires collaboration and group work. Foundational work from Cohen and Lotan (2014) discussed how using group work as an instructional technique is crucial for giving students ownership of their learning. Another essential concept from Cohen and Lotan is status ordering. Status ordering is not always easily identifiable. The researchers discuss the caveats of group work with students who are gifted learners and those who are considered struggling or at-risk.

Foundational group work ideas from Cohen and Lotan (2014) discussed the importance of incorporating group work, as an important instructional technique. Classrooms may be ability grouped and use traditional methods including rote memorization and independent task completions. The use of ability grouping can be detrimental to struggling students and tends to be overused in schools. Student self-esteem may be impacted; they may be aware of being grouped into the lower group. Low self-esteem can impact the motivation of students and their desire to accept challenges. Students grouped into the higher groups may have greater self-esteem towards learning and may perceive themselves as being smarter than others. Although a student may perceive as being more capable than others, they must be motivated to complete PBL successfully.

During PBL, students may not be actively engaged in tasks. These off-task behaviors are more likely to show students are less motivated to complete routine tasks. Utilizing group work encourages students to learn how to contribute to discussions and learn how to take control of their own learning. Instead, teachers should shift their attention to create tasks that focus on conceptual learning. Conceptual learning requires students to apply their skills and synthesize knowledge of content learned.

With conceptual tasks the student, "interacts in ways that assist them in understanding, applying, and communicating ideas" (Cohen & Lotan, 2014, p. 10). Group work that is intentionally designed to engage students increases their content knowledge of a topic and encourages students to share their information and understanding with their classmates. Group work that incorporates tasks which are open-ended and without a clear answer, tend to generate more engagement from all students. The increase in engagement provides students more opportunities to experience more discussions and from a variety of perspectives. When considering how to pair students, Cohen and Lotan (2014) emphasized low-achieving students were at an advantage when working in heterogenous groups. This is considered an advantage so that students are able to be paired with others who are a strength to their weakness. For example, a student who is weak in reading skills could be placed into a group with students who are good readers and can explain directions. A reader who is striving may find that reading the task creates an additional stress for the student. If the task is not reading skill focused, it is counterproductive and can discourage students from participating in the task.

Cohen and Lotan's (2014) research also revealed that ELL students benefit from working with peers who are stronger academically, as it provides an opportunity for them to experience an authentic task. The student is immersed in an authentic learning experience. English Language Learners can benefit from having concepts explained to them from peers. This interaction with classmates fosters new friendships and can help with building student confidence.

Status Ordering: Academic, Peer, and Societal Status Influences

Group work presents challenges such as ensuring that the more academically successful students do not dominate tasks (Cohen & Lotan, 2014). Status ordering occurs when students are ranked in order of importance. The higher the rank, the more competent and the more important the person is. Students who are of elementary age unconsciously categorize peers as smart by observing whole group discussions with the teacher or by their own observations. Students may draw conclusions that because their classmates are "smarter" that they may not be smart enough to complete classwork tasks. Upon rank being established, those who dominate the group discussions are considered to have provided the most important contributions to project work and discussions. Once the academic status order is established, other students are more likely to fall into more passive roles within the group. Passive roles are accepted by the students who may be academically successful students but may be dominated due to being of a minority group or of a quieter nature.

Cohen and Lotan (2014) presented a scenario where students played a board game called Shoot the Moon, a game of chance. The game has no connection to reading ability, yet students who were seen as the better readers were given the academic status. The authors noted the following:

> Reading ability, as perceived by others, is an important kind of academic status. And academic status has the power to spread to new tasks where there is no rational connection between the intellectual abilities required by the task and the academic skill making up the status order (p. 30).

This example illustrates the importance of drawing correct parallels between student success and student ability. Furthermore, Cohen and Lotan's (2014) work revealed that students who are perceived as being strong in one subject area, continued to dominate discussions, even if they were not the strongest in that particular area. Other students who did not perceive themselves of the same ability were likely to be more passive and if they contributed to the discussions, they were ignored. Clearly, perceptions are key to academic status and attention should be given when building classroom communities. Recognizing peer and societal status are also present in classrooms is important to skewering stereotypes which may be present. Students learn to build status orders at school and outside of school. Newcomers are often considered to have low social status. Students with higher peer status tend to dominate classroom discussions.

Self-efficacy and motivation

Group work dynamics influence self-efficacy and motivation with work completion tasks. One example is understanding how utilizing technology in Project-Based Learning incorporates an interactive learning experience for students. Studies reviewed showed researchers found innovative ways to incorporate technology and connect to the concept of

Bandura's student motivation and engagement. Shin (2018) discussed Bandura's definition of self-efficacy as "a belief in one's ability to organize and perform the activities required to achieve a certain goal"; connecting themes of self-motivation and engagement (Shin, 2018, p. 100).

Hung et al. (2012) explored student motivation through digital storytelling with 117 Taiwanese, 5th grade students. Researchers found that students were more motivated and had better attitudes towards learning; while students found the incorporation of digital storytelling as a "more interesting way of learning" (Hung et al., 2012, p. 376). Experimental results from the study showed that the "project-based learning with digital storytelling could effectively enhance the students' science learning motivation, problem-solving competence, and learning achievement" (Hung et al. 2012, p. 368). Additional work conducted by Hall and Miro (2016) further supports the theme of student engagement. Students were provided instruction by four different digital platforms, which were used to determine the impact on student learning. The significance of including this study is the variety of platforms offered to increase student motivation. Elementary school students could be offered opportunities to choose strategies for their learning and potentially a platform to share their final project.

Research conducted by Oh et al. (2020) used an innovative strategy to increase motivation. The authors revealed that, "using social media as an eLearning platform means that teachers can use existing models to infiltrate these established platforms for PBL" (Oh et al., 2020, p. 43). While elementary students are not likely to be tasked with using social media as a platform, other programs which offer closed discussion boards could contribute to the innovative and motivating component of technology. Findings from this study indicated that college students preferred completing a project versus using social media to update their e-portfolios.

Diverse Learners and PBL

Diverse learners include gifted students and those in need of additional accommodations for learning. Robinson et al. (2014) examined the effects of incorporating STEM intervention on gifted elementary students' science knowledge and skills. Findings from this study were supportive of a "rigorous differentiated science curriculum" (p. 205) and showed significant gains in science process skills, science content, and science concepts. Students were more likely to apply their science skills and used higher-order thinking.

PBL and diverse learners also include those who require additional accommodations yet are entitled to a rigorous curriculum. Alfonso (2017) conducted a study in a pre-kindergarten classroom, with students who had "significant sensory processing issues, two severe cognitive and language delays, and four had mild language delays or sensory issues" (p. 59). Alfonso found the need existed to find ways to incorporate PBL to ensure students were authentically engaging in their learning. Alfonso's (2017) study connects to Montessori's work with students who have disabilities in learning. The idea that Montessori believed that education happens, "not by listening to words, but by experience upon the environment" (Boss, 2011, para. 4), supports Alfonso's concluded that students were able to generate answers based on firsthand experiences, while continuing to grow and remaining engaged with the project. However; the researcher felt that the end product was not representative of an authentic, independent learning experience due to the amount of teacher direction needed.

Social emotional learning (SEL) is another way learners may be considered diverse. Fitzgerald (2020) examined the impact of integrating SEL and literacy skills learning through the use of PBL. The gap in literature for SEL learning indicated the need to conduct more research in the elementary classroom. Fitzgerald (2020) noted that the teacher observed for the study, had a classroom community that aligned with features of socio-emotional learning and PBL. Classroom community is important for building a supportive learning environment for students. Specific SEL needs can be addressed in the classroom community through the use of literature or morning meetings. SEL contributes to students understanding how to regulate their emotions when problems arise during the critical thinking phase of PBL.

PBL and Equity

Based on the literature, PBL is considered an effective teaching technique. It is important to consider how PBL can be accessible for all students. Advocating for equity is important so students from all socio-economic levels have an opportunity to experience PBL. From the researcher's experience, funding for schools and teacher quality are crucial for ensuring equity for all students. Title I funding provides funds for students in high poverty areas. Students living in high poverty areas often experience inequity by having less experienced teachers (Rodas, 2019). Teachers who are less experienced and working in underrepresented and higher poverty areas can experience more stress, due to inexperience with meeting student needs. This stress leads to higher teacher turnover rates in these areas and impacts the students directly by not having a teacher who is skilled in areas such as instruction and behavior management. Rodas (2019) also stated, "Higher paid, more experienced teachers wind up in more affluent schools and lower-paid, less experienced teachers wind up at low income schools, triggering a cycle of inequity in regard to teacher experience" (p. 3). Teacher inequity includes inexperienced teachers who may not be considered effective.

PBL is not a scripted instructional technique since it requires extensive planning and deep understanding of how students learn. Ensuring teachers have proper exposure to PBL is important, when considering the purpose and effectiveness of this instructional strategy (Hovey

& Ferguson, 2014). Findings from their study include teacher belief that PBL as an instructional strategy is to create projects, which is supportive of the need to ensure teachers are fully supported when implementing this strategy. Hovey and Ferguson (2014) also discussed special education and ELL teachers were more likely to support PBL. It could be inferred the rationale for this is due to the inquiry-based learning experience, which builds and activates background knowledge.

Huinker (2019) asserted the importance of creating equitable structures. System structures are defined as, "policies, practices, or conditions that support or impede student learning" (Huinker, 2019, p. 284). The article specifically references mathematics instruction needing to be more equitable. Huinker (2019) suggests that non-equitable system structures continue to, "lead to opportunity gaps which lead to disparities in learning outcomes" (p. 284). The lack of an equitable system structure creates opportunity gaps which have a greater impact on students of a lower socio-economic status. A study conducted by Corneille et al. (2020) examined the underrepresentation of Black/African American students in STEM disciplines. The goal of this study was to address the barriers that exist for Black/African Americans. Additionally, this study encouraged creating and incorporating, "structurally and culturally responsive practices" (Corneille et al., 2020, p. 48). The authors define culturally responsive education as, "using teaching, learning strategies, topics and materials that are culturally relevant to learners" (Corneille et al., 2020, p. 50). Creating a culturally responsive environment is key to ensuring students feel included and empowered. Topics that are relevant and diverse support students from underrepresented backgrounds by becoming more inclusive and potentially becoming more motivated.

Structural inequality is another key idea when considering equitable structures. Corneille et al. (2020) defined structural inequality as, “embedded bias within organizations, institutions, governments, or social networks which provide advantages for some members and marginalizes or produces disadvantages for other members” (p. 50). While structural inequality does not directly impact students, there is a trickle-down effect. Teachers and administrators may be impacted by the decisions of those with embedded biases. These embedded biases may impact the level of funding and resources, which are allocated for programs with underrepresented populations. Lack of funding may impact schools in lower-socioeconomic areas, which may impact the ability to recruit teachers in higher quality areas. The opportunity gap is most predominant when other factors such as teacher inequality and lack of funding are present. Catapano and Gray’s (2015) case study in an urban, magnet school provided pre-service teachers an authentic experience implementing PBL prior to entering the classroom. Saturday School began as a federally funded grant program. Findings from the study included students who shared their learning experience as fun. For elementary students, the word fun can be synonymous with being a motivator for learning content. Additionally, Catapano and Gray (2015) noted a limitation to the study, “As teachers were pressured by administrators to cover specific curriculum and learning outcomes, attendance at Saturday School dropped” (p. 8). The emphasis on more traditional instruction suggests the positive impact of PBL.

Another area that calls for more equity is for students in rural areas that are provided opportunities to excel within PBL. VanTassel-Baska and Hubbard (2016) conducted a study focusing on the needs of rural gifted students. The study revealed that students needed more support within areas of including more multi-cultural materials and resources. Including these resources is necessary to encourage exploration of other cultures. The authors suggested that the importance of including materials for English Language Learners from their native languages. This prevents students from being expected to assimilate with other cultures and to appreciate their own culture. Including curriculum materials from other diverse cultures ensures that students are exploring cultures beyond their own communities (Van Tassel-Baska & Hubbard, 2016).

Cohen et al. (1999) suggested that incorporating a complex instructional approach can eliminate status problems, which can create equity issues within cooperative learning groups and can contribute to learning problems. This is due to higher-status students contributing and controlling the situation more, whereas lower-status students are not expected to contribute to the task. The lower-status student learns less from cooperative learning tasks, which include group PBL projects. As a result, the researchers indicated that the academic-status for the low-status students continues to widen. Foundational work by Cohen and Lotan suggests students are creating opportunity gaps in the learning community when they achieve academic status or while participating in status ordering. A contrasting study conducted by Carlone et. al (2011) found in that girls of color who "ultimately disaffiliated knew science, could engage in school science's practices, and claimed to like science, but did not define themselves as "smart science person" (p. 479). This study illustrates that female students are successful with their mastering content yet are not willing to label themselves and is consistent with status ordering, while achieving academic status. This could also impact how others in the groups see themselves, if they are lower in status or are motivated by peer influences. Classroom community becomes an essential component for fostering a productive PBL environment.

Conclusion of Literature Reviewed

The literature reviewed a range of applications for PBL. The major themes explored for purposes of this literature review were group work dynamics, incorporating STEM, alternative implementation, diverse learners, social equity, and the impact of PBL. These themes were chosen to show the flexibility and range of PBL for students in kindergarten through university level. Findings from studies ranged from seeing an improvement in student engagement to increased motivation and creativity. Gaps in the literature included the need to explore how the classroom community supports students when implementing PBL. Lopez-Robinson and Haney's (2017) research emphasized the importance in making sure rapport is established with students. One way that they illustrated this was through the use of multicultural literature. Multicultural literature also serves to conquer stereotypes in the classroom and help students to further build understanding together. Another gap in the literature is the lack of studies conducted for elementary grades. Outlier studies were encountered for grades such as kindergarten. Further studies should be conducted to evaluate the effectiveness in elementary school.

The literature reviewed also revealed areas of weakness. Diverse learners are one group that should be included in more studies for PBL. Additional areas within diverse learners are the need to be more inclusive of social and emotional learning. Teachers often think of PBL as an instructional technique that can only be used for gifted learners. Hovey and Ferguson (2014) acknowledged the existing gap in literature for diverse and exceptional populations. Another area that needs additional research is further examining the impact of professional development with PBL. Fitzgerald (2002) noted the "potentially transformative role that curriculum materials and professional learning opportunities may play in supporting transformations in classroom teaching and learning at a larger scale" (p. 596). Stronger professional development opportunities eliminate the opportunity gap for students who benefit from additional learning strategies such as PBL. Alfonso (2017) found that one limitation of her study is the possibility of a project not being developmentally appropriate for children with special needs. This issue could easily be addressed by including a set of modifications. Scaffolding a project provides access for all students and enables them to be successful during the learning process. Alfonso (2017) noted, "our end product was nice, but the process was not authentic because it required so much teacher direction" (p. 63). This indicates the significance of incorporating projects which have substance and rigor. Rigor and substance are crucial for not creating projects for the sake of creating a project. Montessori's foundational work illustrates the importance of giving students ownership of their learning, which also connects to Alfonso's diverse classroom.

PBL is supportive of diverse learners particularly those identified as gifted learners. Diffily (2002) found that gifted learners benefit from the flexibility of PBL, by not having to continue learning content that has already been mastered. Once students understand project work, they are able to use higher order thinking skills and explore topics. Students do not feel the stigma of being gifted, since students are working on different aspects of projects. Additional strategies from UDL within the Multiple Means for Action and Expression guidelines enhance the classroom community by offering students opportunities to creatively collaborate which could eliminate status ordering.

Summary

The literature reviewed elaborates on the positive and negative aspects of PBL. There is an adequate amount of literature that supports incorporating PBL in the classroom. Research reviewed also indicated that students should possess self-efficacy, which leads to motivation to complete a project. Self-efficacy is an important skill to develop over time to encourage students to complete projects, while still being motivated. The articles reviewed of PBL were generally positive; however, there were some limitations to utilizing PBL in the classroom. Larmer et al. (2015) noted, "just because PBL has been shown to be effective in multiple studies, this does not guarantee that it will be effective in multiple studies, this does not guarantee that it will be effective in every implementation" (p. 59). This is an important thought since it can be seen as a quick solution to the resolving constant assessments. Another implication of incorporating PBL is "students who do not place value in the task, might not participate fully in their work, if they don't have enough confidence" (Shin, 2018, p. 102). Lack of confidence is supported by Bandura's definition of self-efficacy. If a student lacks self-efficacy and motivation, they are likely to struggle with PBL.

Chapter 3: Research Methods

An exploratory study utilizing a single-case study design with a mixed methods approach will be used due to the opportunity to conduct research in a third-grade elementary school in North Carolina. This research methodology will be utilized because this study seeks to understand the impact of Project-Based Learning (PBL) on student motivation, academic performance, and student perceptions about STEM careers. Maxwell (2013) discussed three purposes for incorporating a mixed methods approach. One purpose that is relevant to this study is understanding how multiple methods can reveal additional information and assist with conclusions that are not inferred. A mixed methods methodology is also helpful in providing a closer look at the impact of PBL with student motivation, academic performance, and perceptions about scientists and STEM careers. A gap in the research indicated a need for more studies in PBL to be conducted in elementary schools, particularly in grades 3, 4, and 5.

As the teacher and researcher, I have a first-hand account of the PBL experience, by teaching the PBL unit. Alvermann (2017) defined multiple literacies as a practice that is used in everyday settings and is applied in the real world. Standards within guiding documents such as Common Core and North Carolina Standard Course of Study are aligned with promoting real world application of literacy. Literacy should be interacted with in a way that supports practicality, such as reading recipes or developing 'how to' writing pieces. Traditional materials in reading, writing, and digital content with the ML-PBL unit will be encountered throughout the study.

Additional support lessons within English Language Arts and literacy strategies will be utilized to support the literacy initiative of the university lab school. According to Larmer et al. (2015), "multiple K-12 research studies that show students engaged in PBL score higher on both traditional and performance-based assessments compared to similar students learning the same material using traditional instructional methods" (p. 55). The significance of this statement validates PBL as an innovative and effective instructional strategy when implemented correctly. The following research questions were used for this study:

What is the impact of a science project-based learning unit on:

1) student motivation?
2) academic performance (reading, writing, and science)?
3) student perceptions about STEM careers?

Why Case Study?

The decision to use a case study approach is due to the need to examine how PBL can impact a third-grade elementary classroom. Initial epistemological considerations and perspectives for case study design Robert Stake, Robert Yin, and Sharan Merriam were explored (Yazan, 2015). The researcher's framework aligns most with constructivism. Therefore, the design of this case study lies within the constructivist paradigm.

Merriam (1998) describes case study design as a way to gain understanding of a specific situation while focusing on processes rather than outcomes. Based on this definition of case study, this methodology supports the rationale for how to best customize PBL as an instructional strategy to benefit students of all abilities. Merriam and Tisdell (2015) emphasize the importance of selecting a phenomenon with boundaries. Recognizing the boundaries of a case, helps the researcher understand when the case is no longer relevant and becomes a different type of qualitative study. Merriam and Tisdell's (2015) parameters for qualifying as a case study include:

> For it to be a case study, one particular program, or one particular classroom of learners (a bounded system) or one particular older learner selected on the basis of typicality, uniqueness, success, and so forth would be the unit of analysis. (p. 39)

Based on these parameters, a case study is the appropriate method to be used for this study. Boundaries for this study exist as a single, third-grade classroom, in a traditional elementary school. The limited amount of literature available for this unique population (third-grade) suggests a need for closer studies to be conducted.

Prior to beginning the unit, all lessons were aligned to the North Carolina Standard Course of Study (NCSCOS) for third-grade for Science, Math, and English Language Arts. Lessons were followed according to the planned unit; formative assessments were used to ensure objectives were taught and students mastered content. Ensuring that students had the proper amount of time to work on the projects is important to verifying data is reliable.

Providing additional accommodations throughout the unit occurred, just as a teacher would in a regular education classroom setting. The use of graphic organizers, sentence stems, and modified assignments are instructional strategies that were incorporated by the researcher/teacher, within the PBL unit. Trustworthiness was established in the study by teaching the lessons and mini lessons with fidelity. One way to ensure fidelity was to follow the lessons in the order as instructed in the day-to-day plan (Appendix A). However due to restrictions within the district, the order was modified to better suit student learning for the objectives.

Description of the Unit

A Toys PBL unit, developed by Michigan State University and the University of Michigan, was implemented for this study (Toys Storyline 2019-20, n.d.). The unit is science focused and is aligned with the Next Generation Science Standards (NGSS) within the forces and motion objectives. The unit is designed with four learning sets, with each learning set containing between five to seven lessons. The fourth learning set contains the culminating product of the unit and student presentations. Driving questions are posed at the beginning of the unit for students to revisit during each of the lessons. Supplemental texts from the Toys Unit were incorporated. These texts are supportive of promoting diversity in the STEM field and encourage discussions regarding underrepresented populations in STEM careers. Incorporating multicultural literature also seeks to eliminate existing barriers such as gender roles and stereotypes in the science field.

Setting

The setting for this study was a traditional K-5 elementary school, with a total student population of approximately 470 students. Students in K-5 are provided a digital device by the school. According to data collected by North Carolina, 23.8% of students were considered economically disadvantaged. In 2021, Math EOG test scores indicated 64.5% of students met criteria for grade level proficiency (grades 3-5). Reading EOG test data showed 67.8% proficiency in grades 3-5, while Read to Achieve requirements were met by 75.4% of students in third-grade (North Carolina School Report Cards, n.d.). The third-grade classroom in the study consisted of 17 students, ten girls and seven boys. ELL students represented 52% of the classroom. Beginning of Grade (BOG) test scores for the classroom showed 12% proficiency with levels 3, 4, and 5.

Participant Selection

A purposive sample was used for this study. The uniqueness of this study was due to collecting data in a third-grade classroom, with a PBL study focus. Creswell and Poth (2018) described purposeful sampling as a method to “inform an understanding of the research problem and central phenomenon in the study" (p. 326). The decision to select a third-grade classroom, is due to the teacher's assigned role in an elementary school. The gap in the literature reviewed indicated a need for more PBL research in upper elementary classrooms. Participants for this study consisted of the third-grade students at the school. Ensuring that third-grade participants are committed to the study is important. Commitment to the study includes completing assigned work (student notebooks) and student observation lab worksheets. For purposes of this project, assigned work may include additional integrated assignments in English Language Arts (ELA). The purpose of this is to support the ELA and Science objectives. Student notebooks are an informal way to gain knowledge about a topic. Notebook entries support areas to show mastery or identify areas where misunderstandings with concepts may lie. Student observation lab worksheets were used during inquiry activities, and included formative assessments. Modifications for student lab worksheets and responses were modified on an as needed basis. Prior to beginning the study, IRB approval was secured with parental consent. Student assent letters were signed with a copy provided to the parents. Student participants will remain confidential for this study, as will the name of the school. The teacher will also be the researcher for this study.

A total of 12 participants consented to be part of this study. All participants were enrolled in a third-grade classroom, in a public school. Participants in the study were from a variety of backgrounds. Scores for participants were included in the results if there was both a pre and post unit score. All students were provided supports aligned with the UDL guidelines, as needed to support instruction and to provide small group support. Due to time constraints and other conflicts, lessons for this unit were modified and aligned to fit within the requirements of the standard course of study (Table 3) and the district scope and sequence.

Table 3

North Carolina Essential Science Standards Incorporated into PBL Unit

	North Carolina Essential Science Standards
3.P.1	Understand motion and factors that affect motion.
3.P.1.1	Infer changes in speed or direction resulting from forces acting on an object,
3.P.1.2	Compare the relative speeds (faster or slower) of objects that travel the same distance in different amounts of time.
3.P.1.3	Explain the effects of earth's gravity on the motion of any object on or near the earth
	North Carolina Reading Standards for Informational Text *Key ideas and Evidence*
RI. 3.1	Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.
RI. 3.2	Determine the main idea of a text; recount the key details and explain how they support the main idea.
	North Carolina Writing Standards *Text Types, Purposes, and Publishing*
W. 3.1	Write opinion pieces on topics or texts, supporting a point of view with reasons. c). Provide reasons that support the opinion.

This timeline change was based on accommodations for grade level pacing. These decisions were made by inexperienced, non-licensed teachers in third-grade and an instructional coach. Two science objectives in the forces and motion strand were taught prior to beginning the unit. As the teacher/researcher, I was instructed to follow the scope and sequence of the district. As a result, there was some modification to the unit. Required district assessments and tasks were incorporated within the unit. Three days were used for the pre-unit tasks. An additional day was used for a district required task. Nine days were used for the lessons, while an additional two days were used for the post-work (Table 4).

Table 4

Timeline for Forces and Motion PBL Unit

Days	Tasks
Days 1-3	Pre-test Pre-Student Motivation Inventory Pre-What is a Scientist? Pre-writing for inventions
Days 4-5	Lessons 1 & 2
Day 6	District required task
Days 7-10	Lessons 3-6
Days 11-13	Lesson 7-9
Days 14-15	Post-test (district required) Post-Student Motivation Inventory Post-What is a Scientist? Post-writing for inventions

Research Relationships and Data Collection

Routine classroom data was collected for this study. Focus group interviews are not routinely collected, but typically follow the same format as a quick check-in or follow up discussion. Data sources in Table 5 shows the alignment of data collection methods with the research questions, as well as explaining the timing and justification of these sources.

Table 5

Research Question and Data Source Alignment

Research Question (RQ) Alignment	Data Collection Method	Timing*	Justification
What is the impact of a science project-based learning unit on: 1) student motivation?	Focus group interviews with students (qualitative) Student documents (student observation sheets) Observational Field Notes Motivation Inventory	Conducted after the unit has been concluded Completed throughout the unit Kept throughout the unit Completed as a pre and a post-assessment	Focus group interviews provide in-depth feedback that may not be revealed with notes or data. Student documents, field notes, and motivation inventory are used to provide evidence of student motivation.
What is the impact of a science project-based learning unit on: 2) academic performance (reading, writing, and science)?	Student documents (test scores, writing samples, final project) Observational Field Notes	Completed throughout the unit Completed throughout the unit	To evaluate and compare science pre/post-test scores for unit and pre/post writing samples. Additional details may be provided for further qualitative analysis
What is the impact of a science project-based learning unit on: 3) student perceptions about STEM careers?	Focus group interviews with students Student documents (What is a Scientist activity, Inventor writing)	Conducted after the unit has been concluded Completed pre and post unit	Focus group interviews provide in-depth feedback that may not be revealed with notes or data.

	Observational Field Notes	Kept throughout the unit	Student document analysis and field notes are used to provide evidence of student perceptions.

Relationships for this study are important due to the need to receive candid information regarding the PBL process. The researcher fulfilled the role of researcher/teacher and in a third-grade classroom, in a traditional elementary school. As the researcher/teacher, a review of literature helped to build a comprehensive understanding of PBL. Data collection for this study included focus group interviews (student), documents (science pre/post-test, pre/post-writing samples, student observation sheets), and observational field notes.

As a way to gather data, semi-structured informal/check-in interviews were conducted as a group and individually, as needed (Merriam & Tisdell, 2015). An unstructured interview format is likely to occur during the student group interview. This may occur when a student reaches an “aha” moment or makes a connection. The researcher may choose to follow the student connection to see if others agree or disagree, to generate more discussion. Key moments from these interviews will be translated into narrative experiences within the case study.

Students were given a science pre and post-test and writing prompt. The writing sample is a short response that will be used to measure understanding of content. A general writing rubric with a scale of 1-4 was used for content, and 0-2 for conventions. Additionally, a pre and post-student motivation interest inventory was used for this study. This inventory was used to measure student motivation towards learning.

Another method of data collection was observational field notes. Observational field notes assisted the researcher by keeping track of key moments during the lesson. Data was used during the analysis process. Due to first-hand experiences, the role of researcher/teacher can create opportunities for data to surface during discussions and observations. Observational field notes may also have key details from lessons learned during the close of the lesson. This information may also be collected in the form of exit tickets.

Student documents included student lab observation sheets, science notebooks, and feedback during group lessons. Information from student observation lab sheets, answers/feedback could be shared during the group lessons and meetings. Class meetings will follow the established guidelines for the classroom community. The established classroom community ensures students may participate and share in a group setting to build confidence with learning from mistakes.

Focus group meetings were audio recorded and transcribed for analysis. Recording the focus group interviews ensured the researcher was able to analyze all information and find themes during the implementation. During analysis, misconceptions about the lessons, surveys, and assessments were addressed during the analysis. Information shared during group lessons and focus group meetings revealed higher-order thinking processes and indicated areas that students did or did not feel successful.

These data collection methods assisted with achieving triangulation. Glesne (2011) noted, "this strategy reduces the risk that your conclusions will reflect only the systematic biases or limitations of a specific source or method" (p. 93). Furthermore, Glesne (2011) explained that triangulation results in giving the researcher a better understanding of the issues being studied.

Triangulation ensured data is representative of not only my point of view but considers point of views of those in the study and prevents additional potential biases from arising within the study.

Qualitative Data Analysis

Simultaneous data collection (Merriam & Tisdell, 2015) and analysis occurred. Interviews were planned to be recorded, transcribed, and analyzed for additional themes. Data was analyzed daily, to prevent data from being overlooked during the analysis phase. Data to be collected during the implementation of the unit included focus group interviews (student), documents (science pre/post-test, pre/post-writing samples, student observation sheets), and observational field notes. Analysis of existing third-grade data (STAR reading reports, mClass, Beginning of Grade Tests for Reading) could provide additional support for PBL as a supportive instructional strategy for impacting and improving literacy skills. While thematic coding was initially planned to be used for the analysis, it was not used due to the low response rate. The focus group interview was recorded and transcribed. This data was used for analyzing additional themes within the unit.

Quantitative Data Analysis

As shown in the table above, data collected was analyzed quantitatively with descriptive statistics. The intent to use descriptive statistics seeks to show the change within the following areas: student motivation and academic performance. Foundational research from Gottfried (1985) influenced the teacher and researcher to incorporate a student motivation inventory. The Children's Academic Intrinsic Motivation Inventory (CAIMI) was used Gottfried's research was more complex than needed for this study. A general inventory was created after seeing a sample of question types included in the CAIMI. This was created due to the need to simplify and better align the questions with the study. The inventory created included an elementary friendly Likert scale with smiley faces. Student perceptions about STEM careers fell within the areas of reading, writing, and science and were inventoried. The student motivation inventory was given to students pre and post unit, while academic performance was assessed with a science pre-test and post-test.

Validity

The most serious threat to validity in this study was researcher bias. As the researcher and teacher, I ensured that my thinking about PBL remained neutral. My experience with PBL is supportive of it being a positive strategy for learning. I do not have experience implementing PBL in third-grade. Bias will be checked by reviewing interview transcripts. The science standards for this unit align within the NCSCOS forces and motion strand. Two objectives were taught prior to the implementation of this unit. The third objective is aligned with this unit, as well as incorporating the previous standards as prerequisites or supporting standards. A science demonstration by a local university could change perceptions about scientists, which made it a threat to question #3. The original intention was to provide the student motivation inventory before the demonstration. Due to the IRB process and timing, this was not a feasible option.

While existing research supports PBL, this study is aligned to evaluate the impact of a science project-based unit on student motivation, academic performance, and student perceptions about STEM careers. Observational field notes assisted with findings from the project and documented other findings; both positive and negative. The role of the teacher as research was a threat, since it is the researcher/teacher's classroom. Students could be swayed by questions that are leading. Considerations regarding internal generalizability could impact the validity of a study by overly generalizing or drawing conclusions from data that may not be represented or observed (Maxwell, 2013). As the researcher and teacher, it was important when in the researcher role to not make assumptions which could overly generalize or not accurately represent the data collected. Inferences will be supported by looking at the potential impact of strategies used during the PBL unit to support literacy. My experience was a potential threat and bias, since I support the implementation of PBL, through the use of Science and Social Studies.

Considering the impact of the informal interview format could make the interviewee, "feel lost in a sea of divergent viewpoints and seemingly unconnected pieces of information" (Merriam & Tisdell, 2015, p. 111). When conducting informal parts of an interview, it is important to not let the interview stray into areas not related to the purpose. For example, a question such as: what did you enjoy most about this lesson? should not begin to shift into discussion about an unrelated social studies topic. Creating questions for the interviews focused on avoiding leading questions and questions with yes/no answers are important. Yes or no questions are empty, since students will likely stop with answering yes or no. The impact of this is that no additional information will be revealed about the student learning process.

Ethical Considerations

Ethical issues for this project include securing IRB approval prior to beginning the study. Students who are not participating in the study will complete the PBL unit, but their results will not be included in the study. Student identity will be protected by using alternative names throughout the study and any collected data will be de-identified using numbers not associated with the student. Data will be secured in a space that is accessible to the primary investigator.

Summary

The proposed study was conducted in a third-grade, traditional elementary school. The results of this study will contribute to understanding how PBL could be used in the elementary school setting. Additionally, the results will evaluate whether or not PBL is an effective motivator for students. Research-based instructional strategies integrating science and literacy strategies will be used during the implementation of this unit. Data for this study includes focus group interviews (student), documents (science pre/post-test, pre/post-writing samples, student observation sheets), and observational field notes.

Focus group interviews were conducted to reveal areas of strength or weakness in the unit. Interviews were recorded, transcribed, and analyzed for additional themes. The outcome of this case study seeks to generate information for PBL by answering the research questions and identifying additional gaps in the data.

Chapter 4: Results

This study incorporated a modified Forces and Motion PBL unit from Michigan State University and the University of Michigan. The unit was modified to 15 days to fit within the scope and sequence and the school district pacing (for a full-description of these changes, see Appendix E). A case study approach was chosen for purposes of this study, due to the small, unique sample (third-grade students). Data sources (i.e.: observational field notes, student documents, focus group interview data) used for this study were specific evidences to support the following research questions:

What is the impact of a science project-based learning unit on

1. student motivation?
2. academic performance (reading, writing, and science)?
3. student perceptions about STEM careers?

Results

The results of the study were analyzed by research question and data source. For organizational efficiency, each research question was addressed in its own discrete section.

Research Question #1: What is the impact of a science project-based learning unit on student motivation?

In order to answer this research question the following data sources were analyzed: observational field notes, student documents, student motivation inventory, and focus group interviews. Results from this analysis are presented below organized by data source.

Observational Field Notes

When considering the impact of the unit on student motivation, most lessons showed a high level of student motivation. One outlier was Lesson 2, which showed low student motivation levels. For purposes of this unit, motivation during a lesson met the following criteria: participation during the instructional lesson, participation during the activity/project, and completing the student lab sheets. The highest level of motivation was typically at the beginning of the lesson. Students understood that this was a PBL unit, which meant they would be creating toys and investigating movements with forces and motion.

Student Documents

Pre-unit Samples. The following pre-unit samples were used for research question #1: Inventor writing, "What is a Scientist?" activity, and the Student Motivation Inventory. These documents were used to gauge initial student motivation. Students showed high interest levels with the following questions: I enjoy reading, I enjoy projects, and I know what a scientist is. (see Figure 3 below for more detail). One-hundred percent of the "What is a Scientist?" pre-unit activity were completed. Seventy-eight percent of the pre-unit inventor writing were completed. Scores for the pre-unit writing averages were: content/focus 2.2, elaboration 1.6, and conventions 1.1. Students were able to obtain a possible four points for content/focus, four points for elaboration, and two points for conventions. One student who received writing modifications did not make an attempt to complete the task and another student wrote one sentence. One student was able to verbally answer the question when the teacher asked for a response. Since the student does not receive modifications for writing, the student was expected to write their own answer. The student did not write more than one sentence on the paper. Both of these students demonstrated that their motivation to write is an issue. When considering what factors impacted their motivation, it is important to recognize that writing is an area of weakness. However; even with the support of graphic organizers and additional help from the teacher some students were not motivated to complete the writing.

Student Observation Sheets (Lab Sheets). Student lab sheets were used as evidence for student motivation. The student lab sheets for Lesson 4, Part II, were mostly incomplete. Students struggled with understanding how to record their observations on the sheet. Some confusion was from testing the toy on two different surfaces (floor and carpet) and how to record it on the sheet. Twenty percent of students completed the lab sheet in its entirety. The lab sheet was modified by the teacher providing students directions on how to reorganize the lab sheet. This helped student to organize and record findings for each surface. While this helped students, most could not apply the vocabulary words (i.e: slower, faster) in the description of how the toy's motion changed. The activity showed students were very motivated however, the lab sheet showed they were unable to complete it in its entirety. This could be attributed to student motivation or it could be that the directions on the lab sheet were not modified enough for student understanding, which could also be attributed to student motivation. The same lab sheet was completed by students for the toy car. Before recording their findings for the toy car, the teacher modified the copy to reflect the boxes for the two surfaces and wrote the vocabulary words that could be used on the lab sheet. After this modification, 70% of student lab sheets were completed. Some students drew pictures instead of describing with words; however, the pictures were reflective of the words showing motion.

Student Motivation Inventory

The pre-unit and post-unit Student Motivation Inventory results are shown in Figure 3. The results were scored using a Likert scale, from 1-5.

Table 6

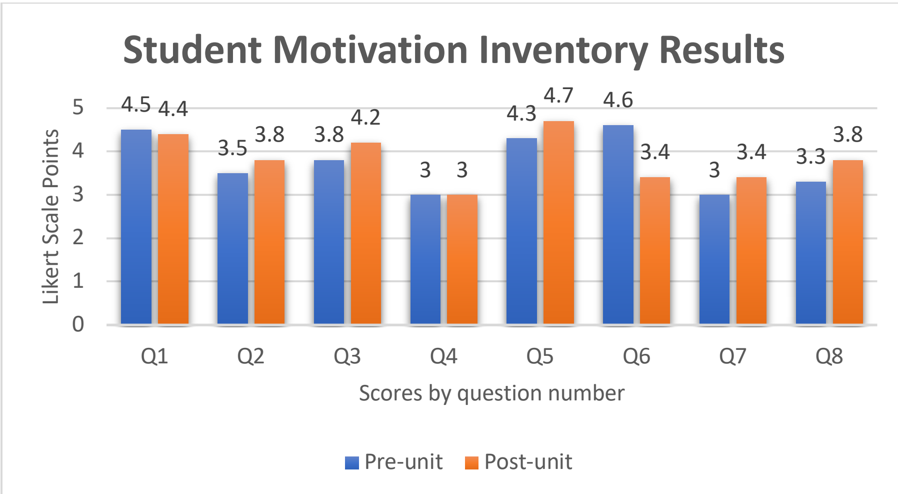
Student Motivation Inventory

Question number	Question
Q1	I enjoy reading.
Q2	I like to complete reading response activities about what I have read.
Q3	I like science.
Q4	I would rather write about science than reading.
Q5	I enjoy projects.
Q6	I know what a scientist is.
Q7	I would rather read about science than write about it.
Q8	I would like to learn about other jobs in STEM or the science field.

Students were asked to answer questions using an emoji scale, from smiling to dissatisfied. These pictures were scored on a Likert scale from 1-5. The number five indicated students strongly agreed with a statement, versus the number one which indicated a strong disagreement with a statement. Results are displayed by averages in Figure 2 to show the difference from pre-unit to post-unit survey. The graph shows averages for individual student participant responses which are categorized by the question number.

Figure 2

Results from the Student Motivation Inventory



The gains in the post-unit inventory are reasonable, since discussions during the focus group interview that they enjoyed the projects that were part of the unit. Question 2, which deals with student's interest in responding to what they read, showed an interesting gain. Based on previous experience with this group of students, they are not typically engaged during reading response activities. For purposes of this unit, reading response activities was limited to the invention writing pre and post writing task. Responses to question 3 showed students were motivated for science post-unit. Science prior to this unit consisted of a more direct instruction model. This is an important finding, since motivation and engagement remained high throughout the unit. In comparison, responses to Question 7 showed a gain, yet students noted they would rather read about science than write about it. One possibility for this is that students may have preconceived ideas of what a reading response activity is as compared to a writing about science activity. Question 8 showed another increase in being motivated to learn more about careers in the STEM field. One factor that could have contributed to this gain is students completed the PBL unit and read books from the Inventor's collection in Epic! During the focus group interview, when asked if any of the books changed their thinking about science, one student said, “I used to think science was boring.” Question 5 showed students enjoyed projects more post-unit. This is attributed to the nature of the PBL unit. Participants in this PBL unit were engaged in their learning and used vocabulary to demonstrate their understanding of forces and motion concepts in writing and during discussion.

The most dramatic difference pre to post-unit was in student responses to Question 6 which showed a 1.2 points decline from pre to post. As this content deals most with Research Question #3, it will be explored further in that section. Additional information from the focus group interview and the “What is a Scientist?” activity did not reveal additional information that would show any additional misunderstandings. The reason for this is unknown and will be discussed in Chapter 5.

Focus Group Interviews

The focus group was conducted in two parts (Appendix A). Questions one through five were included in Part I. Part I of the interview focused on the forces and motion unit. During Part I of the interview, student responses indicated that they enjoyed the inquiry learning process. Enjoyment of the inquiry-based learning aligns with being motivated to complete the lesson. The following student responses indicated motivation for the lessons: “My favorite was the car because you could literally make it and then test it…test out different things like how fast it can go when it has different things in it…” Another student response shared during the interview was, “I liked the magnets because I got to color and move around on the track”. Students noted their favorite moments as being able to make a car and test it out. Another student enjoyed being able to create and test movement with magnets, while another enjoyed the creation of the track used for the magnets and cars.

The most surprising moment of the unit was with magnets. All students agreed that they have never played with magnets before. One student said, “I was surprised that the magnet car and the other magnets stick together with the magnet at the bottom and the car at the top where it was actually moving on the top.” They discussed their experiences with moving the magnets around on the cardboard and even not realizing that magnets can attract each other even with non-magnetic materials between (cardboard). Another said that they tested the car on an incline and the magnets did not stick, but did not understand why. When thinking about what they would change about the unit, two students shared that they would change how short it was because they wanted to do more projects. One student said, “I want to change the magnet car to a boat and draw a cardboard sea.” A common theme for this interview was magnets. Students were impressed by how they can repel or attract depending on the pole of the magnet. When asked how did this unit help you understand forces and motion, a student responded with the answer, “You need to push something to make it move.” The focus group contributed to the teacher’s understanding of the most influential and motivating parts of the unit. This was a key data collection with understanding what students enjoyed most about the unit. While enjoying a task does not equate to an impact on academic performance, it does show areas that students are engaged and learning, which could contribute to better academic performance. During the focus group interview, the final question that students were asked included whether or not they had a better understanding of forces and motion after completing the unit. Of the responses, seven said yes, while 3 said it helped with their understanding somewhat. Based on the responses of the students, the supplemental Inventor’s reading collection in Epic! is supportive in building and supporting student learning of engineering concepts. Students used the key words during discussion such as: make, build, and create. The use of this terminology shows science is an active learning experience.

Key Findings

There were several key findings for research question #1. Student motivation during lessons was noted as high, with the exception of Lesson 2, which showed students had low motivation levels. When analyzing the Student Motivation Inventory, student agreement for most questions increased over time. One question that students did not have a gain with was, I know what a scientist is (Q6). This question showed a 1.2 point decline from pre-survey to post-survey. The reason for this change is unknown and will be discussed further in Chapter 5.

From the focus group interviews, enjoyment of the inquiry-based learning aligns with being motivated to complete the lesson. This is supported by students who commented during the lessons with quotes such as, “My favorite was the car because you could literally make it and then test it…test out different things like how fast it can go when it has different things in it…” These findings are key to understanding how PBL impacts student motivation positively.

Research Question #2: What is the impact of a science project-based learning unit on academic performance (reading, writing, and science)?

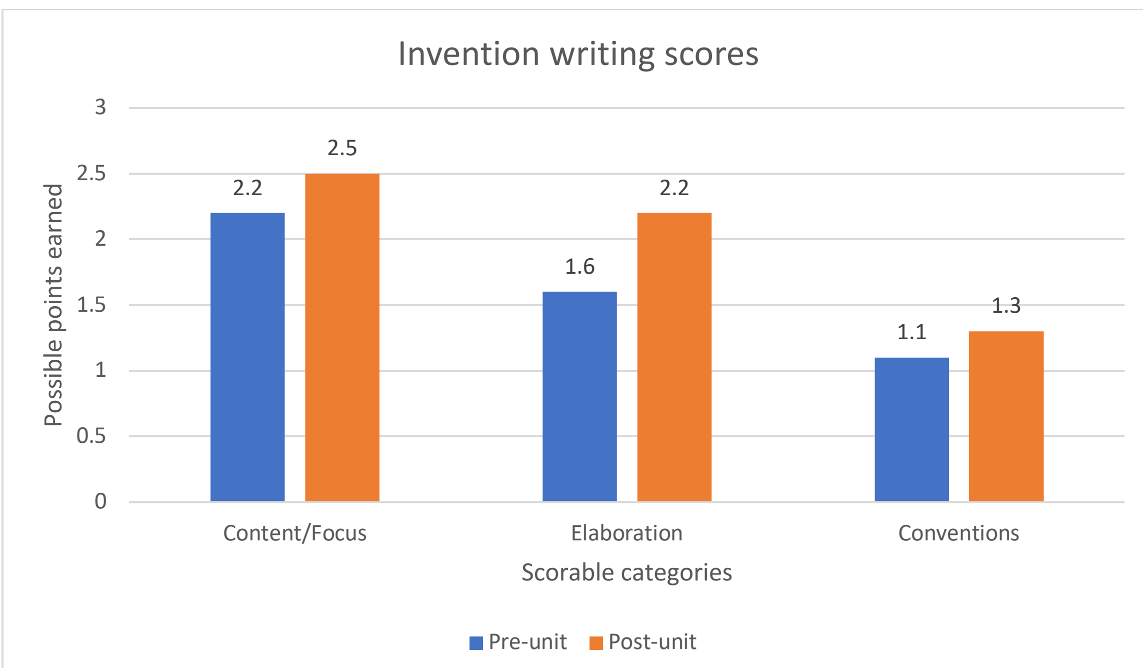
In order to answer this research question the following data sources were analyzed: student documents (invention writing, science assessment, supplemental reading – inventor’s collection, and observational field notes). Results from this analysis are presented below organized by data source.

Student Documents

Invention Writing. The Invention writing (Appendix B) was scored with a rubric (Appendix C) with three categories: focus, elaboration, and conventions. Focus consisted of elements that showed staying on topic of being an inventor and creating an invention. Elaboration components included specific, developed details, while conventions showed correct usage of writing including capitalization, punctuation, and spelling. Students constructed a response on the prompt: Pretend you are an inventor. What new invention will you create to make life easier for humans? How will this invention make life easier? This prompt was selected to encourage students to synthesize their reading and experiences with the PBL unit. Available points for focus and elaboration were from 0-4, while conventions were 1-2. Conventions are scored as zero for students who received modifications with writing, if the writing is scribed. This is due to the student not writing their own text, which means they cannot receive credit for conventions.

Figure 3

Results from the Invention Writing

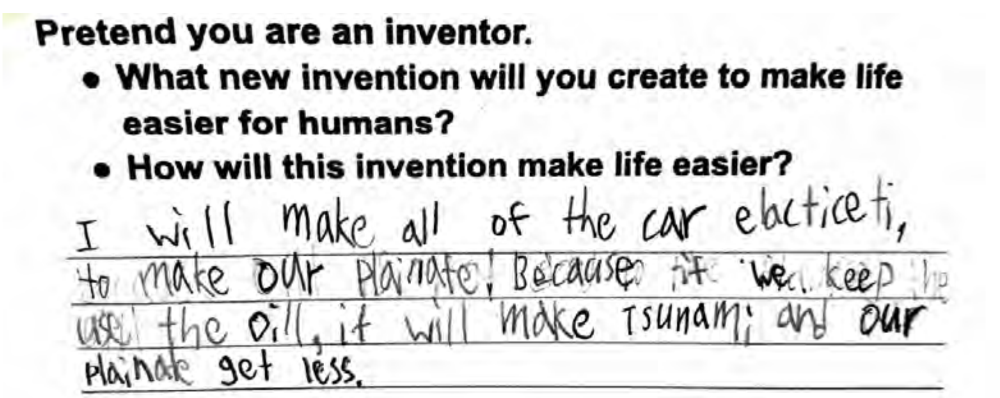


Results from the Invention writing showed a positive change from pre-unit to post-unit. As can be seen in Figure 3, the greatest change in the score was in the elaboration category of the rubric (an increase of 0.6 points) while the content and conventions categories showed small gains. The content/focus average increased by .3 points, while the conventions category showed a .2 point gain.

Improvement in elaboration included providing more support and details for the invention and explaining why it would make life easier. One student response post-unit did not show elaboration in length, but was specific in details. For example, one student referenced details for creating an invention to avoid a specific weather phenomenon from happening. This student activated prior knowledge of an event that could cause a weather event to occur, which shows synthesis. The same student's response, shown in Figure 5, indicates that the invention itself did not have as much detail or development.

Figure 4

Post-unit Invention Writing


Pretend you are an inventor.

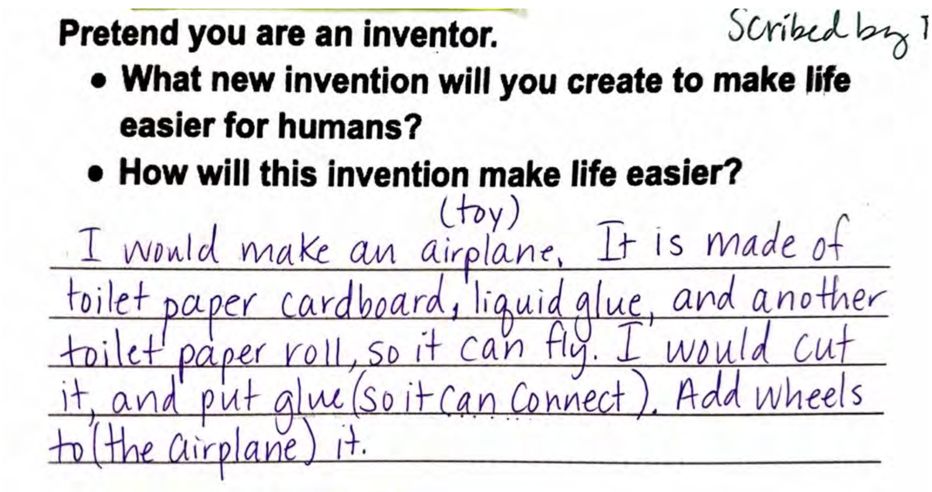
- **What new invention will you create to make life easier for humans?**
- **How will this invention make life easier?**

I will make all of the car elacticeti, to make our plainate! Because if we keep to use the oil, it will make tsunami and our plainate get less.

As shown in Figure 5, the student elaborated on an invention, but had a weak focus. While the content of the writing was weak, this student used new knowledge from the PBL unit to create a new toy invention. This provided more support for the answer.

Figure 5

Post-unit Invention Writing



Pretend you are an inventor. Scribed by T

- **What new invention will you create to make life easier for humans?**
- **How will this invention make life easier?**

I would make an (toy) airplane. It is made of toilet paper cardboard, liquid glue, and another toilet paper roll, so it can fly. I would cut it, and put glue (so it can connect). Add wheels to (the airplane) it.

During the focus group interview, students revealed their favorite choices. One student chose *Exciting Entertainment Inventions*, "because it tells how and why things were made." Additional inventions that students wanted to learn more about included telephones (past and present), video games, and popsicles. When students were asked if they had a better understanding of inventions from reading books in the collection, five students said yes, while five students said a little bit. Results indicated that the project-based unit and supplemental resources contributed to improving these students' writing in content and elaboration. Justification for this includes helping students build their schema through inquiry-based learning experiences, such as PBL.

Science Assessments. The district required assessment was used for the pre-test and post-test. The results of the tests are included in Table 7 below.

Table 7

Pre-test and Post-test Results

	PRE-TEST	POST-TEST
	100%	93%
	20%	20%
	100%	100%
	20%	47%
	67%	40%
	67%	60%
	100%	100%
	60%	67%
	67%	87%
AVERAGE	67%	68%

Results indicated a slight increase by one percentage point in the average overall. Three students showed an increase from the pre-test to post-test average. Three students showed no change, while three students showed a decrease in their score. Due to the slight increase, the researcher found the data did not represent the PBL unit impacting science academic performance.

Supplemental Reading

The Inventors collection created on Epic! was used to determine the impact of PBL on reading. Students were offered a collection of 22 books, with invention topics in a variety of areas. The Lexile (L) levels ranged from 460 to 1080. Five books offered the Read-to-Me, while the remaining books were digital copies. Graphic Novels (GN) were also used to increase student interest, while one book was Adult Directed (AD). Adult directed texts are suggested when adults can assist with the texts. However; students who are reading in the higher Lexile ranges are typically able to read these texts unassisted. Data collected from Epic! was recorded in Table 8 below.

Table 8

Time Spent Reading in Inventors Collection

Read to me	Lexile	Author	Year	Title	Number of times read (greater than one minute)
X	GN860L	Blake Hoena	2021	Amazing Inventions Sneakers – A Graphic History	1
X	GN860L	Blake Hoena	2021	Amazing Inventions The Electric Guitar – A Graphic History	
X	GN720L	Sean Tulien	2021	Amazing Inventions Video Games – A Graphic History	1
	770L	Nadia Higgins	2014	Brilliant Beauty Inventions	
	700L	Laura Hamilton Waxman	2017	Fabulous Fashion Inventions	9
	820L	Chris Barton	2016	Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions	12
	680L 730L	Nadia Higgins	2014	Fun Food Inventions Terrific Transportation Inventions	7 3
	720L	Ryan Jacobson	2014	Exciting Entertainment Inventions	4
	670L	Ryan Jacobson	2014	Marvelous Medical Inventions	3

Read to me	Lexile	Author	Year	Title	Number of times read (greater than one minute)
	990L	Not available	Not available	Genius Communication Inventions	1
X	640L	Barbara Kramer	2015	Alexander Graham Bell	1
	1170L	Joe Rhatigan	2018	Inventions That Could Have Changed the World … But Didn't	1
	610L	Darren Sechrist	2009	Inventions and Inventors	2
	640L	Barry Wittenstein	2018	The Boo-Boos That Changed the World	4
	1050L	Marcia Schonberg	2005	I is for Idea	3
	1080L	Jill Keppeler	2018	Weird Food Inventions	3
	------	Jim Murphy	2016	Weird and Wacky Inventions	
	------	Ashley Spires	2014	The Most Magnificent Thing	
	1000L	Daniel Faust	2018	Weird Inventions For Your Pet	4
	460L	Virginia Loh-Hagan	2018	Stranger Than Fiction – Odd Inventions	5
X	AD790L	Anne Renaud	2019	The Boy Who Invented the Popsicle	21

Books were recorded only if students spent more than one minute reading a book. The data revealed the top books included *The Boy Who Invented the Popsicle* (Renaud, 2019) and *Whoosh! Lonnie Johnson's Super Soaking Stream of Inventions* (Barton, 2016). This would seem to indicate that students were not interested in books just because it was a Read-to-Me. Students who read *Whoosh! Lonnie Johnson's Super Soaking Stream of Inventions* (Barton, 2016) were excited to listen to the re-read during the lesson. Students showed more confidence and participated during the lesson, since they read the book ahead of time. Some students logged less than one minute reading books. While not included in the table, this data shows students considered different areas to learn more about, but ultimately were not interested in reading at the time. Evidence of this is from the focus group interview, when students were asked about their favorite books that they read. Interests in future topics shared by students included: video games, popsicles, and the telephone/rotary telephone.

Key Findings

Key findings for RQ #2 show the impact of PBL on academic performance for writing and reading performance. Students were motivated to read in the inventors collection when they had choices of books. This information was gleaned from the focus group interview and data collected from Epic! While there was not a test to show reading performance, some students used information from the books they read in their post-invention writing. Results from the Invention writing showed a positive change from pre-unit to post-unit. The greatest change in the score was in the elaboration category of the rubric (0.6). Improvement in elaboration included providing more support and details for the invention and explaining why it would make life easier. The impact of PBL on science academic performance was not evident, since the average test score increased by one percentage point.

Research Question #3: What is the impact of a science project-based learning unit on student perceptions about STEM careers?

In order to answer this research question the following data sources were analyzed: focus group interviews, student documents (Invention writing, “What is a Scientist?” activity, and observational field notes). Results from this analysis are presented below organized by data source.

Focus Group Interviews

Focus Group, Part II questions focused on the Epic! Inventor’s collection, the Inventor writing prompt, the “What is a Scientist?” activity, and ideas about inventions/science. Part II of the focus group interview centered around the Epic! Inventor’s collection, the Invention writing prompt, “What is a Scientist?” activity, and ideas about inventions/science. One of the common themes in the pre and post writing for the “What is a Scientist?” activity was the traditional lab coat, goggles, and lab with beaker glasses. None of the students could reference a specific example for why they chose to draw a scientist this way. However, they justified their reason and provided examples of why you would wear a lab coat or goggles (to protect themselves from spills, chemicals that can hurt their skin, and to protect their eyes). The books in the Inventor’s collection were selected by the teacher to supplement reading for students. A range of books with a variety of Lexile levels and various topics were chosen for students to read and explore. During the interview, students were asked what their favorite books were in the collection. Student favorite books included *Whoosh! Lonnie Johnson’s Super-Soaking Stream of Inventions* (Barton, 2016) and *Inventions that Could Have Changed the World, But Didn’t* (Rhatigan, 2018). Students said they loved learning about the Super Soaker to understanding that inventions are discovered from mistakes or accidents. When asked if students were interested in learning any more about these inventions, one student responded with wanting to learning more about “old-fashioned telephones – rotary phones” and another responded with “planes and vehicles”. The

Inventors collection was considered a supplemental, since it offered a variety of areas to get students interested in learning more about inventions and to enrich their learning. This evidence is supportive of the Inventor's reading collection being positive to student perceptions about STEM careers and inventions.

Student documents

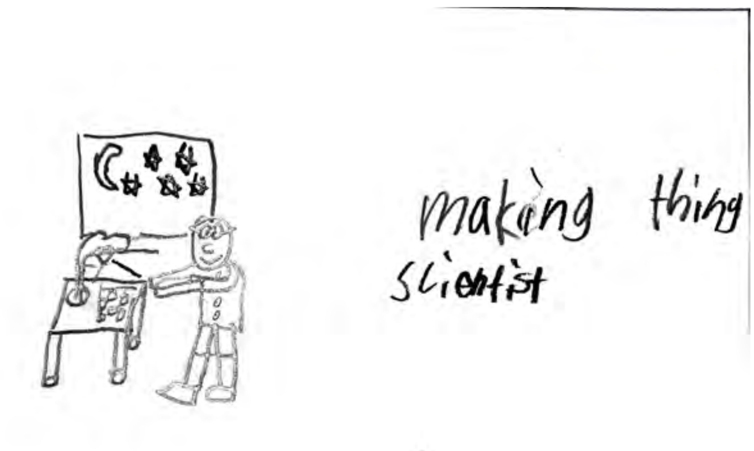
"What is a Scientist?" activity. The pre and post-unit responses were consistent with students having an understanding of the jobs scientists have. Student responses showed common themes: understanding scientists invent, make, or study things. For the "What is a Scientist?" activity (Appendix D), students generated responses for what a scientist's job is, what they look like, and if they are male/female or both. The purpose of this pre-unit data collection was to see if students had preconceived ideas of what scientists look like and what they do. Student responses included scientists make toys, are both male/female, or non-binary. One student identified the physical characteristics of scientists including hair, eye, and skin color. Students had an understanding of scientist jobs; with many assuming that they work in a lab setting. Additional themes in drawings not shown include consensus that scientists are mostly male, even though students indicated that they can be either male/female. This is reflective in their drawings of male scientists and their responses beginning with "he."

Traditional details of scientists wearing white lab coats were drawn to include a traditional set up of a scientist in a lab (with beaker glasses, goggles, and exploding concoctions). In Figure 6, the pre-unit drawing illustrates a male scientist as working with samples/specimens and is wearing glasses and a lab coat. The post-unit drawing did not indicate change in setting or with creation. Both drawings used verbs for scientists creating or making things, showing the student's understanding that scientists are active and involved in their work.

Figure 6

Student Responses for "What is a Scientist?"

Pre-unit



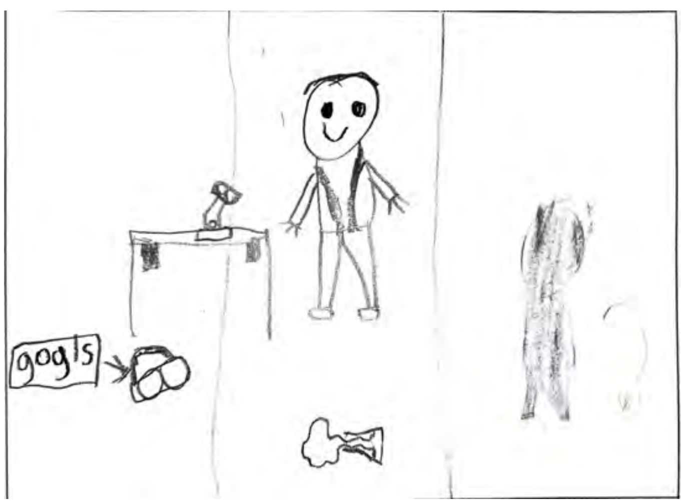
Post-unit

Figure 7 shows a scientist in a lab setting with goggles, beaker glasses, and spilled concoctions. Overall, there was not much change from pre-unit to post-unit. This indicates that the student remained consistent with their understanding of who a scientist is. The pre-unit written response indicated that scientists "do exspiramints [experiments] to study stuff" and post-unit the response was consistent with "studying stuff". Additionally, the details and the response were consistent with the scientist wearing a white shirt; however, post-unit the scientists also wear goggles. Based on the written response, the gender of scientist remained the same that they could be both (male or female).

Figure 7

Student Responses for "What is a Scientist?"

Pre-unit



Post-unit

Figure 8 indicates this student's understanding that scientists also specialize in areas of science. In the pre-unit drawing, the female scientist is studying space and is examining a sphere (likely a planet). The written response to what is a scientist's job question pre to post-unit remained consistent. This student responded with, "to study different things" pre-unit and "to study things" post-unit. In the post-unit drawing, the scientist is studying birds. It should be noted that the attire of the scientist changed in the written response pre-unit to post-unit. Pre-unit, this student responded, "they have white uniforms" and post-unit, the response was, "gloves and maskes [masks]." This could be interpreted as understanding that the student understood a scientist's attire depends on the type of work that they are doing. Details in the drawing show that the scientist studies birds and their parts (wings, feet).

Figure 8

Student Responses for "What is a Scientist?"

Pre-unit

Post-unit

Figure 9 shows the drawing from the pre-unit is labeled with the physical characteristics of the scientist. This includes clothing, height, hair/eye color, shape of eyes, any skin color, as well as hair style. The drawing appears to resemble scientists who are comparing their physical characteristics. According to the pre-unit student written response, a scientist's job is to, "do projects and to understand and find things out." The post-unit response was similar with the student responding, "I think scientists like [to] study things and see what works or what doesn't." Additionally, the student acknowledged pre-unit that, "a scientist can be both male and female, or non b." Non b suggests that the student is referring to the scientist being non-binary. There was not a discussion regarding gender identity prior to beginning the unit. This suggests that the student has opportunities and experiences external to the school setting which prompted the response that scientists can also be "non b". Post-unit, the written response simply noted, "both." The post-unit drawing in Figure 9 shows similar responses with understanding that scientists study things, while seeing what works and what does not. This student remained consistent with answering that the scientists can have any skin, eye, hair color, and attire.

Figure 9

Student Responses for "What is a Scientist"?

Pre-unit

Post-unit

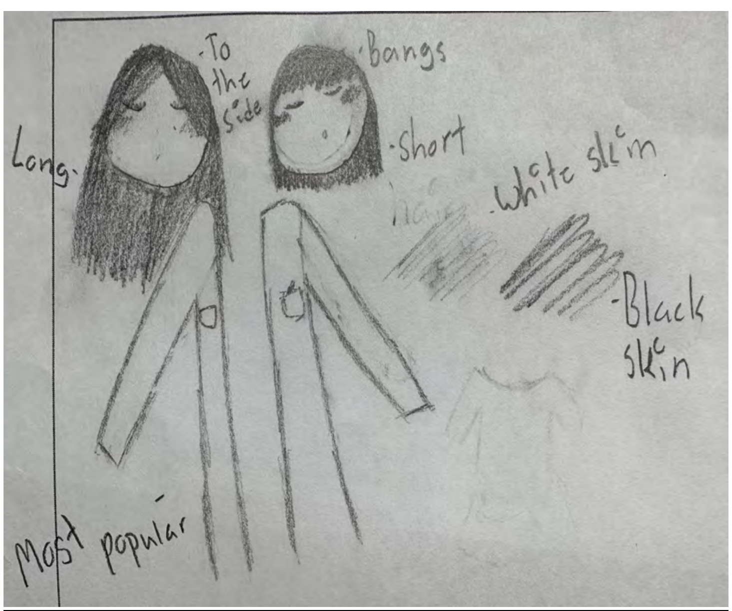
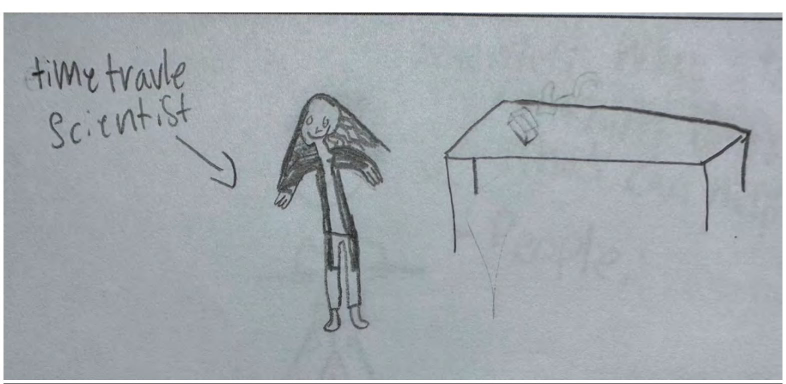


Figure 10's pre-unit drawing shows the student using their imagination by captioning the scientist as one who studies time travel. This student's written response for what is a scientist's job pre-unit was, "to study different kind's [kinds] of sciens [science]." Post-unit, the student's response for a scientist's job was, "they discofer [discover] new things." Additionally, the written response indicated both times that scientists can be either male or female. The post-unit response shows that the student chose a realistic example of a scientist and drew a picture of a lab setting with the caption noting the scientist is an animal scientist. This student shows an inventive approach to what a scientist's job is. Based on this response, it is important to consider the role of the instructions for the "What is a Scientist?" activity. The instructions remained the same, by asking students to provide their interpretation of scientists. This revealed that the instructions should have included some clarification or additional parameters for what does a scientist in the real-world study.

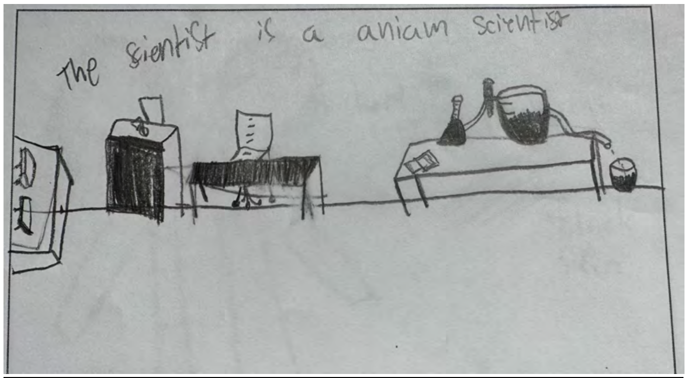
Figure 10

Student Responses for "What is a Scientist?"

Pre-unit



Post-unit

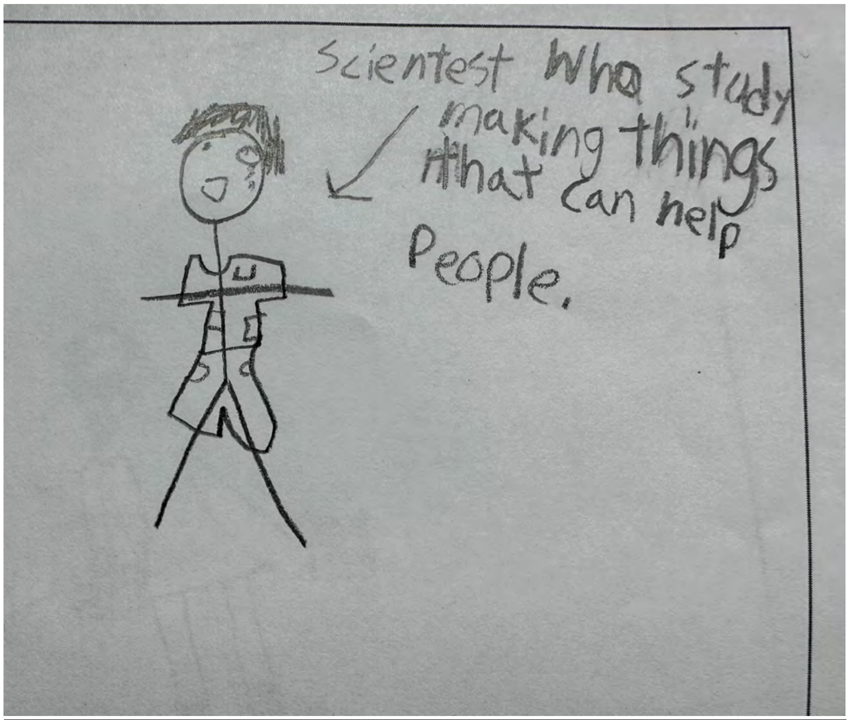


Written responses for Figure 11’s pre-unit included the student understanding a scientist’s job is “scientists study science” and scientist’s look like they “wear white shirt with lots of pockets.” This student also had an understanding that a scientist can be either male or female. The pre-unit drawing represents a scientist who studies making things that can help people. Whereas, the post-unit response for what is a scientist’s job is, “learn about the earth or animals – sometimes scietist [scientist] invent something”. This response elaborates more on student understanding that there are many categories of science that exist. The written response post-unit indicated that the scientist looks like, “they where [wear] white stirt [shirt]– some time normal.” Pre and post-unit responses of whether a scientist is male or female remained the same with, “both”. The drawing of the scientist post-unit included more details with a drawing of Benjamin Franklin and described the type of science as learning about electricity while flying a kite with a key. The background shows a thunderstorm with lightning.

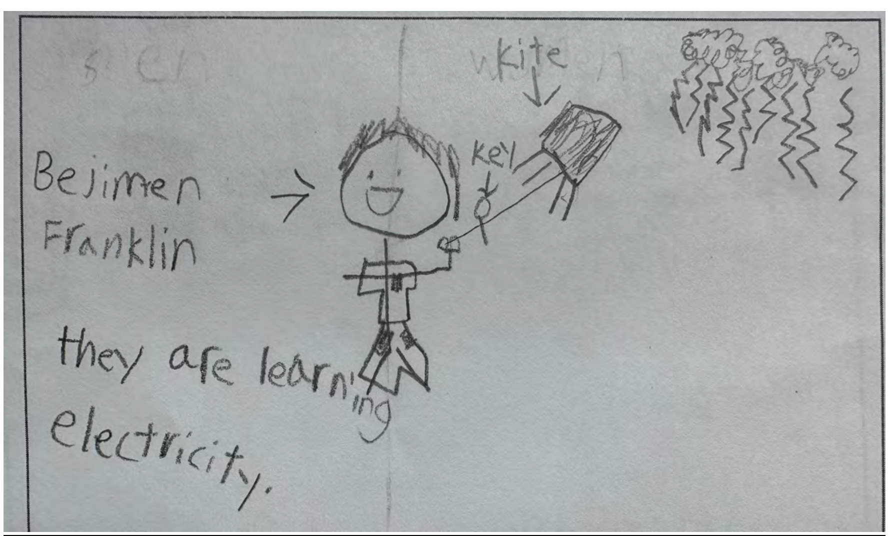
Figure 11

Student Responses for "What is a Scientist?"

Pre-unit



Post-unit

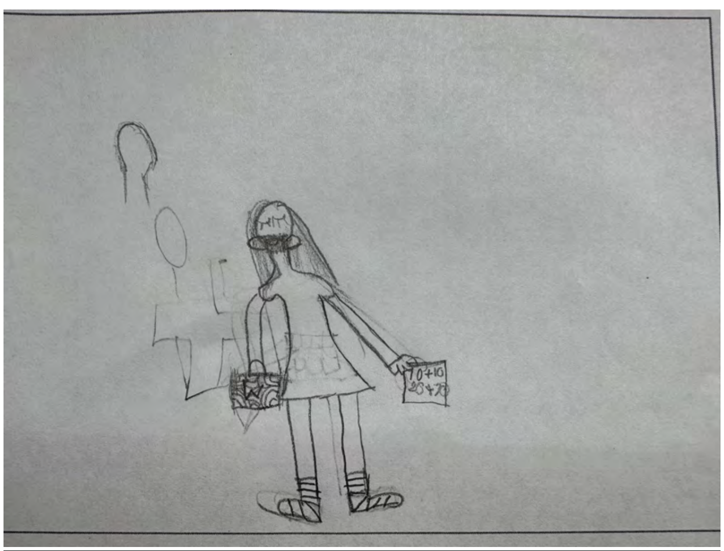


Responses for Figure 12 pre-unit included understanding that a scientist's job is "sometimes they do math" while scientist's look "like a person." The written response also indicated pre-unit that scientist is either male or female, with the response "both." While the post-unit response indicates that a scientist is a "girl." The pre-unit drawing shows a female scientist wearing a dress, while carrying a handbag and a board with math on it. Post-unit Figure 12 shows that the scientist is wearing a crown, a skirt, and is holding a small toy. It's unclear if the picture is of a toy. However, additional information provided by the student includes the person/doll is holding a toy chair.

Figure 12

Student Responses for "What is a Scientist?"

Pre-unit



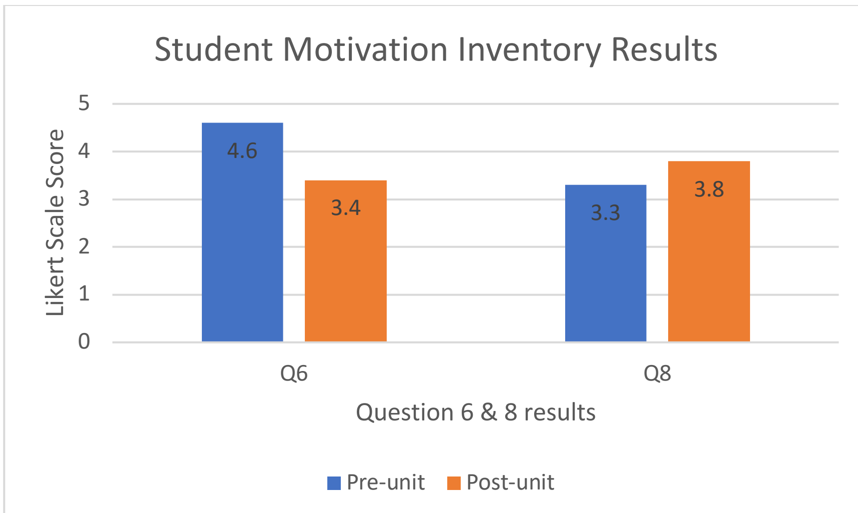
Post-unit

Student Motivation Inventory

Results from Question 6 of the Student Motivation Inventory post-unit showed a strong decrease with understanding what a scientist is (Figure 13). There was a decrease of 1.2 points. The decrease in understanding what a scientist is could be attributed with a misconception that scientists are presented as chemists in a lab. This is based on drawings with scientists in labs with beakers. During the focus group interview, part 2 the teacher/researcher asked a follow up question about the "What is a Scientist?" activity. During this follow up, the teacher/researcher stated that a lot of the students thought that scientists wear white lab coats and shirts. Where did this idea come from? One student responded, "Usually scientists wear white lab coats to protect themselves from anything that might accidentally spill on their clothes or stain." During the focus group interview, the researcher presented the idea to students that scientists are in many different fields. The Inventor's collection offered a variety of inventions in engineering, fashion design, etc. It was not clear how or why students did not understand what a scientist is post-unit. Upon analysis of data collected from the "What is a Scientist?" activity, one possible explanation is that they believed that scientists only work in labs with white lab coats. When shown the many options of how scientists present themselves in the real world, this may have created confusion about a clearly defined career as a scientist.

Figure 13

Results from the Student Motivation Inventory



Observational Field Notes

Field notes from Lessons 7-8, the Lonnie Johnson Story, were divided into two lessons. This lesson contributed to determining the impact of student perceptions on STEM careers. Students were provided an Inventor's collection to read from on Epic! One of the books included in the collection was *Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions* (Barton, 2016). Students recognized that Lonnie Johnson wanted to be an engineer early in life. Discussion centered around inferences that students could make in understanding how the reader knew Lonnie wanted to be an engineer. One student referred to the text and said, "it says in the text he wanted to be an engineer" while another student said they were "confident test[s] he took said he would make a good engineer." However; this was inaccurate as the book states that

Lonnie took a test that showed he would not make a good engineer. As discussed in the book, the Super Soaker model was not something that was planned to be created, but happened when Lonnie was designing a cooling system for a refrigerator.

This lesson also promoted equity, since Lonnie Johnson is an African American, NASA engineer. Students learned about Lonnie Johnson's life, including his success with building a robot during his time at the University of Alabama. The story shows the injustices that Lonnie Johnson faced, including being subjected to segregation at the science fair five years earlier (Barton, 2016). While the topic of segregation was discussed previously, this book helped students to make connections to an African American leader who may not be well known. In the book, students were able to see that there was a lack of diversity in places, like the science field.

Key Findings

Key findings for RQ #3 show the impact of a science-based PBL unit on student perceptions about STEM careers. A common theme in the pre and post writing for the "What is a Scientist?" activity was the details in scientist drawings which showed the traditional lab coat, goggles, and lab with beaker glasses. None of the students could reference a specific example for why they chose to draw a scientist this way. However, they justified their reason and provided examples of why you would wear a lab coat or goggles (to protect themselves from spills, chemicals that can hurt their skin, and to protect their eyes). The pre and post-unit responses for the "What is a Scientist?" activity were consistent with students having an understanding of the jobs scientists have. Student responses from the questions on the activity revealed that students had an understanding that scientists invent, make, or study things. The focus group also revealed that students are interested in learning more about STEM careers and inventions. Students responded with wanting to learn more about "old-fashioned telephones – rotary phones" and “planes and vehicles” are important to show students are interested in other areas. It was not clear why students did not understand what a scientist is post-unit. One possible explanation for this is, when shown the many options of how scientists present themselves in the real world, this may have created confusion about a clearly defined career as a scientist.

Summary

Data collected for research question #1 examined the impact of PBL on student motivation. Sources of data included observational field notes, student documents, Student Motivation Inventory, and focus group interviews. From the observational field notes, a student was considered motivated by meeting the following criteria: participated in the lesson, participated during the activity/project, and for completing student lab sheets. Participants for the PBL unit remained motivated throughout the unit. Lessons 4, 5, and 9 were lessons that were student favorites. This is evidenced by their responses during the focus group interviews. Lesson 2 indicated the lowest student motivation, since students were not actively engaged and were more passive in their learning.

Research question #2 used data collected from the pre-unit and post-unit Inventor writing and the pre-test and post-test. Academic results were mixed with results from the Inventor writing showing gains in content/focus, elaboration, and conventions. Completing the PBL unit and having exposure to an Inventor’s collection of books also contributed to better understanding of creating inventions. The results for the pre-test and post-test showed a one percentage point difference from pre-test to post-test. The impact of PBL on test scores could not be determined, since the gain was minimal.

For research question #3, the impact of PBL on student perceptions of STEM careers was justified with data collected from the focus group interview and the “What is a Scientist?”

activity. One area of weakness was with the Student Motivation Inventory Q6. It was not clear how or why students did not understand what a scientist is post-unit. Upon analysis of data collected from the ”What is a Scientist?” activity, one possible explanation is that they believed that scientists only work in labs with white lab coats. When shown the many options of how scientists present themselves in the real world, this may have created confusion about a clearly defined career as a scientist. The focus group interview provided evidence of the Epic! Inventor’s collection as a useful resource for developing understanding of inventions in and out of the science field. Students were motivated to learn more about other inventions and referenced wanting to learn more about telephones (past and present), video games, and even popsicles. The “What is a Scientist?” activity showed minimal change in what students understand of what a scientist is. Students understood that scientists can be in a variety of fields in science. Students drew similar pictures post-unit as in the pre-unit activity. Responses for the “What is a Scientist?” activity included more realistic details of scientists post-unit. One student was influenced by the PBL unit and acknowledged that scientists make toys. This was different from the initial response that scientists study math. Additional themes that did not change pre to post-unit include acknowledgement that scientists are male or female, although most students chose to represent scientists in their drawings as male.

Chapter 5: Conclusions

A PBL unit for forces and motion was implemented in a third-grade classroom. The unit was modified from the original format to fit within the scope and sequence of the district. The data collected indicates that PBL had a positive impact on student motivation and provided context into understanding student perceptions about STEM careers. In the following sections, discussion continues with analyzing the literature links, addressing the gaps, and understanding the limitations and implications of the study conducted. Conclusions for the research conducted were based on the following research questions:

What is the impact of a science project-based learning unit on

1. student motivation?
2. academic performance (reading, writing, and science)?
3. student perceptions about STEM careers?

Analysis

Analysis of the research questions and the literature are crucial for understanding how the literature and research are interconnected. Data collected during the implementation of the unit is supportive of increases in self-efficacy and motivation. These key elements are embedded in understanding the impact on student motivation and academic performance, within the areas of reading, writing, and science. Additional supporting elements include group work dynamics which influence self-esteem. These elements were present when tasks were completed in small groups or with a partner. Previous research by Carlone et al. (2011) conducted with diverse learners is supportive of understanding how students could perceive STEM careers while emphasizing science is not a male dominated career.

Research Question #1: What is the impact of a science project-based learning unit on student motivation?

This research study demonstrated that PBL had a positive impact on student motivation. Self-efficacy and motivation are key elements within the implemented PBL unit. Important concepts in the unit focused on using the toys to create and analyze movements. Bandura's research with self-efficacy was found to be a direct relationship with organizing and completing activities to achieve a goal (Shin, 2018). As students within this study worked with creating the toys and the magnets, all students were highly motivated to complete the activities. Research by Larmer et al. (2015) revealed that adults and students are motivated by similar conditions. While students did not receive pay for the study, they were motivated to complete the tasks, because they were very interested in the PBL unit. The PBL unit used for this study varied from regular science lessons. Lessons used for the science standards include district created activities, Google Forms, and Google Slides, which focused more on direct teaching rather than student centered activities.

When reflecting on the modifications for the PBL unit, students would have been easily overwhelmed by the original unit and would have been subjected to cognitive overload (Dole et al., 2017). Concepts within the unit were related to the overall topic of forces and motion, however; these concepts were not related to the NCSCOS. Some students could benefit from the rigor of the original unit, however; most students would have been subjected to cognitive overload. The consequence is that students who experienced cognitive overload would not reach the Bloom's Taxonomy level of analysis or synthesis. In order for the original unit to be implemented, the possibility or need of incorporating more mini-lessons would be necessary. Bloom's Taxonomy standards deepen the NCSOS standards, but are not related to the NCSCOS.

This is due to Bloom's Taxonomy focusing on higher-order thinking skills, not the learning objectives.

Research Question #2: What is the impact of a science project-based learning unit on academic performance (reading, writing, and science)?

This study indicated that there were mixed results in terms of PBL's impact on student academic performance. The data shows that student performance on reading and writing improved from pre-test to post-test, the data for science was less conclusive with only a one-point change in performance. Literature reviewed with group work dynamics and equity is supportive of understanding the impact of academic performance on a science PBL unit. Cohen and Lotan's (2014) focus on group work dynamics and status ordering influences were present during the unit, which are influences in student learning. These elements were most evident when working on the lab sheets and during small group work. Students were provided autonomy with choosing their group. Students were more likely to listen to the student who was stronger academically. However; when students were working together to create the toys, the student who was not considered the stronger academic student was fully engaged with problem solving and helped the stronger academic student. This is supportive of Cohen and Lotan's (2014) research with group work dynamics and status ordering.

When considering the needs of students, equity plays an important role in academic performance. As previously noted in Chapter 2, PBL is not a scripted instructional technique since it requires extensive planning and deep understanding of how students learn. Ensuring teachers have proper exposure to PBL is important, when considering the purpose and effectiveness of this instructional strategy (Hovey & Ferguson, 2014). Literature reviewed by Rodas (2019) referred to high poverty schools and inequity. While this school is not categorized as a Title I school, teacher inequity is present. Examples of inequity include not having teachers who are fully licensed. Research from Huinker (2019) suggests that creating an equitable structure is important for addressing any opportunity gaps that may be present. Teacher inequity is one example of a widening opportunity gap. An example of an opportunity gap is refusing the opportunity for students to participate in an inquiry-based learning experience with this study.

Research Question #3: What is the impact of a science project-based learning unit on student perceptions about STEM careers?

This study supports that PBL can have a positive impact on student perceptions of STEM careers. The Lonnie Johnson story (Barton, 2016) provides an example of the impact of equity on student perceptions about STEM careers. The SEL/Equity Sustaining Culture Goal is aligned with the Lonnie Johnson story: We can use science, engineering, and technology to collect and strengthen all our voices and promote equity. When considering the role of the classroom community, it is one that included diversity and students from a variety of cultures. In the Barton's (2016) book, the main character, Lonnie Johnson experiences challenges with achieving his dream. He wanted to be an engineer, but took a test that said he would not be a very good engineer. As the story continues, Lonnie ultimately perseveres. Research by Carlone et al. (2011) found in her study that girls of color understood science, liked science, yet could not define themselves as smart science people. If students are willing to accept that they are considered smart science people, their motivation and self-esteem could improve. Support from additional areas like a strong classroom community and also have a positive influence on students learning. Students learn to see the differences in abilities and find that all students may contribute something to the classroom, even if it is not at the same academic level.

Addressing the Gaps

One of the identified gaps in the research included the lack of studies conducted specifically for third-grade students. This study addresses this gap and demonstrates that PBL can be used at the third-grade. The original intention was to implement the unit from beginning to end, as designed. As is the case with research studies, lessons within the unit were adapted to the environment. The unit was modified to align with the NCSCOS science standards being taught. Due to decisions made by other inexperienced and non-licensed third-grade teachers, the standards were divided. The division of standards proved to be challenging, when implementing a unit that could also fit within the scope and sequence of the district. The teacher/researcher was required to follow pacing as directed by the instructional coach and grade level. The unit allows for modification and allows the teacher to add notes or skip lessons. The benefits of using this unit included the unit having been tested prior to use in the classroom setting. The implementation of this unit contributed to better understanding the impact of a science PBL unit on third-grade students' motivation, academic performance, and perceptions about STEM careers. This unit also contributes to better understanding how students learn through the use of inquiry-based skills. Knowledge gained from the PBL unit did not result in a significant impact for academic performance when comparing the pre and posttest results of the district created assessment. Huinker's (2019) research is supportive of opportunity gaps that were present. Due to non-participation in the PBL study, not all students in the third-grade were offered an educational opportunity of equal status. An example of an educational opportunity of equal status would be an inquiry-based learning experience. Not having an inquiry-based learning opportunity creates barriers for all students, including those who may be underrepresented. Teachers who chose not to participate in the study were not experienced, licensed elementary teachers. Students enrolled in the researcher's classroom were provided the opportunity to participate in the PBL lessons. Data was not collected and used in this study for these students without prior consent.

Limitations

There were several limitations with conducting the research in a third-grade setting. The unit that was used offered modifications. Due to constraints within the grade level and district setting these modifications may not have been enough to support student learning. The standards for forces and motion were divided to accommodate the need to follow scope and sequence. This was significant, since the first objective was taught and nine weeks later, the rest of the standard for this unit was taught. Students were able to master content, as evidenced by the discussions and lab sheets. Teaching the forces and motion standards together, with the unit would have most benefited the student learning process. Specifically, the one percentage point difference from pre- to post-assessment is important to note. Traditionally, students build on the development of science concepts in a strand. Two of three objectives within the strand were taught prior to beginning the unit. This decision was not made by the researcher, but with consensus of the other teachers in the grade level and the instructional coach. Instead, teachers decided they followed previous district/teacher created direct instruction lessons. Participating with a PBL unit was not something teachers in the grade level were willing to cooperate with. This indicates teacher inequity which contributes to lack of opportunities for student learning, like PBL or inquiry-based learning.

Additionally, the district required assessment was teacher created at the district level, while the PBL unit was created by a university and tested prior to being available. Test questions for the assessment were not normed and were not a good indication of student success. Students used common vocabulary during the PBL unit to ensure their understanding would carry over to the assessment. As the results indicated, students only improved their scores by one percentage point. The traditional model for instruction in this district for science is teacher-centered, whereas, the PBL unit offered a student-centered approach. During implementation of the unit, it became clear that this PBL unit may have included content that was too rigorous for the standards. This contributed to the need to modify the unit to accommodate student's learning. Understanding curriculum and how to modify a PBL unit requires complete understanding of how students learn, how to properly align standards, and ensuring students have access to additional modifications that are aligned with a learning framework such as UDL. The student motivation inventory was created by the teacher/researcher, which could be revised with different questions that may reveal more strengths or weaknesses in the development of the unit. The motivation inventory used was created by the teacher/researcher. While it was an informal measure, there could be a more appropriate inventory to use.

Revisiting the Conceptual Framework

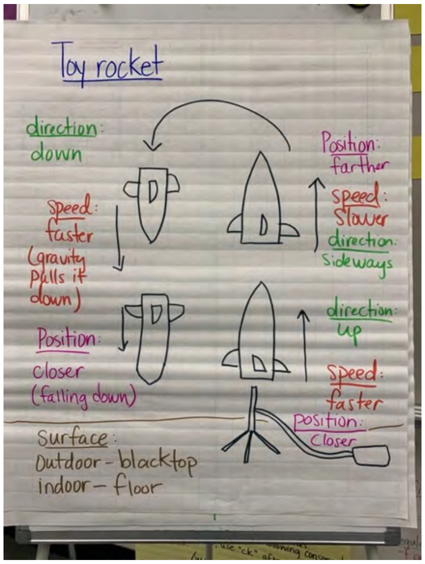
Learning Framework

When reflecting the use of UDL in the PBL unit, the most relevant category of the UDL framework (Figure 1) focused on providing multiple means for representation. Some participants in the PBL unit were English Language Learners (ELL). Illustrating through multiple media was a key concept for this unit. Students were able to watch demonstrations for how to construct toys and were able to make connections to the real-world by watching a student construct his own toy. Modifying the lab sheet to become more of a graphic organizer helped all students organize their thinking to better answer questions from the activity. Without these key elements, students would have struggled to make connections for how to complete construction or how to better understand how to answer questions.

The unit implemented videos for students to activate background knowledge and to provide additional support for construction of their toys (skimmer and car). These tools were beneficial to students who are ELL and for those who need to receive modifications in the classroom. The teacher created chart (Figure 14) shows the explicit links in vocabulary and concepts for the unit. Vocabulary was displayed on cards (Figure 15) on the Driving Question in the form of questions from students and also on teacher created charts in the classroom. Examples of these charts are in the figures below.

Figure 14

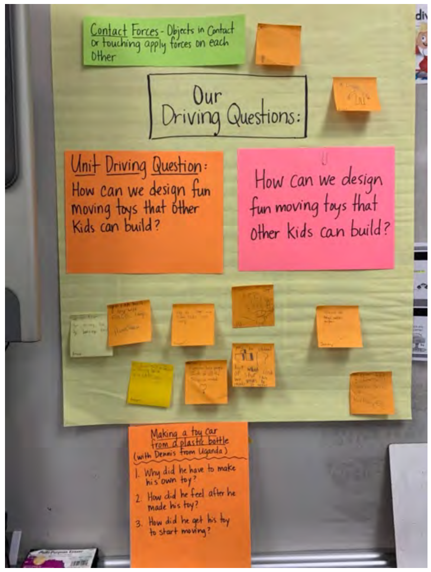
Toy Rocket Movement with Vocabulary



Note: The chart illustrates the links in vocabulary with the movement of the toy rocket as used in Lesson 1.1 Air Rockets.

Figure 15

Driving Question Chart



Note. Driving Question chart illustrates explicit vocabulary for Lesson 1.3.

Maximizing transfer and generalization incorporated the use of templates (lab sheets) and graphic organizers. Scaffolds for this unit included the use of previous learned vocabulary for Forces and Motion. Students worked independently and in pairs to ensure their success of learning and mastering the content. Evidence of this success was in the group discussions and in the student lab sheets and during teacher observations of collaborative work with creating toys. Comments and answers from discussions students were added to the class chart in Figure 10.

Theoretical Framework

This research directly supports the connection between constructivist theory and PBL. Constructivist theory is the foundational work that PBL is built upon. Xu and Shi (2018) noted specific elements (situation, cooperation, conversation, and meaning construction) as essential to student-centered learning. Elements used in this PBL unit included cooperation and conversation, which were supported with small group tasks during the implementation of the unit. Meaning construction was evidenced by building vocabulary, with the explicit instruction and teacher/researcher modeling, while situation showed the ability to construct and synthesize learning processes for building toy cars. Richardson's (2003) idea that an effective constructivist teacher is grounded in learning theory and not teaching theory, was evidenced in the PBL implementation. Teaching experience coupled with a strong understanding of learning theory is supportive of Richardson's work on an effective constructivist teacher. PBL for this unit is rooted in a strong learning theory. As noted by Richardson, teaching theory can lead to a laissez-faire approach, which creates an unstructured learning experience. The significance of this statement confirms that PBL is a promising strategy, especially when the unit is developed by curriculum experts. Since the science standards were divided, there was some previous interactions with vocabulary and objectives. This was considered a non-traditional approach to teaching the NCSCOS science standards. This non-traditional approach included dividing the standards, which were separated by several weeks.

Dewey's concept of reflective thinking was present during the PBL lessons (Sutinen, 2013). While evidence of synthesis was not present with the posttest, it was present during the discussions with students. These discussions happened before and after instruction. Before instruction, students activated knowledge with background information. Background information includes a follow up of concepts with previous instruction. Students were able to explain vocabulary, provide examples, and show the potential to apply critical thinking skills based on their experiences. After instruction, students provided examples of their experiences during their learning. Synthesis happened as a result of the current lesson. For example, when students constructed the toy car, one student shared, "my favorite was the car because you could literally make it and then test it". During the same lesson, the teacher/researcher observed students helping students construct their toy. One area that most struggled with, was keeping the wheels on the toy car during the movement. The students found a solution by creating tape flags to keep the wheels from falling off. Afterwards, during the class discussion they were able to share what they learned or would change about the construction of the toy car. These thoughts were collected on post-it notes and placed on the class chart. Once this was shared, they synthesized their knowledge of forces and motion with movement vocabulary. For example, students recognized the car moved faster on smooth surfaces. Elements of constructivism meshed with reflective thinking show synthesis of forces and motion.

The PBL unit was designed by Michigan State University and the University of Michigan and modified to the scope and sequence requirements of the district. Although modified, the unit remained structured by following the original plan. Contributions from the Larmer et al. (2015) work are present, as students remained motivated and were encouraged to explore a variety of ways to achieve the intended goal. For example, students were allowed to design their own track for the forces and motion lesson with magnets and motion. Students found ways to test movement with magnets, including non-traditional ways. Some of the non-traditional ways include testing movement on desks and by simply moving the car with a magnet attached. While the tested ways were not always successful, they were able to rule out that way as way to meet the intended goal (showing movement through a track).

Additional standards for forces and motion were taught prior to beginning the PBL unit. Students had opportunities to build upon the previously taught standard in forces and motion. This objective focused on explaining the effect of the earth's gravity on the motion of any object on or near the earth. This unit focused on inferring changes in speed or direction resulting from forces acting on an object, and comparing the relative speeds of objects. This provided a strong foundation as needed for the constructivist teacher, as well as providing students the opportunity to continue constructing meaning from their experiences through inquiry.

Impact of the Reading Collection

The Inventor's collection used shows the Lexile levels and ZPD fit into the scope of the PBL unit. Table 9 lists the books in the teacher created collection. Books are aligned by Lexile and the suggested ZPD range. Graphic Novels (GN) are coded by Lexile with GN, while one book was coded as Adult Directed (AD). The suggested ZPD for students was added, based on information in Table 10.

Table 9

Books Used in the Inventor's Collection

Lexile	Suggested ZPD range	Book title
GN860L	740L-890L	Amazing Inventions Sneakers – A Graphic History
GN860L	825L-975L	Amazing Inventions The Electric Guitar – A Graphic History
GN720L	645L-795L	Amazing Inventions Video Games – A Graphic History
770L	740L-890L	Brilliant Beauty Inventions
700L	645L-795L	Fabulous Fashion Inventions
820L	740L-890L	Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions
680L	645L-795L	Fun Food Inventions
730L	645L-795L	Terrific Transportation Inventions
720L	645L-795L	Exciting Entertainment Inventions

Lexile	Suggested ZPD range	Book title
670L	645L-795L	Marvelous Medical Inventions
990L	955L-1105L	Genius Communication Inventions
640L	560L-710L	Alexander Graham Bell
1170L	1010L-1160L	Inventions That Could Have Changed the World … But Didn't
610L	560L-710L	Inventions and Inventors
640L	560L-710L	The Boo-Boos That Changed the World
1050L	900L-1050L	I is for Idea
1080L	955L-1105L	Weird Food Inventions
------		Weird and Wacky Inventions
------		The Most Magnificent Thing
1000L	900L-1050L	Weird Inventions For Your Pet
460L	370L-520L	Stranger Than Fiction – Odd Inventions
AD790L	645L-795L	The Boy Who Invented the Popsicle

Table 10

Lexile Measure Aligned with Suggested ZPD Measure

Lexile Measure (L)	Suggested ZPD
BR400L	BR350L-BR500L
BR260L	BR210L-BR360L
BR35L	BR135L-15L
185L	85L-235L
345L	245L-395L

Lexile Measure (L)	Suggested ZPD
470L	370L-520L
560L	460L-610L
660L	560L-710L
745L	645L-795L
840L	740L-890L
925L	825L-975L
1000L	900L-1050L
1055L	955L-1105L
1110L	1010L-1160L
1185L	1085L-1235L

Note. Table 10 adapted from Renaissance Learning. (2022).

Informational texts are typically in the higher range for Lexile levels. When considering how this impacts student reading, the top two books that were read were *The Boy Who Invented the Popsicle* (Renaud, 2019) and *Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions* (Barton, 2016). This is also consistent with literature regarding Lexile and ZPD. *The Boy Who Invented the Popsicle* (Renaud, 2019) is an adult directed (AD) book. This book was a Read-to-Me selection in Epic, which supports the reader, who may have lower fluency levels. Fluency is crucial for comprehension. Students were able to read and listen to the book, without reaching the frustration level. Students also chose *Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions* (Barton, 2016). While this book had a lower Lexile, the book was read significantly less. This book was used for a read aloud lesson in the unit, and some students revisited this book during their independent reading time. Connecting Vygotsky's ZPD work and PBL, encourages students to explore additional texts. For the PBL unit, students explored titles that were in the higher Lexile range. To increase rigor with reading, students should always read on the higher end of their Lexile. Informational texts are typically more challenging with vocabulary and concepts, which is one reason they fall in the higher range of Lexile.

While exploring how magnets can move toy cars, students were also involved in a form of play and used their imagination to create a cardboard track. The track was used to navigate the course, using magnets. Students were learning concepts with forces and motion, which aligns with Vygotsky's idea of play and school instruction being parallels. Students manipulated magnets by placing them on top of toy cars, under the cars, and even on different surfaces, such as desks. The freedom to test new strategies with magnets, kept students motivated and engaged in their learning.

Connections to Other Literature

How does experiential learning fit into PBL? Kolb's take on experiential learning is one that is aligned with the PBL unit. The learner interacted with the environment (classroom and classmates) and created knowledge (synthesis of forces and motion). Elements of growth are seen not in the pre/post-tests, but with the discussions after the projects. Students discussed key takeaways from the lessons, which aligned with Sutinen's (2013) idea that growth occurs when experiences change the way a person thinks. Evidence for this growth was discovered during the focus group interviews. This is a significant connection to the literature, since PBL is developed and encourages the use of critical thinking skills. Throughout the unit, students made mistakes during the different projects that they created.

Implications

The PBL unit that was implemented was well designed and tested at the university level. There were many issues with implementing this research at the third-grade level in North Carolina, especially since there were decisions made by non-licensed and inexperienced third-grade teachers supported by the instructional coach. All third-grade classrooms were invited to participate in this study. However, the other teachers declined to participate. This is an example of an equity issue created at the local level. Students were not offered a project-based experience of similar caliber.

The teacher/researcher encountering issues that required modification of the unit during the implementation. Students in the teacher/researcher's classroom needed modifications with lab sheet terminology and how to complete the sheets. Examples of this modification included the need to change student lab sheets for better student understanding and combining lessons, due to time constraints. The timing of this unit was during the late fall, which presented issues since students were absent with illnesses and other issues.

Additional challenges during this timeframe included, the missed work which was harder for students to make-up, since it required more time to create the projects. Students who were absent during the time of making the toys (skimmer and car) were given a student leader who assisted with the building of the car. A benefit of this was that the student leader showed synthesis of the lesson and could explain and pose questions for their peers. The inquiry teaching method was still present, yet modified to accommodate scheduling issues.

The unit that was used created an issue, since it was not fully aligned with the state standards. The original unit was not practical for all students. The unit focused on deeper concepts within the science standards based on Common Core. Due to the need to align with the district pacing, it was not practical since the timeline provided was approximately two weeks. This unit was housed in Sprocket (Sprocket, n.d.), which provided additional tools to modify, make notes, or even skip lessons. The ability to modify specific information within the lesson helped to make the unit practical for students, but issues such as teaching the objectives separately further compounded problems with implementation. Stringent requirements for scope and sequence are not reflective on the unit itself, but more an issue of curriculum problems at the district/school level. The unit is well-designed and high quality, just not useful for this regular classroom setting. This is based on the unit not aligning well with the NCSCOS. This is where the gap remains in elementary for PBL and should be further addressed.

Recommendations for Future Implementation

The intention of this PBL unit was to explore the impact on student motivation, academic performance, and student perceptions on STEM careers. Based on the teacher/researcher's experience with implementing the PBL unit for this research, these are recommendations for future implementation:

1. Ensure experienced teachers are involved in implementing PBL units. This is due to having knowledge of how students learn. PBL is more than just direct instruction, and at times requires modification of the lesson after the unit has started. PBL is not a cookie-cutter approach and some teachers will struggle with making a shift to more student-centered learning. Curriculum modifications should be monitored by specialists who have an understanding of how students learn.
2. Implementation of the Student Motivation Inventory revealed a change in understanding what a scientist is during the unit. Further exploration into this area could determine if this is consistent with science based PBL. Additionally, it would also be beneficial to further investigate what may have caused a decline in students' understanding.
3. Consider using more formative assessments, in lieu of summative assessments for evaluating the effectiveness of the unit. A final project is ideal; however, time constraints can be an issue with ensuring this can happen. A digital component may be effective for

some students, while an actual hands-on project may benefit other students. Options include a blended approach. A blended approach offers students a digital or hand-on opportunity. This differentiates learning for all students, who may have difficulties with navigating digital tools. Before beginning a unit of study, this should be considered.

4. Use a curriculum model to evaluate the effectiveness of a unit after implementation. If a unit is to be implemented at the district level, it should also be evaluated at the district level. Most teachers do not have the expertise or time to fully evaluate the effectiveness of a unit. The rationale is to ensure that the unit does not continue to have weak areas where content could be missed or lacking. Continuing to implement a problematic PBL unit will likely reflect as PBL being the issue. However; the real issue would likely be more aligned with not understanding how or why to modify content or instruction.
5. Develop PBL units for third-grade and align with the state standards. This will require understanding PBL is more than just projects. While the goal is to enrich learning, there should always be consideration for whether expectations for a unit are developmentally appropriate and can be modified to support or enrich learning.
6. Incorporate additional supplemental work within the unit including reading collections and writing responses. Writing responses should be aligned with the PBL unit and the reading collections. This can strengthen informational reading skills, which can be difficult for students. Student created responses can range from imaginative to more real world.

Recommendations for Future Research

The following recommendations for future research include conducting additional studies to better understand PBL.

1. Conduct the PBL unit in the third-grade, without modifications to the unit. Conducting a full implementation could yield different results when considering the same research questions.
2. Expand implementation of a PBL unit to fourth grade. This is due to the potential to complete the unit without interferences from the required state testing. The time allotted for students for science is typically greater since the time for reading typically lessens.
3. Conduct a study to implement a series of PBL units, modified to the state standards. The implemented unit was not designed for North Carolina standards. Aligning to the NC standards helps with not creating holes in the PBL design.

Conclusion

The Toys Invention Unit utilized for this case study revealed areas of weakness with incorporating PBL in a third-grade classroom. When examining the impact of a science PBL unit on student motivation, students showed motivation with enthusiasm throughout the lessons. Survey results of the Student Motivation Inventory (pre-unit and post-unit) revealed that students remained highly motivated with reading, writing, and science. From the researcher standpoint this is a small but important conclusion that shows the impact of inquiry-based learning. Students were excited to create products within the unit. After the unit, they continued to ask when we can do more science like the Toys unit.

The impact of a science PBL unit on academic performance in the areas of writing and reading showed positive results with students having the greatest change in the score in the elaboration category of the rubric (0.6). Improvement in elaboration included providing more support and details for the invention and explaining why it would make life easier. It can be concluded that the Inventor's collection and the PBL further developed student's writing.

When examining the impact of the PBL unit on academic performance the pre-unit and post-unit results indicated a slight increase in test average overall. Three students showed an increase from the pre-test to post-test average. Three students showed no change, while three students showed a decrease in their score. The data shows that there was a one percentage point increase in the post-unit scores. A larger sample size is needed to be more conclusive, since the overall average was not a large gain.

The impact of a science based PBL unit on perceptions of STEM careers, revealed pre-unit and post-unit responses, was not consistent with students having an understanding of the variety of jobs scientists have. This was due to the decrease in student response post-unit. Student responses showed the following common themes pre-unit to post-unit: understanding scientists invent, make, or study things. While this activity did not have a quantitative measure, it was beneficial for the researcher to understand how interests can influence preconceived ideas of scientists. Some of this understanding was revealed in the focus group interview. Based on the responses of the students, the supplemental Inventor's reading collection in Epic! is supportive in building and supporting student learning of engineering concepts. Students used keywords in their discussion: make, build, create which show science is an active learning experience.

Based on these findings, the researcher believes there is evidence to conclude PBL as a motivating instructional strategy for improving third-grade writing and potentially science performance. Additional support is needed when considering if or how beginning teachers can effectively modify and implement units. This conclusion is based on the teacher/researcher who implemented this unit is experienced with working with students with diverse needs. Summative tasks, writing prompts, and assessments should be better aligned with vocabulary and other tasks within the unit.

The low response rate for participation changed what conclusions could be drawn about PBL. This research study did not measure fidelity in the original unit implementation; however, lessons that were used were taught with fidelity. The teacher and researcher used lessons as presented, to prevent curriculum from being missed. Key components of the lessons remained intact, however; due to other teachers in the grade level not being cooperative, the effectiveness of the original unit could not be examined since it was heavily modified to fit grade level and district decisions. Using a case study approach for this research was beneficial for the researcher to better understand how students learn, especially using a ready to use PBL unit with a diverse student population.

Summary

Conducting the PBL unit in a third-grade classroom provided valuable insight. Key takeaways from the research conducted includes understanding the practicality of PBL implementation. The unit utilized for this study was research based and well designed. However; due to district requirements, PBL proved to have a mixed performance with impact on academic performance. This is likely due to the district required assessment not being designed for the unit, since the science assessments was teacher created at the district level. While students discussed concepts and illustrated critical thinking skills, these skills did not appear to transfer to the required assessment from the district. Application of these skills transferred to student writing. The student writing prompt was not district created, but added to the unit to supplement student learning. This addition to the unit, supplemented student learning. A result of this was to show growth in their writing. There was more time for students to explore topics with the use of the Inventor's reading collection. These books were higher level in Lexile and ranged from Read to me to standard digital texts with no read aloud option. Using ready-made PBL units enables teachers to use the foundation and supplement the lessons, rather than starting from the beginning. Creation of a PBL unit requires understanding of how students learn, as well as carefully crafting the overall Driving Question for the unit and each individual lesson. Strict requirements from the district pacing are also restrictive, unless the unit is embedded in the pacing requirements. If embedded within the curriculum, it requires teacher understanding of how students learn to offer differentiated options and opportunities to supplement lessons. Supplementing lessons with additional independent content support an integrated approach of all subjects. Curriculum models should be used to evaluate the effectiveness of the PBL approach. Projects are fun; however, if evaluating the impact short-term a curriculum model should be used. This requires someone who is skilled with understanding areas of curriculum that should or could be revised to better support student learning.

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Appendix A: Day-to-Day Instruction/Data Timeline

*Lessons may be modified/eliminated for time purposes

Day*	Lesson Summary	Qualitative data	Quantitative data
0	Pre-test/student inventory/pre-writing prompt		• Pre-test • Student inventory • Pre-writing prompt
1	Students observe a toy air rocket and brainstorm questions about how it moves. Groups of students explore different types of air rockets, generate questions about how rockets work and why each moves the way it does, share observations. (L1.1)	• Student lab sheets/reflections • Observation field notes	
2	Students as a class develop, share, and revise models to represent the changes in motion of the air rocket during its flight. (L.1.3)	• Student lab sheets/reflections • Observation field notes	
3	Students view a video of a boy making his own toy. Groups of students build simple prototypes of a moving toy and record observations of patterns in motion as the toy moves. (L1.4)	• Student lab sheets/reflections • Observation field notes	
4	Students develop and share models that show how their toy moves as a pattern. (L1.5)	• Student lab sheets/reflections • Observation field notes	
5	Students engage in the Lonnie Johnson story *Woosh!* to obtain information about the engineering design process. (L1.7)	• Student lab sheets/reflections • Observation field notes	

Day*	Lesson Summary	Qualitative data	Quantitative data
6	Students investigate the rocket to model the forces that cause the rocket to start moving and forces that cause changes in motion. (L2.1)	• Student lab sheets/reflections • Observation field notes	
8	Students engage in a text to support the design of a fair test of balloons traveling on a line. (L2.2)	• Student lab sheets/reflections • Observation field notes	
9	Students use mathematics to record and compare the different distances that cars travel across different distances. (L2.3)	• Student lab sheets/reflections • Observation field notes	
10	Students develop and share models of the balanced and unbalanced forces they observed in their toys. (L2.4)	• Student lab sheets/reflections • Observation field notes	
11	Students revise the design of the toy using the ideas of forces and how they affect motion. (L2.5)	• Student lab sheets/reflections • Observation field notes	
12	Students develop models, obtain information from text, and design solutions to problems related to gravitational forces. (L3.1)	• Student lab sheets/reflections • Observation field notes	
13	Students plan and conduct an investigation of magnets and how they work to move objects. They construct a claim with evidence that magnets are non-contact forces that depend on particular properties of the objects. (L3.2)	• Student lab sheets/reflections • Observation field notes	

Day*	Lesson Summary	Qualitative data	Quantitative data
14	Students ask additional questions and then plan and conduct an investigation comparing the properties of objects and the relative change in motion. Students develop claims based on the new evidence they collected. (L3.3)	• Student lab sheets/reflections • Observation field notes	
15	Students define a solution based on the evidence from the learning set, and engage in texts about non-contact forces. They share their plans with peers in order to get feedback and revise their solutions. (L3.4)	• Student lab sheets/reflections • Observation field notes	
16	Students redesign their toys based on new evidence, present their solutions, and argue that there is evidence that supports their design solution. (L3.5)	• Student lab sheets/reflections • Observation field notes • Student focus group/interviews	
17	Post-test/post-Student Inventory/post-Inventor writing		• Post-test • Post-Student Inventory • Post-Inventor writing

Appendix B: Inventor Writing

Pretend you are an inventor.
What new invention will you create to make life easier for humans?
How will this invention make life easier?

Appendix C: Writing Rubric

	4	3	2	1
Focus	Maintains focus on topic/subject throughout response.	May exhibit minor lapses in focus on topic/subject.	May lose or may exhibit major lapses in focus on topic/subject.	May fail to establish focus on topic/subject.
Elaboration	Elaboration consists of specific, developed details.	Elaboration consists of some specific details.	Elaboration consists of general and/or undeveloped details, which may be presented in a list-like fashion.	Elaboration is sparse; almost no details.
Conventions			Exhibits REASONABLE CONTROL of grammatical conventions appropriate to the writing task: sentence formation; standard usage including agreement, tense, and case; and mechanics including use of capitalization, punctuation, and spelling.	Exhibits MINIMAL CONTROL of grammatical conventions appropriate to the writing task: sentence formation; standard usage including agreement, tense, and case; and mechanics including use of capitalization, punctuation, and spelling.

Appendix D: Student Perceptions of Scientists

What is a scientist?

1. What is a scientist's job?

2. What does a scientist look like?

3. Is a scientist a male, female, or both?

4. Draw a picture of what a scientist looks like, below. Add details to your picture and tell what kind of scientist they are.

Appendix E: Description of Lessons

Before discussing the results of the study, it is important to provide context about the nature of the learning experience. The following notes and observations occurred during the unit. The first day of the implementation of the unit was day four. On day four, the first lesson from the adapted Toys unit was Lesson 1 – Air rockets. Driving questions were categorized as unit, lesson set, and lesson. Lesson set refers to the question for the set of lessons, while the lesson driving question is specific to the content being presented for inquiry. The Lesson set driving question for Lesson 1 was: How can we make toys that move? While the Lesson driving question was: What can we ask about the motion of our toys? After modeling the stomp rocket, we discussed the purposes of the different driving questions. Students contributed responses to our Driving Question Board (DQB) by writing responses on sticky notes.

The unit driving question was: How can we design fun moving toys that other kids can build? Due to the rainy day weather, the initial modeling of the stomp rocket was inside the classroom. Students were excited to watch the lesson and wanted to participate by testing the stomp rocket. We charted observations made while watching the rocket in motion. Part of the science standard 3.P.2 was taught prior to the beginning of the unit, since standards were divided. The vocabulary words: force, motion, and weight were previously introduced and taught with the 3.P.2 standard, which meant students were able to activate prior knowledge. Before modeling the rocket motion, the following questions were posed: What impacts the movement of the rocket? How does weight impact the movement? The teacher modeled the movement of the stomp rocket by gently tapping the base versus firmly pressing down on the base with force. The teacher modeled by emphasizing the gentle pressing on the stomp rocket pad versus a more forceful, quick stomp on the pad. Students first observed the slow motion, then the fast motion of the rocket. Responses from the students included, “when you do it fast, it goes faster” and “it is the weight and speed that makes it fly.” Students were very interested and engaged with the modeling of the stomp rocket. One additional discussion for the lesson included the advertisement on the box and the claim that the rocket can go up to 100 feet. We tied this in with estimation and how many rulers it would take to go 100 feet. Students included details from our discussion on the lab sheet. Off-task behaviors were more present when completing the lab sheet This lab sheet was modified to reflect the use of Rocket 1 only. For the lab sheet observation, students were instructed to write two things they noticed and two questions about the pattern of motion and the shape of the parts of the rocket. Notable observations from students are summarized in the Table 11 below.

Table 11

Notable Observations from Lesson 1

I notice…	I wonder…
When you put more force on the air box, it goes higher. *Picture of foot and the word STOMP! Picture of the rocket and the word ZOOM!* The darts are foam because if it were hard, it could break something. *Picture of a broken window.*	I wonder why the blue pole is divided into four. I wonder how the air does not get out.
I notice that when you put your foot on the pad it fly’s higher than when you just put the tip or the heel of your foot. *Picture of stomp pad and launcher.*	I wonder if you drop something like a crayon box on the pad, will it still fly? *Picture of a crayon box falling towards the stomp pad.*
A picture of a foot a toe gently pressing on the stomp pad and the result of the rocket not shooting up high.	How could the toy go up to 100 feet? *A picture of a smiling person and the rocket shooting up and curving to the right.*
Can this rocket move very fast? *Picture of a rocket shooting straight up.*	I wonder can that rocket go to space? *Picture of the rocket in space.*

Day 5, Lesson 2 - Predicting Motion was modified, since no additional models were developed, as presented in the original lesson plan. Instead, students tested the stomp rocket by using force and no force. Students were excited to play with the stomp rocket at recess. They experimented with force (light tapping versus jumping) as modeled in the classroom. They compared the conditions of the environment (wind versus no wind). In the classroom, students observed the patterns of motion, described the changes in speed, and the position of the objects. Students observed the movement of a ball rolling across the floor and incorporated vocabulary: speed, force, fast, slow. Notable findings from the student lab sheets are included in Table 12 below.

Table 12

Notable Findings from Lesson 2

Hard push = fast Light push = slow
I push the ball with force and speed. *A picture of a ball rolling towards a wall.*
Slow motion. *A picture of a ball rolling to another person.* Fast speed. *A ball rolling showing one direction.*

Lesson 2, showed that students were not interested or motivated in predicting the movement or describing the motion of toys. When the teacher modeled the ball rolling across the room, students were distracted and did not participate. This is likely due to the lesson not requiring students to be actively engaged in the lesson. The time allotted for this lesson was modified due to low motivation and participation. As a result of the low motivation, the supplemental Inventors collection on Epic! was introduced for student independent reading time.

Day six of the unit included was a district required graded task focusing on friction. While the lessons focused on the material from the Toys Unit, additional support with vocabulary was used. Additional support for this included a mini-lesson with reinforcement for vocabulary associated with forces and motion: friction, surface, relative speed, mass, gravity, push and pull, speed, direction. A Brainpop Jr. video entitled Pushes and Pulls strengthened their understanding of movement. This task was used as a formative assessment to check for understanding prior to the assessment.

Day seven, Lesson 3, was Making Moving Toys. This lesson was used as it was in the unit and divided into Part I, Part II, and Part III. Dividing the lesson into three parts was due to time constraints and to ensure students had time to reflect on testing their toy. Two of the toys, skimmer and toy car were made. For Part I of the lesson, students were engaged with minimal distractions. Students were engaged and highly motivated with making a toy. The Driving Question (DQ), How can we design fun moving toys that other kids can build? was posed to the students, prompting further discussion of why students may want or need to build their own toys. Students watched a video of a West African boy, Dennis, who made a toy. This video showed a boy using materials he had access to: water bottle, sticks, wheels, bottle caps. The questions in the lesson plan included the following: Why did he have to make his own toy? How did he feel after he made his toy? How did he get his toy to start moving? Student discussion immediately focused on Dennis' socio-economic status, including differences in clothing. Dennis was dressed in a very large shirt and flip flops. One student noted that the "kid did not have money". The general consensus among the participants was Dennis was making his toy due to not having money. They based this answer on his clothing, which is not similar to what they wear. During this discussion, there was a reinforcement of the vocabulary: motion, speed and direction, and changes in position. This lesson generated excitement about building a toy and investigating the movement of the toy.

Day eight, Lesson 4, was Part II Making Toys. For this lesson, students made the skimmer toy. Student motivation for the lesson was high, since they were excited to make a toy. Before making the toy, the mini lesson focused on using the motion words from the lesson plan. A tree map was used to organize the words, as a way to categorize speed, direction, and position. These words were used to support understanding for the student observation lab sheet to be completed after this lesson. This investigation required preparation time with cutting the milk cartons. Within this lesson, a demonstration for how to build a skimmer was shown to the students, to construct their skimmer. One modification for this lesson was to find a way to make the skimmer move, versus using a hairdryer as shown in the video. Once their toy skimmer was built, and before this could be discussed, students began finding ways to make the toy move. This included sliding the toy across their desk. Once all students had their toy skimmer built, as a group, we discussed finding ways to show motion of the toys. Immediately, students began conducting their own tests with the toy skimmer across different surfaces (carpet, tables, and on inclined surfaces). To substitute for the air from a hair dryer, students created their own wind by blowing it across different surfaces. The student observation sheet included the modification of sentence starters and included the two different surfaces that were used. The position words added to the observation sheet reminded students to continue using the motion words during discussion and in their writing. The students struggled to complete the student observation sheet. The struggle was due to the need to apply motion words to what they observed. Only one student completed the observation sheet. As an additional modification to the lesson, the teacher decided to meet with the class on the carpet to discuss their findings. While most of their findings were not revealed on their observation sheet, they were able to discuss the question: How is the motion changing – with speed, direction, and position? Did the surface impact the change?

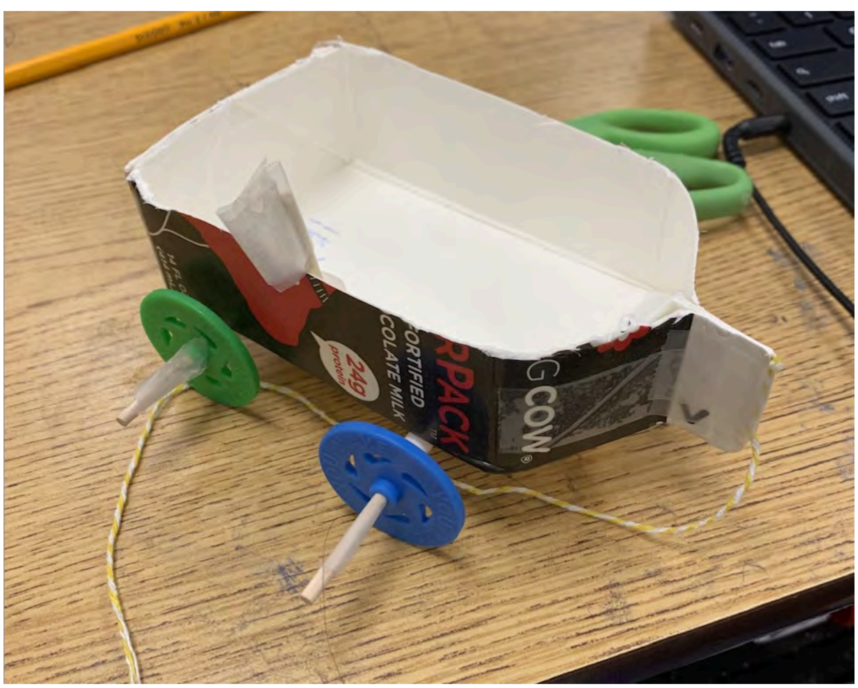
Day nine, Lesson 5, Part III Making Toys was the activity that students really looked forward to making. First, they watched the video for the toy car – instructions in We Read. Materials used for making this car differed from than the ones listed suggested by the lesson plan. This was due to the cost of the material and the availability. After additional research, the teacher found wheels that are used for STEM activities. This material was used as a modification, since it could be purchased in bulk. Student motivation for this lesson was high. Each student had their own materials to make a car. Even as students worked to build their car, they encountered challenges along the way. Students were helpful to each other, especially when presented with challenges. One challenge was understanding that the dowel used for the wheels needed an axel covering so the dowel could rotate. Some students taped the dowel to the milk carton, which prevented the rotation of the dowel. The students helped each other solve problems, by showing how it worked. An additional challenge that presented itself was the use of different wheels. The push pop wheels that were suggested for use did not need end caps. The use of a different wheel required students to be creative with how to keep them from sliding off the dowel. Students made tape flags to keep the wheel from sliding off easily and made other coverings using straws. Some students became frustrated with the overall construction, even with being able to rewatch the instructions for how to build the toy car. Figures 11 and 12 show a student created toy car.

Figure 11

Student created toy car

Figure 12

Student created toy car



Once students completed the construction of the toy car, the teacher provided instructions to test their car on different surfaces and observe the movements using the motion words. Students encountered issues with the wheels on the car falling off, due to fast movement. As a result, students spent time trying to remedy the problem by creating additional solutions, such as creating end caps out of the leftover straw. Without prompting, students began adding mass to the car (glue sticks, pencils, and other classroom materials). This parallels Dennis' experience with using found items for the toy. Dennis demonstrated how the toy was able to move by showing motion and pulling it along a rough surface (road).

The same student observation sheet used for the skimmer was used for the toy car. Participants were more successful with completing the observation sheet, since the teacher modified the instructions to include writing a single motion word to indicate the movement of the toy car. The motion words used were first introduced with Part I of the lesson. During our discussion, students were able to describe the motion of the toy car using the motion word. After completing the student observation sheet, we met as a group and discussed the Driving Questions and anything they could add, to further show their understanding of the questions. Some responses from their sticky notes included examples of motion and force, understanding forces are a push or pull, and motion is any type of movement. Additional responses were specific to the movement of the toy car. For example one student noted being able to push the toy car more, and forces of motion you push or pull something so it can move for kids to play.

Day ten, Lesson 6 Modeling Motion extended learning with the toys made. This was a brief lesson, since it was an extension to previous lessons. Students focused on drawing and labeling models and motion. To model the movement, the teacher drew the movement of the stomp rocket used at the beginning of the unit. Discussion about the movement of the stomp rocket model and how rockets move was generated throughout the lesson. As noted in the Modeling Motion lesson plan, directions included identifying the toy, showing changes in speed, direction, and position. Once this was complete, the teacher modeled with the rocket drawing how to use suggested prompts with a partner to discuss the movement and motion of their toy. Students were given 10 minutes to complete their drawing. The prompts for discussion were reflective of the modification to the lab sheet, to show the movement differences at the beginning, middle, and end. For example, one student's drawing of a toy car was labeled with three movements of the car going in one direction, with the initial car showing the movement words: position/closer, direction/forward, and speed/fast. The second car showed the following movement words: position/farther, direction/left, speed/slow. The third car was labeled with the movement words: position/farther, direction/left, and speed/slower. This illustrates understanding of key content with the pattern of the toys' motion. At the end of this lesson, students completed the second required district task, which focused on speed. This task was used to formatively assess their understanding of speed. Results from this task showed that students were successful with their understanding of speed and factors that affect speed. Movement words like fast/slow, friction were used on the task.

Following the Part III lesson, students who were absent were able to make the skimmer and toy car. The teacher decided to let another student lead the assembly of the boat and car. The student modeled by explaining the process to his peers. As he explained the rationale for the construction of the toy car, the teacher corrected his explanation of axle covers (straws). The student leader coached his classmates and provided positive feedback "nice job" and allowed both students to complete their own toy car. The teacher assisted with the end caps for the wheels, since it was evident that there was frustration with keeping the wheels from falling off.

The students tested the boat on smooth and rough surfaces. After testing their toys on different surfaces, the teacher reviewed the motion words with the students and used the questions: Did your car go forward, backward? Did the car go faster/slower? The words closer/farther had to be explained, but the students were able to describe that the position of their cars. The last question posed to the students was, Did the direction of the car go forward/backward or curve? I checked for understanding by listening to student's questions and responses. Students were accurate in their responses to the questions posed. The student who led the group lesson needed additional assistance with the question stems and needed to see a list, which was provided by the teacher/researcher.

Days 11-12, Lessons 7-8, Lonnie Johnson Story, was divided into two lessons. Student motivation for this lesson was high. This lesson was used as presented in the Toys unit. The driving question for this lesson was – How did Lonnie Johnson design the Super Soaker? This question is one that connects to the Epic! Inventor's collection that the students read from independently. The demonstration for the Super Soaker was not done, due to the lack resources. However, Lonnie Johnson showed the Super Soaker in the video embedded in the lesson plan. The teacher posed the question – How was Lonnie influenced by his work to make the Super Soaker? Students were surprised to learn that it was an engineer who designed the Super Soaker. During the read aloud of the book *Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions* (Barton, 2016), students recognized that Lonnie Johnson wanted to be an engineer early in life, some based this on details such as taking a test that shows he would make a good engineer. After reading the book, the teacher discussed the prototype for the Super Soaker model and how it was not something that was planned to be created, but happened along his way to designing a cooling system for a refrigerator. This answered the question posed by the teacher at the beginning of the lesson, when discussing how he was influenced by his everyday job to make the Super Soaker. One additional of the goal for the lesson was to promote equity. Lonnie Johnson is an African-American, NASA engineer. While it was a brief discussion, the teacher reiterated the idea that Lonnie Johnson was a leader in the field.

Day 13, Lesson 9, Magnetic Forces, lesson had a different learning set driving question. The lesson set driving question posed was – how can we design toys that will begin to move without being touched? While the lesson driving question posed was- how can a magnet move a toy? This lesson was modified, due to resources and alignment to the standard, and was used as the culmination project activity. Student motivation for this lesson was high, due to their interest in creating their own track to move cars. The teacher reviewed the different activities (rolling the ball, stomp rocket skimmer, toy car) with different movement words (push, forces, surfaces, push/pull). Prior to beginning this lesson, a mini-lesson on magnets was taught, activating their knowledge with the North and South Pole. Donut magnets were used to show the resistance of magnets with north and north facing each other. This created a bouncy spring as the donut magnets were resisting connection. Once the magnets were turned around with opposite poles (north and south), the students were able to see that they connected. The concepts of non-contact force was briefly discussed, but not emphasized, since this lesson focused more on the movement. This lesson focused on making objects move with magnets, which was important for their understanding. Students were given materials (cardboard and markers) to create a track. Some students chose to make their track straight, while others added curves. Others were more creative and envisioned their tracks being around obstacles such as trees or bridges. Once the track was created, students were provided a car with a taped magnet, an additional donut magnet, and a wand magnet. Students tested the movement without the wand magnet and even took the magnet and car to places like desktops. Others tested the movement on the cardboard with inclines and tried to move the cars on top of the cardboard with their magnets. While there were many different approaches, the students figured out the easiest way to generate movement was by placing one magnet under the cardboard and using the wand to direct the car. As students tested their car, the teacher heard movement words being used such as forward, backward. This indicated students are able to understand the patterns of movement being created by their cars. After the activity, the teacher met with the students on the carpet to discuss their findings from the activity. Notable responses from the activity included: recognizing that movement from magnets could be generated on top of the cardboard, not just one attached to the bottom of the cardboard and showing movement of the car with an incline.

Vita

Tania Cruse was born in Hickory, NC and lived in the area until beginning her undergraduate degree at East Carolina University. While attending East Carolina University, she interned in Media Relations/Sports Information. In 2002, she earned a Bachelor of Arts in Communication with a concentration in Public Relations and English. In 2004, she began her teaching career and graduated with a Master of Arts in Teaching-Elementary Education degree from the University of North Carolina at Charlotte in 2007. In 2011, Tania achieved National Board Certification in Middle Childhood. During completion of her Education Specialist degree, she interned with the Friday Institute at North Carolina State University, in the Research and Evaluation Department. In 2016, she graduated with an Education Specialist degree in Community College and University Leadership from Appalachian State University. Tania's doctoral journey began in 2017 in the Educational Leadership program. During this time, she earned a certificate in Digital Media and Literacy, as well as her doctorate in Educational Leadership, from Appalachian State University in 2023. Tania has almost 20 years of experience in K-6 education.