The Use of Project-Based Learning to Scaffold Student Social and Emotional Learning Skill Development, Science Identity, and Science Self-Efficacy

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THE USE OF PROJECT-BASED LEARNING TO SCAFFOLD STUDENT SOCIAL AND EMOTIONAL LEARNING SKILL DEVELOPMENT, SCIENCE IDENTITY, AND SCIENCE SELF-EFFICACY

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DEDICATION

To my family. This would not have been possible without your unwavering support and love. You have put up with almost as much stress and worry as I did these past few years, and I owe so much to you. I love you.

Specifically, to my husband, you are earning this degree right along with me. You are my rock and I am deeply grateful for you, your love, your encouragement and your ability to talk me off the ledge. To my children, you amaze me every day and I have never experienced a love like yours. You are so special and I hope you always know how loved you are. To my parents...this degree would not have been possible without you. Thank you from the bottom of my heart. Your generosity and love have made my dream come true and I am forever thankful.
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ABSTRACT

Project-based learning (PBL) offers an ideal approach for cultivating a robust STEM workforce, empowering students to actively construct their knowledge. This process has the potential to enhance science identity and self-efficacy. Furthermore, because PBL is inherently collaborative, it fosters the development of 21st-century skills, many of which align with social and emotional learning (SEL). While past studies have explored the relationship between PBL, SEL, science identity, and self-efficacy, there is a research gap in examining all three variables collectively within a high school context. Thus, this mixed-methods action research study aimed to determine if the implementation of a PBL unit, with specific inclusion of SEL skills, had an effect on high school AP Biology student SEL skill development, science identity, and science self-efficacy. Quantitative pre–post unit data on student SEL skills, science identity and science self-efficacy, along with qualitative data from focus group interviews, student reflection journals, and teacher notes and observations indicate the PBL unit resulted in significant and positive changes in each area of interest. This research suggests implementing PBL with purposeful inclusion of SEL skills can significantly increase student SEL skills as well as their feelings of confidence in science and science identity.
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LIST OF ABBREVIATIONS

AP ................................................................. Advanced Placement
CASEL ............................................ Collaborative for Academic, Social, and Emotional Learning
COVID .......................................................... Coronavirus Disease
FG ................................................................. Focus Group
IRB ............................................................... Institutional Review Board
NOS .............................................................. Nature of Science
NSF ............................................................... National Science Foundation
NSTA ............................................................ National Science Teachers Association
OECD ........................................................... Organization for Economic Cooperation and Development
PBL .............................................................. Project-based Learning
PIP ............................................................... Pupils in Poverty
PISA ............................................................. Program for International Student Assessment
RJ ................................................................. Reflection Journal
SCT .............................................................. Social Cognitive Theory
SECA .............................................................. Social and Emotional Competency Assessments
SEL ............................................................... Social and Emotional Learning
SELDS .......................................................... Self-Efficacy for Learning and Doing Science
SSI ............................................................... Student Science Identity
TON ............................................................... Teacher Observation Notes
WCSD .......................................................... Washoe County School District
CHAPTER 1: INTRODUCTION

From an early age, I loved science. I was the kid who played in the rain and made makeshift dams to see what would happen to the water when it flowed toward and around the dam. I picked up every bug and rock and cool leaf. My curiosity was insatiable, and I was fortunate to grow up with two scientists as parents; they supported and encouraged my interest in science by sending me to wildlife summer camp, taking our family to national parks, and supporting my crazy science experiments. My parents would always make time to answer my questions and would never blow me off.

However, in school, my science educational experiences were hit or miss. I can only remember three teachers in my entire K–16 schooling who really made learning science seem fun, worthwhile, and relatable. The majority of the science teachers I had were forgettable, and the teaching was boring and lecture-based. I often wonder if my interest in science would have faded without the support and encouragement I was lucky to have at home.

When I decided to become a science teacher, I vowed to be the teacher who made learning science fun, engaging, and accessible to anyone who enters my classroom. I want to be that science teacher I did not have for all my students. I want to foster interest and a love for science in all my students, regardless of their circumstances and prior experiences. Through my classes, I want my students to be exposed to and gain a basic understanding of science and science practices. One of my goals in teaching is to help
develop students into individuals who are confident in their ability to understand and do science. I ultimately want my students to develop strong science self-efficacy skills and identify as “science people.”

Another long-standing goal of mine is to connect with my students and develop strong student–teacher relationships that can last beyond our time together in high school. Additionally, my classroom has always been open and inviting. I work from the very first day of class each year to establish a classroom environment where students can feel comfortable sharing their thoughts and emotions. I have never explicitly reflected on these teaching characteristics; they are just second nature to me. However, when the COVID-19 pandemic caused schools to close in the spring of 2020, I was suddenly not entirely sure how to continue connecting to my students and maintain a comfortable and inviting class in a virtual setting. Fortunately, I had spent most of the year with those students and created relationships I could sustain during the remainder of the school year. Yet, our district remained virtual in the fall of 2020, when the new school year started.

In the spring of 2020, when schools initially moved to a virtual platform, it happened so quickly that many teachers did not have the time or training to effectively pivot to virtual (Hamad, 2022; Pokhrel & Chhetri, 2021); teachers and students both gave and received grace and leniency with due dates and content. However, when school started again in September of 2020, even though we were virtual, our classes met regularly every day, and students had to be online for 6–7 hours a day. Students were also largely isolated at home and had little in-person social interaction. Due to these changes, teachers and students alike struggled to adjust (Chaturvedi et al., 2021; Mazlan et al., 2021; Pokhrel & Chhetri, 2021). For example, I could no longer rely on my typical
methods of getting to know and connecting with my new students. I had to quickly develop new ways to reach my students emotionally and create a virtual class that was as inviting and open as my physical classroom.

I also realized early on that many of my students were struggling with adjusting to the new school year. Quite a few students reached out and asked to meet one-on-one with me. During these individual meetings, I learned that almost all of the students with whom I spoke were having a hard time focusing in the virtual setting. They also displayed worrying emotions such as apathy, helplessness, anxiety, and disrupted sleep schedules. I realized quickly that I needed to address my student’s social and emotional needs to enable them to focus and participate in my class. From then on, and throughout the 2020–2021 school year, I started class each day with 5–10 minutes of content-free discussion. Over 97% of my students remained virtual throughout the school year, and that time at the start of class each day became vital for us to talk about issues and for my students to voice any concerns and anxieties regarding school or the continuing pandemic.

From this experience, I began to think about how I could assimilate social and emotional learning (SEL; Jagers et al., 2019) directly into my content when school resumed in a more typical setting. It comes naturally when school meets in person to have those types of student-led meaningful discussions; however, I aspired to scaffold SEL and fold it into my content. After delving into these issues and thinking about how I could reach my teaching goals, I began to think that project-based learning (PBL; Beier et al., 2018) may be the perfect vehicle for developing and scaffolding SEL skills as well as enhancing student science identity and self-efficacy (Britner & Pajares, 2006; Carlone & Johnson, 2007).
Up until that point, I strongly preferred lecture-based instruction. Throughout my 19 years as a teacher, I maintained strict control over how content was presented in my classroom, to the extent that I hesitated to welcome a student teacher, fearing a deviation from my preferred teaching style. I was deeply comfortable with the lecture format, firmly believing it was the most effective way for students to learn. The prospect of adopting PBL, a teaching method entirely new to me, made me nervous. Despite my apprehensions and lack of experience in developing or teaching with PBL, I understood the need to step out of my comfort zone. I recognized the necessity of trying something different to effectively integrate SEL into my classroom while simultaneously working to enhance students' science identity and self-efficacy.

**Problem of Practice**

The problem of practice that this study attempted to address is multifaceted. First, I want to ensure I am teaching the standards while also helping to grow my students’ social and emotional skills. Second, I want my students to identify with science and gain self-efficacy. One way to accomplish both goals is incorporating SEL into PBL. SEL is the process through which individuals, particularly children and adolescents, acquire and apply a range of skills and competencies related to understanding and managing their emotions, building positive relationships, making responsible decisions, and effectively navigating social situations. SEL programs and initiatives are designed to foster emotional intelligence, empathy, self-awareness, self-regulation, interpersonal skills, and decision-making abilities (Collaborative for Academic, Social, and Emotional Learning [CASEL], 2022).
Thus, for this action research study, I wanted to incorporate PBL into my Advanced Placement (AP) Biology classes and investigate the potential effect PBL, specifically including SEL skills, had on developing students’ SEL skills, science identity, and science self-efficacy.

Student mental health can affect student success in the classroom. O’Connor et al. (2016) asserted that positive mental health during adolescence and childhood can improve academic achievement and educational attainment in the longer term. As is increasingly apparent, during the COVID-19 pandemic, students experienced heightened levels of mental health issues, including anxiety and depression, among other symptoms (Jones et al., 2022; Magson et al., 2020). Hence, an increased number of educators and psychologists have fought for more SEL in school curricula to assist students in dealing with such mental health problems as well as supporting mental well-being (Billy & Garríguez, 2021; Carbone, 2020). CASEL (2022) outlined five key SEL skills: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. Unfortunately, in my school and district, caring for student mental health and including SEL are not overt goals, and many teachers do not take the time to incorporate SEL into their lessons purposefully. This is unfortunate since teachers have the unique opportunity to support positive mental health regularly given their daily interaction with students (Substance Abuse and Mental Health Services Administration, 2019; U.S. Department of Education, 2021; Wiedermann et al., 2023; youth.gov, n.d.). Dresser (2013) argued teachers are the most influential factor in students’ academic success because they can deliberately and successfully incorporate SEL into their lessons.
PBL is an engaging, interactive teaching method in which students confront and attempt to solve or answer a real-life, relevant, significant problem or question (Beier et al., 2018). Students work together in small groups on the project for few weeks up to an entire semester to devise a solution (Buck Institute for Education, n.d.). The PBL unit culminates in a group artifact and public presentation. Research has demonstrated that PBL results in high academic achievement compared to traditional approaches (Chen & Yang, 2019; Krajcik & Blumenfeld, 2006). A number of PBL models exist, and they share commonalities that include: student inquiry, directed by the driving question; student voice and choice; authenticity; reflection and revision; collaboration and teacher facilitation (Chen & Yang, 2019; Krajcik & Blumenfeld, 2006; Thomas, 2000). A unique component of PBL is that the project is central to the curriculum; students learn the content via the project itself. Knowledge construction and transformation are significant outcomes of PBL (Krajcik & Blumenfeld, 2006).

PBL has been studied extensively in K–16 education for the past 20 years. In addition to fostering high academic achievement, PBL promotes high levels of sustained student engagement (Almulla, 2020; Schneider et al., 2002). Numerous studies at the collegiate level have examined authentic learning and STEM identity formation. In one study, researchers used a PBL approach in a college engineering course to determine if the active learning experience developed students’ self-confidence in engineering and engineering identity (Major & Kirn, 2017). Results indicated PBL develops students’ perceived engineering identity by creating engineering interest. Corroborating the results, Marshall et al. (2018) studied PBL’s effect on engineering identity and self-efficacy in a civil engineering course. Interestingly, engineering self-efficacy increased; however,
math self-efficacy decreased. Research has also demonstrated that STEM undergraduates who participate in authentic course-based research develop stronger STEM identities (Anthony et al., 2017; Mraz-Craig et al., 2018).

Although scholars have studied the use of PBL and its interaction with SEL skill development, science identity, and self-efficacy, the three variables have not been investigated in conjunction with one another in a high school setting. This action research study attempted to determine how PBL influences SEL skill development, science identity, and self-efficacy in AP Biology students.

**Theoretical Framework**

This action research study employed a theoretical framework rooted in constructivism, social cognitive theory (SCT), and identity theory, utilizing these three lenses to guide the investigation.

Constructivism has a long history with roots in philosophy, psychology, sociology, and education (Olusegun, 2015; Últanir, 2012). For cognitive constructivists, such as Piaget, knowledge is actively constructed by learners based on their prior knowledge and experiences (Ackermann, 2001; Krajcik & Blumenfeld, 2006). In social constructivism, knowledge acquisition is also influenced by society and peers. PBL is rooted in constructivism and can even be seen as a type of situated learning (Krajcik & Blumenfeld, 2006). In PBL, students work collaboratively to solve a real-world problem, and through this process, students construct new knowledge based on their current and past experiences.

Bandura (1971) postulated SCT and expanded the theory over many years. A major component of SCT is observational learning, where someone learns by watching
another person’s behavior and the subsequent consequences of that behavior. Thus, a person learns what behaviors are acceptable and rewarded, and they also learn to inhibit socially unacceptable behaviors by seeing what behaviors are frowned upon. SCT reflects Bandura’s (1971) belief that learning occurs in a social context with a dynamic and reciprocal interaction of the person (i.e., cognitive factors), environment (i.e., situational context), and behavior.

Bandura (1977) expanded on SCT by discussing self-efficacy, positing that an individual’s self-efficacy directly correlates with increased persistence and the effort one expends on a perceived difficult task. Those who persist longer tend to reinforce their belief in themselves, whereas those who give up earlier will retain their belief that they cannot complete a task. Self-efficacy is not related to a person’s general feelings of confidence; rather, it is more situation specific. For example, students in a science class where lab experiments are common might develop—or lack—confidence related to designing and completing an experiment. In other words, people establish self-efficacy assumptions in relation to specific situations or goals. In a science classroom context, teachers can promote positive student self-efficacy by providing constructive experiences in Bandura’s (1977) four proposed sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and affective states. For instance, ensuring positive experiences during a lab activity allows students to feel they can succeed in a lab setting. Because self-efficacy develops over time and is situation-specific, teachers are uniquely positioned to foster confidence in their students in their specific content area.

Erikson’s theory of psychosocial development states that the main developmental task for adolescents (ages 12 to 18 years) is to experiment with and develop an identity
A person’s identity is generally defined as being recognized as a certain “kind of person” (Gee, 2000, p. 99). Identity development is both an individual and social phenomenon and is an ongoing process (Adams & Marshall, 1996; Sokol, 2009). Carlone and Johnson (2007) developed a conceptual framework that specifically elucidates science identity. The framework includes three interrelated dimensions: recognition, competence, and performance. The first component, recognition, means that an individual recognizes themselves as a “science person” and could also include the same recognition by others. Competence, the second component, is the knowledge of science skills, concepts, and practices. The third component is performance and includes a person’s successful social performance of science practices (Carlone & Johnson, 2007). A fourth component, interest, has also been suggested to significantly contribute to science identity (Hazari et al., 2013; Vincent-Ruiz & Schunn, 2018). Science identity is thought to be important in potentially leading to students’ persisting in and staying in science fields (Trujillo & Tanner, 2014).

Constructivism, SCT, and identity development served as valuable frameworks guiding my approach in this study. PBL presented an ideal pathway for students to actively construct new knowledge related to content, engage in practical applications, and refine their SEL skills (Beisel, 2021). For example, as students work together toward solving the PBL driving question or problem, they learn about themselves; they gain insight into their strengths and challenges, such as time management and leadership. These skills would help the students develop the SEL skill of self-awareness. Further, the collaborative nature of PBL lends itself to advancing students’ relationship skills and personal responsibility, two additional SEL competencies. During the duration of the
PBL unit, which can last quite a few weeks, students work closely with one another in
groups and must learn to communicate, collaborate, and even resolve conflict, all of
which will develop better relationship skills. Students also have to take personal
responsibility in that they need to pull their weight in the PBL unit. During regular self-
reflection in a PBL unit, students analyze their contributions; if they have not lived up to
the group expectations, they can take responsibility for their actions toward the group.
Sharpening SEL skills in a low-stakes setting, like a PBL unit, rather than in a higher-
stakes environment, such as college or even the workforce, is beneficial for students.
Finally, PBL allows students to work in a collaborative, social setting to solve a real-
world problem. The process allowed students to construct their own knowledge based on
their previous experiences and provided an opportunity to do science and engage in
expert practices. In doing so, students could increase their confidence in their ability to do
science, becoming more likely to identify as “science people” (Vincent-Ruiz & Schunn,
2018).

Purpose of the Study, Research Questions, and Rationale

The purpose of the study was to determine whether PBL affected SEL skill
development in high school students as well as bolstered student science self-efficacy and
science identity.

The first research question was: How does incorporating PBL in a science
classroom affect SEL skills among high school students? I was interested to see if the use
of PBL significantly affects SEL skill development in my AP Biology classes. The
specific skills I examined are based on the CASEL (2022) 5 and include self-awareness,
self-management, social awareness, relationship skills, and responsible decision-making.
The second research question was: How does incorporating PBL in a science classroom affect students’ science self-efficacy and identity? I was expressly interested in how the purposeful incorporation of PBL into an AP Biology classroom affects student feelings of confidence in their AP Biology and general science abilities. This would correlate with their science self-efficacy. Additionally, I wanted to see how PBL affects science identity in my AP Biology students.

Ensuring a STEM-literate society is vital. The recent COVID-19 pandemic brought to light the critical necessity of a population well-versed in scientific principles. A society with a strong foundation in scientific literacy is better equipped to respond effectively to public health crises, adapt to evolving circumstances, and advocate for evidence-based practices that enhance public health and well-being. Furthermore, a scientifically literate society is less susceptible to the dissemination of misinformation. During the pandemic, misinformation proliferated rapidly, prompting the World Health Organization (2020) to coin the term infodemic to describe the extensive propagation of misleading and inaccurate information. Unfortunately, such misinformation often contradicts scientifically supported evidence, and one of the most effective ways to counter this infodemic is through a firm grasp of and trust in science.

Potential pandemics are not the only reasons to have a science-minded public. Scientific literacy is also necessary with emerging technologies, rapid medical advances, and climate change. Today’s citizens need a basic level of scientific understanding and an appreciation for the nature of science to make informed personal and societal decisions (National Science Teachers Association [NSTA], 2020). Furthermore, as the National Science Foundation (2007) explained, “In the 21st century, scientific and technological
innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy” (p. 2).

Developing a scientifically literate society requires effective and thorough K–12 STEM education (National Academies Press, 2012; Reiss, 2020). Students begin developing their knowledge and understanding of STEM early in their educational experience and build on their elementary skills during middle and high school. However, according to a recent report by the National Academies of Sciences, Engineering, and Medicine (2021), only 22% of high school graduates are proficient in science. Although students learn and become proficient in science when they are active participants in the learning process, using the tools and practices of science (National Academies Press, 2012), in a nationally representative survey of science teachers, less than 50% reported using these types of instructional practices at least once a week and only around 25% reported placing heavy emphasis on increasing students’ interest in science (National Academies of Sciences, Engineering, and Medicine, 2021).

In December 2018, the National Science and Technology Council’s Committee for STEM Education (Executive Office of the President) released short-term and long-term goals for U.S. STEM education, including the use of PBL and 21st-century skills to increase STEM literacy and develop a strong future workforce. As broad sets of skills and knowledge, 21st-century skills are applicable to any career. Indeed, student success in college and careers requires four essential skills: critical thinking or problem-solving, communication, collaboration, and creativity or innovation (Battelle for Kids, 2019). In 2011, the NSTA released a position statement in strong support of incorporating 21st-century skills into the K–16 curriculum. Upon examination, 21st-century skills closely
resemble SEL skills, conducive to the CASEL SEL competency framework. Title IV of the 2017 Every Student Succeeds Act designates funding for states to support “safe and healthy students” (Grant et al., 2017, p. 13), which can include funding for SEL.

PBL, by definition, utilizes hands-on learning and actively engages students in a real-world problem or question (Buck Institute for Education, n.d.). Students can develop self-awareness, self-management, social awareness, responsible decision-making, and relationship skills through the purposeful inclusion of strategies that support SEL skill development throughout the PBL unit. Finally, PBL can be an ideal tool to help students become more confident in doing science and potentially help students develop a science identity (Al-Hammoud et al., 2022).

**Researcher Positionality**

The concept of researcher positionality is significant in action research, as it prompts the question, “Who am I in relation to my participants and my setting?” (Herr & Anderson, 2015, p. 37). Action researchers are often personally connected to their research settings and, in some cases, to the participants themselves. This personal connection can influence how the research is conducted, its outcomes, and, ultimately, the results (Rowe, 2014). Consequently, researchers must recognize and acknowledge the various factors that may impact the outcomes and results of their research. This awareness enables researchers to draw valid and honest conclusions, free from undue bias or undue influence stemming from their positionality in the research context.

Strunk & Locke (2019) recommended: “considering positionality . . . by identifying the salient and non-salient aspects of personal identity and the power and privilege embedded in the intersection of one’s salient identities” (p. 17). In my case, I
identify as a White, heterosexual, cisgendered, Christian woman of middle socioeconomic status. Acknowledging that I belong to multiple agent groups is important. I am fully aware that the intersectionality of these identities places me in a position of power and privilege within nearly any community in the United States, including my own classroom. My classes comprise a diverse group of students, reflecting a range of backgrounds, including differences in race, gender, socioeconomic status, as well as individuals who identify with specific target groups related to sexual orientation, gender identity, and religion. Given my salient identities and my role as the teacher responsible for grading, I hold a significant position of influence over my students. To mitigate this power dynamic and ensure the integrity of my research, I recognized the need to conduct my research with full awareness of my role and its potential impact. Throughout the research process, I prioritized reflexivity, consistently revisiting my positionality and how it might affect the research. One effective method I employed to assess my researcher positionality was maintaining a reflexive journal. In this journal, I documented the decisions I made during the research, the reasons behind those decisions, my interpretations of the data, my identity and its connection to both my students and the research, as well as my personal value system. This practice allowed me to maintain transparency and self-awareness, ultimately enhancing the rigor and objectivity of the research.

In the context of my action research study, I adopted the role of an insider. This decision was driven by the fact that I conducted the research within my own classroom and used my own students as research participants. While this insider role offered several advantages, it also presented potential challenges. One of the primary concerns was the
potential for ambiguity, as I simultaneously held the roles of both teacher and researcher. To address this challenge, I took deliberate steps to balance my roles effectively. First, I carefully designed the PBL unit in advance, ensuring it aligned with the educational standards I intended to address. This preparation helped me maintain my role as a teacher while collecting data. During the PBL unit, I deliberately assumed the role of a facilitator rather than a traditional teacher. This shift allowed me to minimize my influence on the students and reduce the likelihood of inadvertently biasing the data. Furthermore, because my participants were also my students, to mitigate potential bias in their responses to surveys and interview questions, I took proactive measures to minimize the impact of my insider position. This included ensuring anonymity and confidentiality in data collection and analysis, emphasizing the voluntary nature of their participation, and clarifying that their grades were in no way contingent upon their involvement in the research.

Throughout the entire PBL unit, I remained vigilant to avoid consciously or subconsciously assigning grades that reflected participation in the study. This approach ensured the data would be as unbiased and valid as possible, allowing me to draw meaningful conclusions.

This study involved several key stakeholders, including me, who sought to enhance my teaching methods while pursuing personal objectives related to boosting students’ science self-efficacy and science identity. Additionally, the school’s administration, guidance department, and principal played crucial roles as stakeholders due to their vested interest in students’ mental well-being. Showing that PBL can improve students’ SEL skills could prompt the school administration to promote a similar approach among other science teachers. Similarly, district office staff members could
also show interest in the study, as they are dedicated to supporting students’ mental health district-wide. Ultimately, the results of this study could prove beneficial to future AP students, as they may reap the rewards of the findings in terms of improved educational experiences and outcomes.

**Research Design**

In this action research study, I employed a convergent mixed-method approach, combining both quantitative and qualitative data collection methods (Creswell & Creswell, 2018). To gain a comprehensive and clear understanding of how PBL influenced the development of SEL skills, science self-efficacy, and science identity, I utilized a longitudinal survey design. I administered pre-unit surveys to all participating students to determine baseline data and post-unit surveys to determine outcome data (i.e., whether the PBL intervention had any effect on a student’s SEL skill development, science self-efficacy, and science identity). The surveys provided quantitative data, yet with inherent limitations in that students could have misconstrued the instruments’ close-ended questions. To lessen these potential shortcomings and obtain a more nuanced understanding, I also gathered qualitative data through teacher observations, focus group interviews, individual interviews, and student reflection journals. The interviews complemented and validated the observational data (Efron & Ravid, 2020), as I adopted open-ended, unscripted questioning techniques so participants could freely express their thoughts and perspectives on specific topics (Creswell & Creswell, 2018). Additionally, the interviews played a crucial role in grounding the findings in the actual experiences and insights of the students involved in the research.
Context and Participants

This study took place at a large suburban high school in the Southeastern United States. I used my two AP Biology classes for this study. The classes are 110-minute block classes that meet every day over the course of the school year. Most of the students in my AP Biology courses are 11th- and 12th-grade students who have completed Honors Biology I and Honors Chemistry I. Students who do not complete these prerequisite courses are required to have a parent waiver to enroll in AP Biology. The number of students I have each year ranges from 45 to 55, which is around 3% of the total school population. The year I conducted this research, I had 56 students, 52 of whom agreed to participate in my research study. Yearly fluctuations aside, I usually have a fairly even distribution of male and female students. Over the past 5 years, the classes have consisted of approximately 40% White, 46% Asian, 11% Black, and 3% Hispanic students. Although my school as a whole consists of around 44% of students identified as pupils in poverty (PIP), in my AP Biology classes, that number is greatly reduced, with only around 8% of my students identified as PIP.

Data Collection and Analysis

Prior to beginning experimentation, I developed a PBL unit with specific incorporation of SEL skills to include all aspects of the CASEL 5. To measure SEL skills, I gathered quantitative data via a pre–post unit survey, while informal teacher observations and student reflection journals yielded qualitative data. To assess science identity, I conducted pre–post unit surveys to determine the extent to which students identified as scientists before and after the unit and collected qualitative data via focus group interviews and student reflection journals. Finally, I used a survey instrument to
measure self-efficacy, collecting accompanying qualitative data via student reflection journals and individual interviews in which open-ended questions guided discussion of how confident students felt with science practices and their ability to understand and do science.

After completing quantitative and qualitative data analysis, I triangulated the data to gain a holistic view in response to the research questions. Finally, to close out the research, I conducted focus group interviews to gain additional depth and insight into the PBL unit, the incorporation of SEL skills, and how to improve the unit for future use.

**Significance of the Research**

Action research, as defined by Efron and Ravid (2020), is an inquiry conducted by educators within their own educational settings with the objective of advancing their teaching practice and enhancing their students’ learning experiences. The primary aim of this study was to enhance my teaching methodology by implementing PBL as a means to strengthen the development of SEL skills, science identity, and science self-efficacy among my AP Biology students. Given my primary focus on improving my teaching practices within the context of my classroom, action research proved ideal.

While extensive research has explored the advantages of SEL in educational settings, particularly in areas like language and the arts, there exists a noticeable gap in the current literature concerning the impact of PBL on the development of SEL skills, science self-efficacy, and science identity among students. This study aims to fill this gap by investigating the potential influence of PBL within a science classroom context. Evidence that integrating PBL into science classrooms effectively enhances students’ SEL skills, boosts science self-efficacy, and strengthens science identity would
underscore the value of incorporating this approach into ongoing lesson plans. Furthermore, the findings could be instrumental in advocating for the adoption of PBL not only within my school but potentially at the district level as well. Promoting PBL as a method to bolster SEL skills and cultivate the next generation of citizen scientists could lead to substantial benefits for students and the broader educational community.

**Limitations of the Study**

One of the primary limitations of this study arises from the specific characteristics of the student sample involved. The research focused exclusively on AP Biology students, a group distinct from the larger student population at the high school in two notable ways. First, AP Biology students typically operate at a higher academic level compared to many of their peers, having already demonstrated success in previous science courses and actively opting for advanced science education. This characteristic introduces significant limitations for the study’s results. For one, the findings may not be applicable to other classes within the high school, particularly those comprised of students from a more diverse academic spectrum. The outcomes could be unique to advanced science courses or AP programs, given that they draw from a specific subset of students. Also, the students in AP Biology classes may already strongly identify with science and exhibit high levels of self-confidence in scientific fields. This inherent predisposition could influence the results of the study. To address this potential bias, I employed a pre–post survey method to assess whether students already had elevated levels of science self-efficacy and a robust science identity. Therefore, while the findings offer valuable insights within the context of AP Biology classes, exercising caution when attempting to generalize these findings to a broader student population or apply them to
different courses within the high school is crucial. The distinctive characteristics of the sample warrant consideration when interpreting the results and their relevance to various educational settings.

Although the factors at play in my particular high school may not directly apply to other schools, the results of this study could inform teachers and administrative teams in other schools that PBL is a worthwhile endeavor not only to increase high school students’ SEL skills, but also to develop future citizens. Because this study is grounded in action research principles rather than traditional research methodologies, the results do not directly apply to other contexts or educational settings. Attempting to generalize the findings to different schools would not be appropriate due to the study’s relatively small sample size and the unique population and variables present in each school environment (Efron & Ravid, 2020). However, other schools could consider adopting the general methods and concepts employed in this study if they wish to explore the potential benefits of implementing PBL within their own unique settings. While the specific outcomes may differ, the approach and strategies used in this research could serve as a valuable starting point for educators and researchers interested in investigating the impact of PBL in their respective schools.

Organization of the Dissertation

The dissertation in practice consists of five chapters. Chapter 1, the current chapter, situates the current study and establishes relevance for using PBL to scaffold SEL skill development, science identity, and self-efficacy. Chapter 2, the literature review, includes a thorough review of the existing research that surrounds the following topics: PBL, SEL, self-efficacy, and science identity. Additionally, Chapter 2 includes a
more comprehensive review of the theoretical framework and covers current literature surrounding the connection of PBL to SEL, self-efficacy, and science identity. Chapter 3, the methodology chapter, begins with a brief history of the use of mixed methods in educational research to justify the choice of approach before presenting a detailed description of the mixed-method integrative approach specific to this dissertation. The methodology chapter has several subsections to include the researcher’s role, site and participants, data collection procedures, and data analysis (Efron & Ravid, 2020). Chapter 4 includes a detailed description of the results and findings. Finally, Chapter 5 encompasses the discussion, implications, and recommendations for future study. Chapter 5 also includes a detailed description of the significance of the study as well as the limitations inherent in the findings. The dissertation also includes an exhaustive References section and an Appendix, encompassing the intervention plan, a sample human consent form, Institutional Review Board (IRB) approval, survey instruments, interview protocols, and raw quantitative data.

Glossary of Key Terms

**Project-based Learning (PBL)** – A teaching method whereby students work for an extended period of time with the goal of researching and responding to an authentic, engaging, and complex real-world problem, question, or challenge. In doing so, students learn content and develop skills.

**Responsible Decision-Making** – The ability to make constructive choices about personal behavior and social interactions based on ethical standards, safety concerns, and social norms. Responsible decision-making involves considering the well-being of oneself and others, considering the potential consequences of different choices, and making decisions
that demonstrate respect for others and contribute to positive relationships and communities. Individuals who are skilled in responsible decision-making carefully and thoughtfully consider the decision at hand, think of the potential options, and then look at the potential consequences of each option (CASEL, 2022).

**Relationship Skills** – The ability to develop and maintain healthy relationships. Skills include effective communication, active listening, cooperation, collaboration, and the ability to resolve conflict.

**Social and Emotional Learning (SEL)** – An educational framework and process that focuses on developing students’ social and emotional skills to enhance their overall well-being, personal growth, and success in school and life. It recognizes that emotions, relationships, and social interactions are integral to a student’s overall development and that teaching these skills can lead to positive outcomes academically, emotionally, and socially (CASEL, 2022).

**Self-Awareness** – The ability to recognize and understand one’s emotions, strengths, weaknesses, values, and thought patterns. It involves introspection and self-reflection, allowing individuals to develop a deeper understanding of themselves and their inner world. Self-awareness also includes the ability to recognize personal strengths and weaknesses (CASEL, 2022).

**Self-Management** – The ability to take personal responsibility for one’s behavior and actions. A key component of self-management is managing emotions and thoughts in a variety of situations effectively. Additionally, good self-management skills allow one to delay gratification, manage stress, and use internal motivation to achieve personal goals (CASEL, 2022).
**Social Awareness** – The ability to recognize, understand, and empathize with others’ feelings, perspectives, and experiences. Socially aware individuals are attuned to the emotions and needs of those around them, and they demonstrate respect for diversity and inclusivity (CASEL, 2022).

**Science Self-Efficacy** – A person’s belief in their ability to understand and do science.

**Science Identity** – The extent to which a person thinks “about themselves as science learners…and as someone who knows about, uses, and sometimes contributes to science” (Center for the Advancement of Informal Science Education, 2018, p. 1). Science identity also includes the degree to which a person’s “important social reference groups (e.g., friends, family) perceive the individual as a “science person” (Chen et al., 2021, p. 594).
CHAPTER 2: LITERATURE REVIEW

At present, fostering a STEM-literate society is critical. The recent experience of
the COVID-19 pandemic underscored the absolute necessity of a population well-versed
in scientific principles (Gratz et al., 2021; Siani & Green, 2023). A society grounded in
robust scientific literacy is better prepared to respond adeptly to public health
emergencies, navigate evolving situations, and champion the use of evidence-based
approaches that bolster public health and overall well-being. Additionally, a society well-
versed in scientific principles is less susceptible to the spread of misinformation.
Throughout the pandemic, misinformation spread rapidly, prompting the World Health
Organization (2020) use of infodemic to signify the extensive dissemination of deceptive
and erroneous information. Regrettably, such misinformation often contradicts
scientifically validated evidence. A strong foundation in and trust in science are among
the most effective tools for countering this infodemic.

There are various compelling reasons to cultivate a scientifically informed public
beyond the potential threat of pandemics. Scientific literacy holds equal significance in
light of emerging technologies, rapid advances in medicine, and the critical issue of
climate change. Given such contemporary experience, individuals need a fundamental
level of scientific comprehension and an appreciation for the principles of science to
make well-informed decisions in their personal lives and for the benefit of society as a
whole (NSTA, 2020).
Moreover, as highlighted by the NSF in 2007, the 21st century has witnessed a growing focus on scientific and technological advancements, encompassing challenges and opportunities linked to the rise of an interconnected global economy driven by knowledge and information. Establishing a robust K–12 STEM education system proves to be a highly effective approach to cultivating a scientifically literate society (National Research Council, 2011). According to the NSF (2007), “In this new information-driven and technologically advanced society, students need to elevate their proficiency in STEM subjects far beyond what was previously deemed acceptable” (p. 2).

Moreover, acquiring strong 21st-century skills is essential for individuals to thrive in the workforce and contribute positively to society. Specifically, students’ college and career success hinges on four fundamental skills: critical thinking and problem-solving, effective communication, collaboration, and fostering creativity and innovation (Partnership for 21st Century Skills, 2009). Recognizing the importance of these skills, the NSTA (2011) endorsed their integration into the K–16 curriculum.

As noted in Chapter 1, students begin developing their awareness and comprehension of STEM early in their education and build on elementary skills during middle and high school. Currently, the only widely used assessment to measure U.S. students’ scientific literacy is the Program for International Student Assessment (PISA), coordinated internationally by the Organization for Economic Cooperation and Development (OECD) and administered in the United States by the National Center for Education Statistics. The most recent PISA assessment in 2018 (OECD, 2019) had a scientific literacy component on which U.S. students scored higher than the average, with 9% of U.S. students in the highest Level 5 and Level 6, as compared to the OECD
average of 7%. However, the PISA mean performance in science has not changed significantly since 2009, despite President Obama’s push for STEM education beginning in 2011 (Institute of Education Sciences, National Center for Education Statistics, 2020).

In December 2018, the Executive Office of the President endorsed short-term and long-term STEM education goals, emphasizing project-based learning and 21st-century skills to boost STEM literacy and cultivate a robust future workforce. Research has shown that noncognitive factors such as self-confidence and science identity play important roles in students’ STEM success; higher science self-efficacy and science identity have resulted in higher science achievement in high school students of all levels (Alhadabi, 2021). Students who have indicated stronger interests in science also have demonstrated higher science self-efficacy and stronger science identities. Thus, students who feel more confident in their science abilities and who see themselves as scientists are potentially more likely to practice behaviors such as good study skills and taking more challenging science courses. Ultimately, this could result in students’ choosing to pursue a STEM pathway and then persisting in that pathway.

During the recent COVID-19 pandemic, students faced heightened rates of mental distress, including anxiety, depressive symptoms, and reduced life satisfaction (Magson et al., 2020). The impact of student mental health extends to academic success, with O’Connor et al. (2016) asserting that positive mental health in adolescence and childhood correlates with improved academic achievement and long-term educational attainment. Consequently, there is a growing advocacy among educators and psychologists for SEL to enhance students' resilience and mental well-being, potentially lowering the risk of mental health disorders (Billy & Garríquez, 2021; Carbone, 2020).
CASEL (2022) identifies five key SEL skills: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. However, despite the recognized importance, many schools do not explicitly prioritize student mental health and the inclusion of SEL in their curricula. Teachers, with their daily interactions with students, hold a unique position to contribute positively to mental health (Substance Abuse and Mental Health Services Administration, 2019; U.S. Department of Education, 2021; Wiedermann et al., 2023; youth.gov, n.d.). Dresser (2013) contends that teachers, by intentionally integrating SEL into their lessons, can be the most influential factor in their students' academic success.

PBL may be an ideal instructional strategy for creating and nurturing a strong STEM workforce. Students actively develop knowledge through PBL, which could increase science identity and science self-efficacy. Additionally, because PBL, by nature, is a social activity, it fosters 21st-century skills, many of which are also SEL skills. Although the use of PBL and its interaction with SEL skill development, science identity, and self-efficacy have been studied (Anthony et al., 2017; Culclasure et al., 2019; Mraz-Craig et al., 2018; Williams et al. 2021), the three variables have not been investigated in conjunction with one another in a high school setting. This literature review gives an overview of PBL, including its history and current research on the use of PBL in science classrooms. Additionally, I define SEL, science identity, and science self-efficacy and examine the body of current research on each topic. Finally, I establish the current understanding of the relationship between PBL and how it can influence students’ SEL skill development, science identity, and self-efficacy.
Search terms for this literature review included: PBL and high school and SEL; PBL and secondary education and SEL; PBL and SEL; PBL and high school and self-efficacy; PBL and secondary education and self-efficacy; PBL and self-efficacy; PBL and high school and science identity; PBL and secondary education and science identity; PBL and science identity; self-efficacy and science identity; social cognitive theory and self-efficacy; constructivism and PBL; identity theory; and science identity.

Differentiating between PBL and problem-based learning was important, so I excluded any articles that only referenced problem-based learning. Additionally, to identify and synthesize the most current research, articles that were more than 10 years old were given lower priority or eliminated. The databases included Google Scholar, EBSCO Host, ERIC, PsycINFO, and JSTOR.

**PBL**

The instructional strategy of learning by doing has roots that span centuries, with philosophers like Socrates, Plato, and Aristotle employing active questioning and discussion to teach, fostering critical thinking and inquiry skills in their students (Murphy, 2015). In the late 19th and early 20th century, psychologists Piaget and Dewey underscored the significance of student learning experiences in the process of knowledge construction. Similarly, Maria Montessori supported learner-centric, self-directed learning, emphasizing a child's capacity to shape their own learning experiences. These concepts, along with Vygotsky’s belief that optimal learning occurs through interaction with others, form the core principles of today’s PBL classrooms.

PBL, as an instructional model, traces its roots back to these early pioneers. Dewey, particularly influential in clarifying how children learn, played a key role in
shaping these educational ideas (Sikander, 2016). Convinced children should be active participants in their education, Dewey was a proponent of the learning-by-doing method (Sutinen, 2013). William Kilpatrick, a contemporary of Dewey, developed the project method in the early 20th century (Holm, 2011), based on the idea that students learn best through “wholehearted purposeful activity, proceeding in a social environment” (Kilpatrick, 1918, p. 4). PBL was first introduced, via its close relative problem-based learning, in 1969 at the medical school at McMaster University in Canada (Servant-Miklos, 2019). Problem-based learning challenges students to solve problems they can faced in the real world. The problems are predefined but typically complex, without one right answer. Students have to determine what they need to learn and answer their questions in collaborative groups. This instructional method quickly became standard practice in medical schools. By the 1980s and 1990s, some schools began to incorporate PBL into their curricula.

Conflating PBL and problem-based learning is common because both types of learning are student-centered and involve students’ working together to investigate and ultimately understand a complex concept. Typically, problem-based learning is not quite as structured in that students research various topics that are not necessarily predetermined in order to solve a problem, and the learning goals and outcomes are set by students and their teacher (Allchin, 2013; Savery, 2006). By contrast, PBL usually has predetermined learning goals and is very structured in nature; students actively explore real-world challenges and develop a deep and thorough understanding of the content through the process. Additionally, the outcome of PBL is a specific end product, whereas in problem-based learning, outcomes can vary.
PBL is grounded in the constructivist approach to learning whereby students construct knowledge within a social context and are aware of their learning (Tamim & Grant, 2013). Instead of an afterthought at the end of a unit, a project in PBL is the cornerstone of the unit (Juuti et al., 2021). PBL is an engaging, interactive teaching method where students tackle a real-world, meaningful problem or question. Students collaborate to develop a solution that culminates in a group presentation or product. The process can span a few weeks up to an entire semester. PBL almost always incorporates a driving question that students explore through situated learning facilitated via teacher and community partner input (Krajcik & Blumenfeld, 2006). The driving question helps students determine what they need to know, guiding their use of technology and other resources to research and implement potential solutions. PBL requires students to drive their own knowledge formation, and the teacher’s role is primarily a facilitator rather than the source of knowledge (Aldabbas, 2018; Almulla, 2020; Juuti et al., 2021). The culmination of the PBL unit is an artifact or product that addresses the driving question and is presented in a public forum with an audience that includes peers, other teachers, and ideally community partners (Krajcik & Blumenfeld, 2006). The artifacts can vary (e.g., website, poster, video, phone app) and ultimately communicate student ideas regarding answers to the driving question; working with and producing these artifacts can increase student engagement (Juuti et al., 2021).

Research has demonstrated that PBL results in high academic achievement compared to traditional modes (Chen & Yang, 2019; Krajcik & Blumenfeld, 2006). Yet, the research is inconclusive regarding which academic level of student benefits the most from a PBL approach (Han et al., 2015). Across several PBL models, there are quite a
few similarities: student inquiry, directed by the driving question; student voice and choice; authenticity; reflection and revision; collaboration and teacher facilitation (Chen & Yang, 2019; Krajcik & Blumenfeld, 2006; Thomas, 2000). A unique component of PBL is that the project is central to the curriculum; students learn the content via the project itself. Knowledge construction and transformation are significant outcomes of PBL (Krajcik & Blumenfeld, 2006). Student choice is a central component of PBL design, and research has shown that when students have autonomy to make decisions in their learning process, they show enhanced levels of effort, motivation, performance, and confidence (Patall et al., 2008).

As highlighted in Chapter 1, PBL is rooted in the theoretical framework of constructivism, drawing on principles from philosophy, psychology, sociology, and education (Olusegun, 2015). Cognitive constructivists, such as Piaget, assert that knowledge is actively built upon learners' prior knowledge and experiences (Ackermann, 2001; Krajcik & Blumenfeld, 2006). In the context of social constructivism, which underscores society's role in knowledge acquisition, PBL is considered a form of situated learning (Krajcik & Blumenfeld, 2006). Within the PBL approach, students collaborate to address real-world problems, leading to the construction of new knowledge based on their present and past experiences. From a constructivist perspective, individuals shape their understanding by drawing from their experiences and engaging in reflective processes regarding their past encounters (Jumaat et al., 2017).

**SEL**

SEL is the process through which children and adults learn and manage their emotions and social interactions in ways that benefit themselves and others. Individuals
with a strong SEL skill set are ultimately better prepared to succeed in school, the workforce, or relationships and as citizens (Billy & Garriguez, 2021; Carbone, 2020). For many years, parents and educators have known that children’s social and emotional development directly affects many aspects of their lives, including academic achievement (Tan et al., 2018).

Many U.S. state education departments have issued standards for developing specific SEL skills at each grade level (Humphrey, 2013). The need for SEL even spurred a report by the Aspen Institute that stated, “Integrating social and emotional development with academic instruction is foundational to the success of our young people, and therefore to the success of our education system and society at large” (Jones & Khan, 2017, p. 12).

The benefits of incorporating SEL are wide and include an increase in equity and excellence for children in marginalized communities, reducing disciplinary problems, and increasing academic achievement (Jagers et al., 2019; Jones & Khan, 2017; Tan et al., 2018). The mental health benefits could also be significant by teaching children how to effectively handle emotions, stress, and interpersonal relationships (Jones & Khan, 2017). There are potential long-term benefits, as suggested by Jones and Khan, including gains in labor productivity, crime reduction, less substance abuse, and lower overall health problems.

Although researchers do not completely agree on the SEL skill set (Jones & Doolittle, 2017; Jones & Khan, 2017), the skills commonly span three domains: cognitive skills, emotional competencies, and social and interpersonal skills. Championing SEL since 1994, CASEL (2022) has outlined five key skills: self-awareness, self-management,
social awareness, relationship skills, and responsible decision-making. Research has shown SEL is, indeed, applicable in kindergarten through 12th grade. There are various ways to incorporate SEL, including district-wide initiatives, school-wide initiatives, and even at the classroom level. CASEL supports systemic implementation of SEL via classrooms, schools, homes, and communities. Because reaching such a high expectation may be difficult, CASEL (2022) also outlines how to implement SEL at the classroom level. A successful SEL-focused classroom includes three components: a nurturing classroom environment, the incorporation of SEL into academic instruction, and explicit SEL instruction.

Science Self-Efficacy

As mentioned in Chapter 1, Bandura (1997) initially proposed SCT in 1971 and later extended it to incorporate the concept of self-efficacy. According to Bandura, self-efficacy is not a universal trait but a belief specific to particular domains or tasks. Put simply, individuals can have varying levels of self-efficacy in different areas. The extent of self-efficacy influences the choices individuals make, the effort they invest, their perseverance in challenging situations, and their ability to overcome obstacles. It plays a pivotal role in shaping motivation, behavior, and ultimately, individual accomplishments.

Science self-efficacy, a person’s confidence in their ability to do science, is important for the future STEM workforce, as someone with low science self-efficacy is less likely to move into STEM fields. In fact, students make decisions according to their self-efficacy beliefs and choose educational pathways and careers in areas in which they deem themselves to have the capacity to succeed (Webb-Williams, 2017). Therefore,
students with low self-efficacy beliefs for science would be less likely to choose careers in science.

There are four sources of self-efficacy as defined by Bandura (1997): mastery experiences, vicarious experiences, verbal persuasion, and emotional and physiological states. Mastery experiences are arguably the strongest predictors for high feelings of self-efficacy (Bandura et al., 1977; Usher & Pajares, 2008). Students who succeed at a task or challenge have higher feelings of self-efficacy, and sustained accomplishments create enduring feelings of self-efficacy that could potentially resist minor failures. However, experiencing repeated failures can erode self-confidence. Vicarious experiences include using the lived experiences of others to influence a person’s own feelings of confidence. Perceiving one’s abilities in relation to others is a natural human phenomenon; when the individuals are similar, the comparison is strengthened. Thus, if a peer succeeds at a task, a person is more likely to feel they will also succeed at the same task (Bandura, 1997). Verbal persuasion is the influence a person’s words can have on someone’s self-efficacy. For example, teachers’ positive and supportive feedback can increase student self-efficacy via verbal persuasion (Bandura, 1997). However, verbal praise may not be as influential on self-efficacy as other factors (Bandura, 1977). Finally, a person’s physiological and emotional states can significantly impact perceived confidence. When a person experiences a stressful or anxiety-inducing situation, their heightened arousal can lead to negative feelings of self-efficacy toward the task at hand (Bandura, 1997).

The sources of science self-efficacy seem to vary among age groups. For example, a study of elementary-aged children found mastery experiences to be an important source of self-efficacy but not the most influential source for all participants.
(Webb-Williams, 2017). Additionally, for boys, experiencing success or failure, as opposed to observing others, was critical for their sense of self-efficacy. In contrast, girls were socially focused and rarely referred to independent assessments. Asking students to describe their confidence level in science and predict their science test performance revealed gender differences. Boys’ perceptions of past performance aligned with their actual performance, whereas girls tended to underestimate their performance and hold misperceptions.

A study of college freshmen found that experiencing success in a course as well as personally relevant, student-centered design was vital for scaffolding student confidence in science (McBride et al., 2019). However, gender differences and demographics did not show a statistically significant difference in the development of science self-efficacy. Interestingly, McBride et al. also found that prior experience in AP science courses and high school GPA did not predict science self-efficacy, whereas previous college experience in a science course did predict science self-efficacy.

**Science Identity**

As highlighted in Chapter 1, Erikson's theory of psychosocial development asserts that the primary developmental task for adolescents is to explore and cultivate their identity (Ragelienė, 2016). Identity, in this context, is generally defined as how an individual is recognized as a specific "kind of person" (Gee, 2000, p. 99). This process occurs during stage five of Erikson’s eight stages of development and necessitates a child's success in various tasks with ongoing support from others (Maree, 2021). Therefore, identity development comprises both individual and social components (Adams & Marshall, 1996).
Carlone and Johnson (2007) developed a conceptual framework that specifically highlights science identity as a product of three interrelated dimensions: recognition, competence, and performance. The first component, recognition, means that an individual recognizes themselves as a “science person” and also includes the same recognition by others. Particularly in professional science fields, recognition by others is a vital part of identifying as a scientist (Hurtado et al., 2009). Thus, the model posed by Carlone and Johnson (2007) accounts for the “socially constructed nature of science identity” (p. 1190). Competence, the second component, is the knowledge of science skills, concepts, and practices. The third component is performance and includes a person’s successful social performance of science practices. According to Hazari et al. (2010), when exploring science identity, researchers should also consider student interest, an arguable fourth element. Interest in this context refers to the eagerness and inquisitiveness to engage with and comprehend scientific concepts.

Science identity potentially informs students’ persistence in science fields (Trujillo & Tanner, 2014). Students will make more positive science-related choices if they have a stronger science identity. In particular, science identity is strongly correlated with out-of-school science experiences, suggesting students with a stronger science identity choose to partake in more science-related activities (Vincent-Ruiz & Schunn, 2018). Furthermore, students who identify strongly as scientists are more likely to move into STEM-related careers after graduation (Chen & Wei, 2020; Stets et al., 2017).

Vincent-Ruiz and Schunn (2018), who surveyed seventh- and ninth-grade students, found that developing a strong science identity is especially important for girls. Additionally, they showed that, at this age, interrelated personal and external factors
played an important role in students’ overall science identities. No significant differences existed between the demographic subgroups and students’ reported science identity. A particularly interesting finding of this study was that others perceived as influential (e.g., teachers or parents) are key in developing science identity. Consequently, teachers must view themselves as influential people who can nurture or inhibit students’ science identity. Likewise, Carlone and Johnson (2007) found that developing an acceptable science identity centers not only on proficiency and curiosity in science, but also, as importantly, on acknowledgment by teachers, peers, and other adults as a person with ability in science. Carlone and Johnson’s study highlights the importance of educators’ promoting student confidence and feelings of success in science, especially among students of color and other groups historically barred from being viewed as “science people.” More recent studies have reinforced teachers’ essential role in science identity development, such as a study of high school physics students wherein teachers were highly influential in developing science identity for male and female participants (Hazari et al., 2010).

**Current Literature Connecting PBL to SEL, Science Identity, and Self-Efficacy**

Culclasure et al. (2019) attempted to determine if PBL significantly affected SEL outcomes, academic achievement, and behavior. Interestingly, there were no significant differences in academic performance or behavior. However, the SEL outcomes did show a significant increase in elementary and middle school students. The high school participants were not included in the SEL portion of the study, as the instrument used to measure SEL outcomes was not validated for use at a high school level. Beisel (2021) posited that PBL is an ideal educational model through which to incorporate SEL skill
competencies. As students work through a PBL unit, they can naturally practice and sharpen various SEL skills such as relationship skills, communication, self-management, self-awareness, personal responsibility, and decision-making.

PBL can foster and improve students’ development of 21st-century skills, of which many are analogous to SEL skills. At the culmination of Aifan’s (2022) study of undergraduate students who participated in a PBL unit using PowerPoint, students reported statistically significant increases in the 21st-century skills of communication, collaboration, critical thinking, problem-solving, leadership, creative thought, and personal responsibility. Further studies indicate a PBL approach can support 21st-century skill development in college students and students of all ages from kindergarten through high school (Bell, 2010).

Williams et al. (2021) researched the effect of participation in a citizen science project—which is similar to PBL—on science identity, specifically “nature connectedness and knowledge of curricular material” (p. 1037). The study included middle and high school students from participating schools in Oregon. While student content knowledge increased, science identity and nature connectedness did not improve. The results actually indicate participation in a citizen science project had a small but negative effect on science identity. Few studies have been conducted in this area, so there is little information to determine why science identity did not increase. When students just collect data, they have little connection to identifying themselves as scientists; however, in Williams et al.’s study, students did more than collect data. In another study, Jiang et al. (2022) surveyed 400 middle and high school students, revealing that participation in STEM-focused PBL noticeably enhanced students’ science identity.
Science identity has been studied extensively in Grades K–8 and in postsecondary environments, whereas few studies have occurred in high school settings (Lee & Mun, 2023). Studies at the collegiate level have used a PBL approach in courses and results suggest PBL develops students’ perceived STEM identities (Anthony et al., 2017; Major and Kirn 2017; Marshall et al., 2018; Mraz-Craig et al., 2018).

Schaffer et al. (2012), showed that college students who participated in cross-disciplinary PBL teams significantly improved their science self-efficacy. A similar study in a biomedical engineering computing undergraduate course utilized a PBL approach (Rezvanifar & Amini, 2020) and found that self-efficacy scores increased significantly. However, there were gender differences in that female students reported lower self-efficacy scores than their male counterparts. Krsmanovic (2021) investigated the effects of a university freshman science seminar course redesign, a project-based curriculum, on students’ self-efficacy. Results revealed statistically significant differences—although relatively small—in students’ responses for all learning outcomes before and after the curriculum redesign. The results suggest a well-implemented PBL curriculum can increase students’ confidence in their academic success.

Few studies have focused on PBL and self-efficacy in a high school population. However, the existing studies suggest a PBL approach has positive—albeit small—influences on self-efficacy (Shin, 2018; Zimmerman et al., 2022).

**Discussion**

PBL may be an ideal instructional strategy for creating and nurturing a strong STEM workforce. Students actively develop their knowledge through PBL, which could
enhance science identity and self-efficacy. Additionally, because PBL, by nature, is a social activity, it can foster 21st-century skills, many of which are also SEL skills.

Constructivism, SCT, and identity development theory serve as valuable frameworks for examining the impact of PBL on SEL, science identity, and science self-efficacy. PBL offers an optimal platform for students to construct new content knowledge and refine SEL skills (Beisel, 2021). For instance, as students collaboratively tackle PBL challenges, they gain insights into their strengths and challenges, fostering the SEL skill of self-awareness. The collaborative nature of PBL also promotes the advancement of students' relationship skills and personal responsibility (Aifan, 2022; Bell, 2010). Throughout a PBL unit, students work closely together, enhancing their communication, collaboration, and conflict resolution skills. Regular self-reflection in PBL units allows students to analyze their contributions, take responsibility for any shortcomings, and refine their group interactions. Developing SEL skills in a low-stakes PBL setting, rather than in higher-stakes environments like college or the workforce, proves beneficial for students.

Moreover, PBL provides a collaborative, real-world problem-solving context that enables students to construct knowledge based on prior experiences and engage in scientific practices. This process not only boosts confidence in their ability to perform scientific tasks (science self-efficacy) but also fosters a stronger identification with science. Numerous studies have indicated that STEM-focused PBL experiences significantly impact variables associated with science identity. For example, participants in STEM-PBL experiences tend to exhibit increased interest in science and stronger beliefs in their competence in scientific endeavors (Wan et al., 2020; Beier et al., 2018).
There has been much research on the benefits of SEL in schools and its effects on specific content areas such as language and the arts. However, literature has yet to address the effect of PBL on SEL skill development and student science self-efficacy and identity, particularly in high school students. By examining the intersection of PBL, SEL, and science education in a high school setting, my action research study aims to contribute valuable insights to the existing literature and inform effective teaching strategies that support my students' social and emotional growth while enhancing their engagement with science content.

**Conclusion**

This literature review delved into several key facets. First, it provided a comprehensive overview of PBL, tracing its historical development and investigating contemporary research pertaining to its application within science classrooms. Furthermore, this review defined and explored the concepts of SEL, science identity, and science self-efficacy, delving into the existing body of research related to each of these domains. It sought to paint a clear picture of the current state of knowledge and understanding in these critical areas. Finally, I assessed the existing understanding of the intricate relationship between PBL and its impact on the development of social and emotional skills, the formation of science identity, and the cultivation of science self-efficacy among high school students in the United States. Research has yet to explore the nuanced dynamics and potential outcomes associated with the integration of PBL in the context of high school education in the United States. There remains much to learn regarding the relationship of PBL to U.S. high school students’ social and emotional skill development, science identity, and science self-efficacy.
CHAPTER 3: METHODOLOGY

The aim of this research was to investigate whether integrating PBL impacts the development of SEL skills, as well as the enhancement of high school students’ self-confidence in and identification with science. Existing research indicates PBL is an effective method for students to build knowledge and improve their SEL skills (Beisel, 2021). Moreover, while there is limited research on the relationship between PBL and self-confidence in high school students, existing studies by Shin (2018) and Zimmerman et al. (2022) suggest PBL has positive, albeit modest, effects on self-confidence. Investigations at the college level, focusing on authentic learning and the formation of science identity, indicate PBL nurtures students’ perceived engineering identity by stimulating their interest in engineering (Major & Kirn, 2017; Marshall et al., 2018). Furthermore, as Anthony et al. (2017) and Mraz-Craig et al. (2018) demonstrated, undergraduate students majoring in science who engage in authentic course-based research develop stronger science identities. Drawing from the collective evidence from previous research and my personal experience with my students, I explored the following research questions:

1. How does incorporating PBL in a science classroom affect high school students’ SEL skills?
2. How does incorporating PBL in a science classroom affect students’ science self-efficacy and identity?
Research Design

This study utilized an action research approach. As the practitioner, I primarily aimed to delve into the potential impact of PBL on the development of SEL skills, science self-efficacy, and science identity among my students. My rationale for an action research design stemmed from the intrinsic need to address a specific issue within my educational environment and assess how an intervention like PBL could effectively address this particular concern.

This action research approach aligns with the principles outlined by Efron and Ravid (2020) and Herr and Anderson (2015), who emphasized the paradigm’s suitability for practitioners who identify a challenge within their context and wish to explore the effects of an intervention on that issue. By taking this action-oriented stance, I sought to bridge the gap between theory and practice, seeking practical solutions and insights to enhance my students’ educational experience and outcomes.

Methodological Approach

I deliberately chose a mixed-methods approach to explore the research questions comprehensively. Integrating quantitative and qualitative data, this approach yielded a deeper and more holistic understanding of the phenomena under investigation (Creswell & Creswell, 2018; Creswell & Plano Clark, 2018). Mixed methods enable researchers to approach research questions from multiple angles, enriching the research process with diverse perspectives and insights (Creswell & Plano Clark, 2018; Dawadi et al., 2021). This comprehensive view is akin to examining a topic through a wide-angle lens, allowing a more nuanced and comprehensive understanding of the subject matter.
Specifically, I used an integrated, convergent design, employing quantitative and qualitative methods in parallel to address the same research questions (Creswell & Plano Clark, 2018). This approach facilitated data triangulation, strengthening the findings’ validity and reliability. Drawing upon the strengths of quantitative and qualitative data facilitates a more comprehensive and well-rounded interpretation, giving rise to more robust and nuanced conclusions (Creswell & Plano Clark, 2018).

In the context of this study, qualitative methods were particularly valuable as they allowed for in-depth exploration of the issues under study within the authentic setting where participants experienced them. These methods encompassed techniques such as teacher observation, focus group and individual interviews, and reflection journal document analysis. Qualitative data were instrumental in identifying patterns and themes across various data sources, providing a richer understanding of the complexities surrounding the research questions (Creswell & Creswell, 2018).

Conversely, quantitative methods were well-suited for evaluating the impact of the PBL intervention on specific outcomes, namely SEL skill development, science self-efficacy, and science identity. These methods allowed for the systematic measurement of changes and the assessment of statistical significance, particularly in assessing the effectiveness of the intervention (Efron & Ravid, 2020). By combining quantitative and qualitative approaches, this study offered a more comprehensive and evidence-based exploration of the research questions, contributing to a more informed understanding of the complex interplay between pedagogical interventions and student development. In a mixed-methods approach, both data types carry equal weight as they can each provide
unique interpretations in response to the same research question (Creswell & Creswell, 2018; Creswell & Plano-Clark, 2018; Efron & Ravid, 2020).

**Data Sources**

To collect quantitative data, I used a longitudinal survey design, which involved the administration of pre- and post-unit surveys to all participants. The purpose of this approach was twofold: to initially establish baseline data and subsequently collect outcome data. Comparative analysis assessed whether the PBL intervention had any discernible impact on students’ SEL skill development, science self-efficacy, and science identity. This methodological choice not only facilitated the measurement of any changes that occurred over time but also enabled the evaluation of the effectiveness of the PBL intervention by directly comparing students’ initial responses with their later ones. Through this longitudinal survey design, I aimed to provide a comprehensive understanding of how PBL influences the targeted aspects of students’ development and identities within the context of the study.

Survey instruments used in a pre–post method quantified SEL skills, science identity, and self-efficacy. These surveys provided quantitative data but may have inherent limitations in students may have misinterpreted the close-ended questions. To mitigate these potential drawbacks, I also collected qualitative data via teacher observations, student reflection journals, focus group interviews, and one-on-one interviews. Observations were beneficial in that they allowed me to view my students and their interactions in their groups. I could not only hear students talking but also view nonverbal student-to-student interactions and body language (Efron & Ravid, 2020). Each day of the PBL unit, I took detailed field notes that included descriptions of what I
saw and heard in the classroom. I made sure only to record my observations; I did not attempt to interpret the observations or make assumptions regarding what I observed.

Focus group interviews bring together a small group of participants who can answer interview questions and may share among themselves opinions and feelings regarding the topic of study (Efron & Ravid, 2020). Focus groups also provide a less stressful environment where students are more likely to speak up and share their experiences than in a one-on-one setting where they could feel intimidated. Individual interviews, however, are preferable when asking questions regarding identity because students may feel more compelled to talk openly and without judgment when they are away from their peers (Kaplowitz & Hoehn, 2001). Example focus group and individual interview questions are located in the Appendix.

**PBL Unit**

Prior to starting data collection, I developed a PBL unit with a deliberate focus on the integration of SEL skills, encompassing all aspects of the CASEL (2022) 5 framework: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. This specialized 3-week PBL curriculum, enriched with SEL components, was tailor-made for implementation within the context of this research project. Its primary purpose was to facilitate the teaching of molecular genetics and provide a comprehensive exploration of the genetic foundations of cancer to AP Biology students. A detailed outline of this instructional unit appears in Appendix A.

The infusion of SEL skills was a deliberate and integral element of this curriculum, intentionally woven into various phases of the educational process. Before delving into the subject matter, I conducted a thorough review of essential SEL
competencies, emphasizing fostering self-awareness and self-management skills. This initial engagement was fundamental in equipping students with the necessary SEL tools that would be indispensable throughout their forthcoming PBL journey. To help with this, I administered an identity inventory (see Appendix F). This activity was meticulously designed to prompt students to embark on a journey of self-discovery and self-awareness right from the outset. Its intent was to encourage deep reflection on personal characteristics and collaboration tendencies within group settings, factors that would significantly shape their collaborative efforts during the subsequent PBL unit.

Subsequently, I formed student groups with a conscious effort to separate existing friend groups and position students alongside peers with whom they might not have had prior close connections. I then tasked each group with creating a PBL Group Contract, as outlined in Appendix G. This contractual agreement served a multifaceted purpose, including providing students with an opportunity to openly discuss and acknowledge their individual strengths and weaknesses within the context of group dynamics. Furthermore, it encouraged students to contemplate and establish conflict resolution strategies, thereby reinforcing their interpersonal and collaborative skills.

To ensure the sustained cultivation of SEL skills throughout the entirety of the unit, I introduced a daily reflection journal, as detailed in Appendix I. These journal prompts were thoughtfully constructed to guide students’ reflections on various SEL competencies. For instance, over several days, I prompted students to assess their contributions to group work, thus fostering self-management skills specific to group collaboration and academic tasks. Additionally, certain journal entries encouraged students to develop empathy by asking them to contemplate the emotional experiences of
patients diagnosed with specific types of cancer, envisioning the sentiments these individuals might carry into their genetic counseling sessions. Table 3.1 provides a compilation of SEL competencies along with the corresponding intervention strategies.

Table 3.1 SEL Components and Items Included in PBL Unit

<table>
<thead>
<tr>
<th>SEL Competency</th>
<th>Items Included in PBL Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Awareness</td>
<td>Identity Inventory</td>
</tr>
<tr>
<td></td>
<td>Reflection Journal</td>
</tr>
<tr>
<td>Self-Management</td>
<td>Identity inventory</td>
</tr>
<tr>
<td></td>
<td>Reflection Journal</td>
</tr>
<tr>
<td>Social Awareness</td>
<td>PBL Group Contract</td>
</tr>
<tr>
<td></td>
<td>Reflection Journal</td>
</tr>
<tr>
<td>Relationship Skills</td>
<td>PBL Group Contract</td>
</tr>
<tr>
<td></td>
<td>Reflection Journal</td>
</tr>
<tr>
<td>Responsible Decision-Making</td>
<td>PBL Group Contract</td>
</tr>
<tr>
<td></td>
<td>Reflection Journal</td>
</tr>
</tbody>
</table>

I carefully designed the PBL unit to cater to the needs of my AP Biology classes, centered on the theme of the genetic foundations of cancer. The 3-week unit adhered to the gold standard criteria for PBL outlined by Larmer et al. (2015), systematically addressing all seven essential project design elements: (a) a challenging problem or question, (b) sustained inquiry, (c) authenticity, (d) student voice and choice, (e) reflection, (f) critique and revision, and (g) a public product. The detailed unit plan in Appendix A provides an exhaustive description of the unit’s structure and content, offering a comprehensive overview of the PBL journey designed to enhance students’ comprehension of cancer genetics while nurturing SEL skills in accordance with the CASEL (2022) framework.

Data Collection

Data documented three distinct variables: SEL skills, science identity, and science self-efficacy. The pre-unit surveys occurred the day before the PBL unit commenced, and
I administered the post-unit were the day following the genetic counseling session, which marked the conclusion of the unit. Additionally, focus groups and individual interviews took place in the week following the conclusion of the PBL unit. Student reflection journals also served as data sources, collected on the day after the unit ended. Refer to Table 3.2 for further details.

Table 3.2 Timeline of Data Collection

<table>
<thead>
<tr>
<th>Week</th>
<th>Tasks</th>
</tr>
</thead>
</table>
| 1    | Pre-Unit Survey SEL Skills (Day 1)  
Pre-Unit Survey Science Identity (Day 1)  
Pre-Unit Survey Science Self-Efficacy (Day 1)  
PBL Unit Intervention Began (Day 2)  
Student Reflection Journal Began  
Teacher Observations and Field Notes |
| 2    | PBL Unit Continued  
Student Reflection Journal  
Teacher Observations and Field Notes |
| 3    | PBL Unit Continued  
Student Reflection Journal  
Teacher Observations and Field Notes |
| 4    | PBL Unit Intervention Ended (Day 1)  
Student Reflection Journal Collected (Day 2)  
Post-Unit Survey SEL Skills (Day 2)  
Post-Unit Survey Science Identity (Day 2)  
Post-Unit Survey Science Self-Efficacy (Day 2)  
Focus Groups  
Individual Interviews |

SEL Skills

To quantitatively measure SEL skills, I administered a pre–post survey, specifically the long-form Washoe County School District Social and Emotional Competency Assessment (WCSD-SECA; Appendix D). The WCSD-SECA is a self-
report measure that assesses eight student SEL competencies for fifth- through 12th-grade children based on the CASEL 5 (Crowder et al., 2019). The 40-item survey includes a Likert-type scale with which students rate the perceived difficulty of each statement. The instrument resulted from collaboration among WCSD, CASEL, and the University of Illinois at Chicago, and I chose it based on three main factors: (a) it is a free, open-source instrument; (b) it is self-reported and thus conducive to pre–post assessment of high school students; and (c) it is a validated instrument, as evidenced by the absence of floor or ceiling effects and only a small number of items showing differential item functioning by grade level and student gender, race, or ethnicity (Crowder et al., 2019). The WCSD-SECA was developed over a 4-year period and validated for use in a wide range of grade levels and a broad range of student ability levels (WCSD, 2018). I gave this survey as a pre-unit assessment to gauge initial SEL skills and as a post-unit assessment to determine if growth in SEL skills occurred.

To strengthen the quantitative data collected regarding SEL skills via the WCSD-SECA surveys, I conducted teacher observations via a checklist and descriptive field notes (Appendix H) on each day of the PBL unit. Teacher observations also allowed for real-time data collection on observed student behaviors. Observations provide an authentic lens into what happens in a classroom environment (Efron & Ravid, 2020). I used a semi-structured approach, noting specific SEL skills such as social awareness and social skills on a checklist. I adapted the following items from CASEL (2022): (a) self-awareness, (b) self-management, (c) social awareness, (d) relationship skills, (e) responsible decision-making, (f) and other general observations, such as provides peer support and encouragement and shows a willingness to learn from mistakes.
Observations alone would not necessarily account for all five SEL skill competencies, so I also conducted focus group interviews. Focus groups are widely accepted as a qualitative research method due to their capability to gather in-depth data, allowing for a richer understanding and a more comprehensive exploration of the phenomenon being investigated (Adler et al., 2019). These interview formats prove valuable as participants engage in dialogue with each other, introducing diverse perspectives that can inspire and enhance each other’s thoughts. This dynamic interaction often leads to a wide spectrum of opinions (Efron & Ravid, 2020). Additionally, focus group settings have the potential to create a sense of comfort among students, thereby increasing their likelihood of active participation and vocal expression. Using purposive representative sampling, I attempted maximal variation when forming focus groups with four to six students, representative of a typical class makeup (Creswell & Plano-Clark, 2018). The focus group interviews occurred immediately after school or at lunch on days that each participant was willing to attend, and each interview lasted around 45 minutes. Focus group interviews took place in a collaboration room in our school library to create a relaxed and less intimidating atmosphere for the student interviewees. Throughout the focus group interviews, I ensured that after posing each question, I allowed for an appropriate amount of waiting time for each student. This deliberate pause allowed them to feel at ease and prevented any sense of being hurried as they formulated their responses. After each focus group interview, I presented every student with a typed transcript of their remarks and invited them to confirm the accuracy of their recorded responses. Students had the opportunity to revise or supplement their answers.
Focus group questions centered on the five SEL competencies. The goal was to capture student viewpoints regarding their experiences during the unit by examining them through the framework of these competencies (Appendix E). Finally, I collected qualitative data in student reflection journals. The instructions and prompts are in Appendix I.

Science Identity

To assess science identity, I dispensed pre- and post-unit surveys (Appendix J) to determine the extent to which students identified as scientists before and after the PBL unit. Inviting student self-report, I used a paper–pencil format instead of an online survey to ensure confidentiality and minimize accidental data leaks via online databases. The instrument I used was the Student Science Identity (SSI) questionnaire, which Chen and Wei (2020) developed and validated for use in a high school setting, emphasizing high construct validity and reliability. Furthermore, the instrument is appropriate for longitudinal studies of changes in student science identity. The SSI questionnaire consisted of 24 Likert-type questions where participants rated their level of agreement with each statement from Strongly Agree to Strongly Disagree.

I collected qualitative data via individual interviews. The main goals for the interviews were to visualize student perceptions of their socially constructed identities and to understand how their past and current experiences, particularly in the PBL unit, potentially influenced their sense of who they are in science contexts. I chose individual interviews to assess identity qualitatively because students may be more likely to disclose personal feelings in a one-on-one situation (Kruger et al., 2018). After each interview, I presented each student with a typed transcript of their remarks and invited them to
confirm the accuracy of their recorded responses. Students had the opportunity to revise or supplement their answers.

The interview questions, adapted from Cian and Dou’s (2022) child science identity interview guide, are located in Appendix K. Finally, I used student reflection journals to collect qualitative data. The prompts are included in Appendix I.

**Science Self-Efficacy**

I also used a survey instrument to measure self-efficacy, specifically the Self-Efficacy for Learning and Doing Science (SELDS; Appendix L), which researchers at Cornell University (n.d.) developed. The instrument measures an individual’s confidence in learning science topics and engaging in scientific activities. It contains eight items and a Likert scale of 1–5, where 1 is Strongly Disagree and 5 is Strongly Agree (Porticella et al., 2017).

I employed focus group interviews as a method for qualitative data collection. To choose these focus groups, I utilized purposive representative sampling with the goal of achieving maximal variation, resulting in groups of four to six students. These groups mirrored the class composition, following the approach outlined by Creswell and Plano-Clark (2018). I ensured flexible scheduling, accommodating participants’ availability either immediately after school or during lunch, with each interview lasting approximately 45 minutes. During the interviews, I deliberately incorporated pauses after each question to create a comfortable environment for students, ensuring they did not feel rushed as they formulated their responses. After each interview, all students received a typed transcript of their remarks and had the opportunity to review and confirm the accuracy of their recorded answers or revise or supplement their responses as necessary.
During these interviews, I used open-ended questions to guide discussions on students’ confidence levels regarding science practices and their ability to comprehend and engage in scientific activities. I modified questions from a prior study of self-efficacy in preservice teachers (Arcelay-Rojas, 2018) and organized them into distinct themes, including general background, mastery experiences, vicarious experiences, verbal persuasion, and affective states (see Appendix M). Additionally, I asked follow-up questions to further explore and clarify students’ responses, especially when their answers were incomplete or lacked detail. Finally, student reflection journals also yielded qualitative data.

**Data Analysis**

This study employed a mixed-methods research design, collecting quantitative and qualitative data. Mixed-methods research is increasingly popular due to its capacity to facilitate thorough, holistic data analysis, affording researchers a deeper, more nuanced understanding of the phenomena they are investigating (Ivankova & Wingo, 2018). In the context of this study, systematically gathering a diverse array of data types not only permitted triangulation but also enhanced the overall reliability of the findings (Creswell & Creswell, 2018; Creswell & Plano Clark, 2018). Table 3.3 presents the alignment of research questions, data collection sources, and data analysis.

Table 3.3 Alignment of Research Questions, Data Collection Sources, and Data Analysis

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Collection Sources</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1: How does incorporating PBL in a science classroom affect high school students’ SEL skills?</td>
<td>Quantitative:</td>
<td>Quantitative:</td>
</tr>
<tr>
<td></td>
<td>- Pre–post survey:</td>
<td>- Descriptive statistics</td>
</tr>
<tr>
<td></td>
<td>WCSD-SECA</td>
<td>- Wilcoxon sign-ranked test</td>
</tr>
</tbody>
</table>
Teacher observations
- Student reflection journals

Qualitative:
- Deductive coding
- Inductive coding
- Pattern coding

RQ2: How does incorporating PBL in a science classroom affect students’ science self-efficacy and identity?

Science Self-Efficacy:
Quantitative:
- Pre–post survey: SELDS

Qualitative:
- Focus group interviews
- Student reflection journals

Science identity:
Quantitative:
- Pre–post survey: SSI questionnaire

Qualitative:
- Individual interviews
- Student reflection journals

For both Science self-efficacy and Science identity:
Quantitative:
- Descriptive statistics
  - Wilcoxon signed-rank test and effect size test

Qualitative:
- Deductive coding
- Inductive coding
- Pattern coding

Quantitative Analysis

In the comprehensive exploration of the three distinct phenomena under scrutiny in this study—SEL skill development, science identity, and self-efficacy—I employed a meticulous and structured approach to analyze the pre–post quantitative survey data. The initial step involved the systematic input of the raw survey data for each of these phenomena into Microsoft Excel. This process ensured the data were organized and prepared for subsequent analysis.

For the WCSD-SECA instrument, the total scores for each participant were computed for both the pre and post-unit administrations. Moreover, considering the scale's distinct sub-scales for various SEL competencies, the responses within these
subsets were individually averaged, aligning with the recommendations of the survey creators (Washoe County School District, 2018). This approach facilitated an examination of whether participants demonstrated varying proficiency levels in the various SEL competencies. Similarly, for the SSI questionnaire, total scores were calculated for each participant pre- and post-unit.

For the SELDS instrument, I adhered to the data cleaning and scoring guidelines provided by the survey creators at Cornell University (2018). The initial step involved a meticulous data cleaning process to address potential inconsistencies in participant responses. After entering the data into Microsoft Excel, a working copy was generated, and several checks were implemented. Initially, each row was scrutinized to identify missing participant responses. Rows with over 25% missing responses were then excluded. Subsequently, a second examination of each row led to the exclusion of rows where all responses were identical, except in cases where all responses were threes, as participants may genuinely provide midpoint responses. After the data cleaning process was completed, the scores were computed following specific steps. Initially, responses for questions 3 and 7 underwent reversal, where 1's became 5's, 2's became 4's, 3's remained 3's, 4's became 2's, and 5's became 1's. Following this, the scores for each participant were totaled. Furthermore, since the scale comprises distinct sets of items for learning (items 1-4) and doing (items 5-8), the responses for these sets were separately averaged. This facilitated an investigation into whether participants exhibited varying confidence levels in one self-efficacy concept over the other.

After finishing initial raw data analyses, I transferred the prepared data sets into IBM SPSS Statistics (V29), a powerful statistical analysis software. Conducting
descriptive analysis, I computed the mean, median, and standard deviation. These essential statistical measures provided a comprehensive data snapshot, offering insights into central tendencies, data distribution, and variability. To visually convey the nuances and trends, I generated stacked bar charts that served as valuable tools for presenting the data’s distribution characteristics, helping to elucidate any notable shifts or patterns.

Next, I inferentially analyzed the data using the Wilcoxon signed-rank test, applying this nonparametric inferential statistical test to assess statistically significant differences between the pre- and post-unit data (Roberson et al., 1995). Subsequently, I computed effect sizes by dividing the z-statistic by the square root of the sample size (Fritz et al., 2011). These effect sizes served as indicators of the practical significance of the relationship between the PBL intervention and the respective variable under investigation.

Consequently, I conducted multiple distinct Wilcoxon signed-rank tests, accompanied by effect size calculations. This comprehensive approach illuminated whether the PBL unit statistically impacted SEL skill development, science identity, and student self-efficacy. Additionally, given that the SEL and science self-efficacy survey instruments consist of subskills, I performed separate data analyses for each subskill, contributing to a more detailed assessment of the effects.

**Qualitative Analysis**

Qualitative data came from individual student interviews, focus group interviews, student reflection journals, and teacher observations. All one-on-one interviews and focus group interviews were video recorded using Screencastify, with permission, to facilitate data analysis. To analyze the qualitative interview data, I grouped all recorded interviews
in each area under study (i.e., SEL skill development, science identity, and self-efficacy), transcribed the conversations, and then read the transcripts, checking for accuracy by following along with the video recordings and rectifying any errors before proceeding with data analysis.

I then proceeded to examine all the qualitative data using deductive and inductive coding methods with the assistance of NVivo (V14.23). Initially, I formulated a set of a priori codes aligned with my research inquiries and rooted in prior research as part of the deductive coding process. This approach facilitated the organization of the data into distinct categories based on data type, ensuring the trustworthiness of my study. While deductive coding helped structure the data in alignment with my research questions, I acknowledged that it might only capture a portion of the complete picture. To mitigate any potential researcher bias, I also employed jottings and inductive coding to uncover what naturally emerged from the data, without imposing a predetermined direction (Miles et al., 2014). The inductive codes reflected the frequency of words and phrases in individual student interviews, focus group interviews, student reflection journals, and teacher observations.

Combining deductive and inductive strategies made the data analysis more systematic and rigorous, enhancing the study’s reliability. Incorporating teacher observations, interviews, and student reflection journals allowed for data triangulation, resulting in more dependable and credible interpretations (Efron & Ravid, 2020). This data triangulation encompassed all three variables under investigation: SEL skills, science self-efficacy, and science identity.
Deductive Coding

Initially, I employed deductive, or a priori, coding methods to analyze the qualitative data collected from individual student interviews, focus group interviews, student reflection journals, and teacher observations. These a priori codes aligned with the research questions, focusing on three primary areas: SEL skills, science identity, and science self-efficacy.

To develop the a priori codes related to SEL skills, I conducted a comprehensive review of the CASEL (2022) framework, the WCSD-SECA survey instrument, and the teacher observation checklist. I extracted the key concepts and themes associated with each component from these sources and subsequently created categories, subscales, and codes that aligned with each data collection tool. I intended to craft these categories, subscales, and codes in a sufficiently specific way to accurately capture the data while maintaining a level of generality that would allow their application to various instances of the concept. Table 3.4 shows a detailed listing of the a priori codes I established for SEL skills, along with their definitions.

Table 3.4 A Priori Codebook for SEL Skills

<table>
<thead>
<tr>
<th>SEL Skill</th>
<th>A Priori Codes</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relationship Skills</strong></td>
<td></td>
<td>Skills that involve the ability to establish and maintain healthy and positive relationships with others.</td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td>Any exchange of thoughts, ideas, and feelings through talking, writing, or body language.</td>
</tr>
<tr>
<td>Relationship building</td>
<td></td>
<td>Any demonstration of making friends, getting along with classmates, and developing connections with teachers. Also including evidence of being friendly, considerate, and open to forming positive bonds with others.</td>
</tr>
<tr>
<td>Teamwork</td>
<td></td>
<td>Any evidence of collaborating with peers on assignments, projects, or extracurricular activities. Including students’ demonstrating clear communication, sharing responsibilities, and supporting each other to achieve common goals.</td>
</tr>
<tr>
<td>Responsible decision-making</td>
<td></td>
<td>The ability to make constructive choices about personal behavior and social interactions based on ethical standards, safety concerns, and social norms.</td>
</tr>
<tr>
<td>Analyzing situations</td>
<td>Any evidence of students’ being able to look at problems or challenges, understand their details, and think critically about possible solutions.</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Ethical responsibility</td>
<td>Evidence of students’ making good choices, being honest, and treating others fairly.</td>
<td></td>
</tr>
<tr>
<td>Identifying problems</td>
<td>Any instances where students recognize issues or difficulties in academics, relationships, or personal life.</td>
<td></td>
</tr>
<tr>
<td>Reflecting</td>
<td>Evidence where students think about their actions, experiences, and learning to ultimately make improvements and grow as students and people.</td>
<td></td>
</tr>
<tr>
<td>Solving problems</td>
<td>Any instances where a student uses their critical thinking skills to overcome challenges, whether related to homework, conflicts, or decision-making.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Self-awareness</th>
<th>The ability to accurately recognize and understand one’s own emotions, thoughts, and values.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate self-perception</td>
<td>Evidence where students show an understanding of their strengths and weaknesses realistically, aiding choices in academics and activities that suit their abilities and interests.</td>
</tr>
<tr>
<td>Identifying emotion</td>
<td>Evidence of students’ recognizing their own feelings and understanding the emotions of others.</td>
</tr>
<tr>
<td>Recognizing strengths</td>
<td>Any instances where students acknowledge their talents, skills, and positive qualities.</td>
</tr>
<tr>
<td>Self-confidence</td>
<td>Belief in oneself and one’s abilities.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social Awareness</th>
<th>The ability to recognize and understand others’ emotions, needs, and perspectives.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empathy</td>
<td>Understanding and caring about others’ feelings and perspectives.</td>
</tr>
<tr>
<td>Perspective-taking</td>
<td>The ability to put oneself in someone else’s shoes, seeing things from their point of view.</td>
</tr>
<tr>
<td>Respect for others</td>
<td>Evidence of students’ treating classmates, teachers, and staff with courtesy, kindness, and consideration. It includes valuing diverse backgrounds and opinions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Self-management</th>
<th>The ability to regulate one’s emotions, thoughts, and behaviors effectively.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-discipline</td>
<td>Any evidence of managing time, staying focused on studies, and avoiding distractions.</td>
</tr>
<tr>
<td>Self-motivation</td>
<td>Any demonstration of setting goals, staying enthusiastic about learning, and working toward achievements independently.</td>
</tr>
<tr>
<td>Stress management</td>
<td>Refers to techniques and strategies for coping with academic pressure, extracurricular commitments, and personal challenges.</td>
</tr>
</tbody>
</table>

To facilitate the development of a priori codes related to science identity, I conducted an extensive review of Carlone and Johnson’s (2007) definition of science identity and also examined the SSI questionnaire. From these sources, I identified the key concepts and themes associated with each component and proceeded to create categories, subscales, and codes that aligned with each data collection tool. I intended to formulate these categories, subscales, and codes in a manner specific enough to accurately capture...
the data and sufficiently general to make them applicable to various instances of the concept. A comprehensive list of the a priori codes established for science identity is in Table 3.5.

Table 3.5 A Priori Codebook for Science Identity

<table>
<thead>
<tr>
<th>Category</th>
<th>A Priori Codes</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Identity</td>
<td>Competence in science</td>
<td>Students’ ability to understand and apply scientific principles and knowledge effectively. It includes performing well in science courses, conducting experiments, and solving scientific problems with confidence.</td>
</tr>
<tr>
<td>Performance of science</td>
<td>Actively participating in scientific activities, such as conducting research projects and presenting findings. Emphasis is on hands-on engagement with scientific concepts.</td>
<td></td>
</tr>
<tr>
<td>Recognition of self as science person</td>
<td>Having a personal identity and sense of belonging in the field of science. It means feeling a genuine interest in science, seeing oneself as capable in the subject, and finding enjoyment in scientific exploration.</td>
<td></td>
</tr>
<tr>
<td>Recognition by others as a science person</td>
<td>Being acknowledged and respected by teachers, peers, and mentors for their enthusiasm and aptitude in science. It includes receiving validation and encouragement from the school community regarding their scientific interests and abilities.</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Science identity refers to an individual’s sense of belonging, identification, and self-concept as a person who is interested in, knowledgeable about, and capable of engaging with science. It encompasses how someone views themselves in relation to the world of science, their feelings of connection to the scientific community, and their belief in their capacity to participate in scientific activities.*

To support the generation of a priori codes linked to science self-efficacy, I conducted a thorough examination of Bandura’s (1997) research on self-efficacy and analyzed the SELDS survey instrument. From these sources, I identified the four key sources of self-efficacy and proceeded to create codes that aligned with the data collection tool. I intended to formulate these codes in a manner specific enough to
accurately capture the data and sufficiently general to make them applicable to various
instances of the concept. A comprehensive list of the a priori codes established for
science identity is in Table 3.6.

Table 3.6 A Priori Codebook for Science Self-Efficacy

<table>
<thead>
<tr>
<th>Self-Efficacy Component</th>
<th>A Priori Codes</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective States</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emotions</td>
<td></td>
<td>An individual’s emotional or affective responses in relation to a particular task, activity, or situation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A range of emotional and mood-related conditions students may experience. These states include emotions such as happiness, sadness, anger, fear, and stress, as well as mood fluctuations.</td>
</tr>
<tr>
<td>Mastery Experiences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning during unit</td>
<td></td>
<td>The specific instances within the instructional period when a student successfully comprehends and applies the subject matter.</td>
</tr>
<tr>
<td>Previous success</td>
<td></td>
<td>Instances in which a student has previously demonstrated proficiency or skill in a particular subject or related concepts.</td>
</tr>
<tr>
<td>Verbal Persuasion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peers</td>
<td></td>
<td>The influence of others’ words, encouragement, or feedback on an individual’s beliefs about their own capabilities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Students’ trying to influence each other using spoken words, arguments, or emotional appeals. This could include instances when one student encourages or convinces another to adopt a particular viewpoint, engage in specific behaviors, or make choices based on verbal communication. Peers can use various strategies like providing reasons, sharing personal experiences, or using persuasive language.</td>
</tr>
<tr>
<td>Adults</td>
<td></td>
<td>Involves adults, such as teachers, parents, or school staff, attempting to influence or motivate high school students through spoken communication.</td>
</tr>
<tr>
<td>Vicarious Experiences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family</td>
<td></td>
<td>The process of learning by observing the successes and failures of others.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Refers to students’ gaining knowledge, values, or attitudes by observing or learning from the experiences, actions, and behaviors of their family members.</td>
</tr>
<tr>
<td>Peers</td>
<td></td>
<td>Involves students’ learning from the experiences and actions of their fellow students. This could encompass situations where students observe and learn from their peers’ successes, failures, decisions, and behaviors.</td>
</tr>
</tbody>
</table>

*Note: Definitions per Bandura (1997).*
**Inductive Coding**

Inductive coding represents a more fluid and organic approach, where themes naturally surface during data analysis (Miles et al., 2014). In this method, I coded various data sources such as teacher observations, student reflection journals, individual interviews, and focus group interviews using NVivo (V14.23) software. NVivo allowed me to create codes that directly mirrored the students’ own expressions and words.

The coding process necessitates multiple iterations to refine and pinpoint the focal points within the data. Initially, I conducted a comprehensive review of all qualitative data sources and created jottings to capture my ideas and reflections (Miles et al., 2014). I then proceeded with open coding, creating codes based on the inherent information within the data. In subsequent rounds of coding, I identified emerging themes that organically emerged from the data. These identified themes then served as a foundation for extracting crucial qualitative data, including direct quotations and observational data, representing how the students responded to the PBL unit.

**Setting and Sample**

The setting for this study is a high school in a large, suburban school district in the Southeastern United States. The Archer High School (pseudonym) community includes suburban, rural, and military families. Retail and business growth in the area has increased steadily over the past few years, which is slowly creating a more urban profile. Currently, Archer High has a culturally diverse student body, with 44.5% identified as pupils in poverty and racial minorities making up 64% of the 2217 ninth through 12th graders. Approximately 51% of the students identify as Black, 31% White, 9% Hispanic, 6% Asian, and 3% other. Regarding socioeconomic levels, household incomes range
from 18% below $10,000 per year to 12% above $75,000. Within the past 3 years, the Hispanic enrollment has more than doubled, and the school has seen an increase in the number of lower-income families and a decrease of higher-income families moving into the area. In addition to comprehensive academic, special education, and career and technology education programs, Archer High School houses two magnet math and science programs, and the school is an Arts in Basic Curriculum site.

During the semester when the action research occurred, the student population in my AP Biology classes consisted of 56 total students: 30 students in one class and 26 in the second. Three students did not consent to participate, so the study sample consisted of 53 students. In one class, there were 27 participating students, and in the second class, there were 26. The student distribution consisted of 28 12th graders, 24 11th graders, and one 10th grader. These students spanned in age from 15 to 18 years. The gender breakdown comprised 21 males and 32 females. Regarding ethnicity, the group included 24 White students, 14 Black students, three Hispanic students, and 12 Asian students, originating from the Middle East, India, and the Far East. Most students were relatively homogeneous with regard to previous academic performance, as measured by weighted GPA. Analysis of unweighted GPAs revealed all students had at least a 3.5, with only 5 having over a 3.9. Two students had 504 accommodation plans, and 14 students were members of the Discovery Magnet program, an honors math and science magnet housed at our high school. Five students were in Explorations, a college preparatory magnet math and science program at our school. Six students did not meet the prerequisites for Biology II Honors and were waived into the course by their parents. The characteristics of the participants are included in Table 3.7.
Table 3.7 Demographics of Study Participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>32</td>
<td>60.4</td>
</tr>
<tr>
<td>Male</td>
<td>21</td>
<td>39.6</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>14</td>
<td>26.4</td>
</tr>
<tr>
<td>Asian</td>
<td>12</td>
<td>22.6</td>
</tr>
<tr>
<td>White</td>
<td>24</td>
<td>45.3</td>
</tr>
<tr>
<td>Hispanic</td>
<td>3</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>28</td>
<td>52.8</td>
</tr>
<tr>
<td>11</td>
<td>24</td>
<td>45.3</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Magnet program participation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honors program</td>
<td>14</td>
<td>26.4</td>
</tr>
<tr>
<td>College Prep program</td>
<td>5</td>
<td>9.4</td>
</tr>
<tr>
<td>Neither program</td>
<td>34</td>
<td>64.2</td>
</tr>
</tbody>
</table>

Note. \( N = 53 \). Only consenting student participants provided data. The student information database, PowerSchool, yielded demographic data.

I included 20 participants in the SEL focus groups, and interviewed 15 students individually to explore their science identity. Additionally, there were 20 participants in the science self-efficacy focus groups. The characteristics of these students appear in Table 3.8.
Table 3.8 Demographics of Focus Group and Individual Interview Participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Focus Group Participants</th>
<th>Individual Interview Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Asian</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>White</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td><strong>Magnet program participation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honors program</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>College Prep program</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Neither program</td>
<td>13</td>
<td>65</td>
</tr>
</tbody>
</table>

Note. N = 53. Only consenting student participants provided data. The student information database, PowerSchool, yielded demographic data.

**Initiating Research**

During the first few weeks of the course in August of 2022, I verbally informed students in my AP Biology classes of the research I would conduct during the spring semester. To obtain Institutional Review Board (IRB) approval from the University of South Carolina and permission from the school district, I created a descriptive cover letter and accompanying consent form (Appendix B). In mid-January 2023, I disseminated these items to all of my AP Biology students for them to read and share with their parents.
or guardians. I gave students a 3-week period to complete the forms. As the teacher of the course and the person in charge of assigning grades, I recognized I was in a position of power. Due to this potential influence, I ensured all students and guardians understood that participation was 100% voluntary and that there would not be any penalty for students who chose to opt out of the action research study.

I noted the students who granted permission, although all students took part in the PBL unit. However, I only collected data from those students who elected to participate in the study. To help with data collection, I established formal cooperative groups for those students who agreed to take part in the research and placed those who chose not to participate in a separate group. Formal cooperative learning includes groups of students working collaboratively on shared goals and assignments (Johnson et al., 2014).

For the duration of the study, I practiced reflexivity by revisiting my positionality and considering how it could influence the research process. Specifically, I kept a reflexive journal in which I logged a variety of events and happenings, including my decisions throughout the process and justifications thereof, what I derived from the data, who I am, my relationship to my students and the research at hand, and my value system. As an insider in this research process, I could have introduced ambiguity by simultaneously teaching and researching. The reflexivity journal helped me reflect on and limit my potential personal influence over the research process.

**Data Validity**

In any study, the researcher and their audience should be able to trust the data. To ensure trustworthy data that are reflective of the issue under investigation, a researcher must strive for data validity (Creswell & Creswell, 2018; Efron & Ravid, 2020). Data
validity pertains to quantitative and qualitative research; however, the approaches vary for each type. To ensure quantitative data validity, I purposefully chose surveys for this study that had been previously tested for content validity (Creswell & Creswell, 2018; Efron & Ravid, 2020). Additionally, the three instruments showed reliability over time.

Once I completed quantitative and qualitative data analysis, data triangulation gave me a panoramic view in line with the research questions. Focus group and individual interviews illuminated the PBL unit itself, the incorporation of SEL skills, and how to improve the unit for future use. The focus group interviews facilitated thick description directly from the students’ own words, which enhanced the trustworthiness of the data (Efron & Ravid, 2020). Finally, to ensure data validity, I recruited a colleague from my school to serve as a peer reviewer (Efron & Ravid, 2020). This individual was not a classroom teacher and was not familiar with my students; thus, they offered an unbiased perspective on my data, results, and conclusions. This person examined and coded 25% of the transcripts from the focus group and individual interviews. Once they finished, we were able to compare codes and came to a consensus.

I realize my student sample is not representative of the school nor the district. The small student population I enlisted for this study historically performs at a higher academic level as determined by GPA and is not representative in demographics nor socioeconomic status. Thus, my conclusions are only partially transferable to other settings. To avoid external validity threat, the results of this study only apply to the sample population. At the very least, the results may be partially transferable to other AP science classes in my school with similar student populations.
CHAPTER 4: FINDINGS

This research focused on assessing the influence of PBL on AP Biology students. The initial objective was to evaluate the effects of PBL in two key areas: the development of social and emotional skills and the enhancement of student science identity and self-efficacy. Consequently, when designing the PBL unit, I carefully incorporated SEL components throughout the unit. Additionally, I sought to investigate whether the implementation of PBL impacts the development of SEL skills in high school students and whether it strengthens their self-confidence and identity in the field of science. The research questions were:

1. How does incorporating PBL in a science classroom affect high school students’ SEL skills?

2. How does incorporating PBL in a science classroom affect students’ science self-efficacy and science identity?

Adopting a mixed-methods action research approach, integrating quantitative and qualitative data, yielded deeper insight (Creswell & Creswell, 2018; Creswell & Plano Clark, 2018). Specifically, I took an integrated, convergent approach by using qualitative and quantitative methods throughout the study to answer the same questions. Quantitative data came from three pre–post surveys on SEL skills, science identity, and science self-efficacy. Qualitative data gathered throughout the unit consisted of teacher observations and field notes and student reflection journals. I also collected qualitative data at the end
of the unit through focus group and individual interviews, posing questions related to SEL skills, science identity, and science self-efficacy.

Participants

As noted in Chapter 3, in mid-January 2023, I invited all 56 of my AP Biology students to participate in the study, giving them 3 weeks to decide in conversation with their parents or guardians. All students in the course took part in the PBL unit. However, I only collected data from those students who elected to participate in the study.

A total of 53 students returned consent forms. The students were primarily in 12th and 11th grades, with one 10th grader, aged between 15 and 18. The gender distribution included 21 males and 32 females, while the ethnic background featured a mix of White, Black, Hispanic, and Asian students from various regions (see Table 3.6). A few students had specific accommodations, while others were part of honors or magnet programs at the school. Additionally, some students were waived into the course by their parents due to not meeting Biology II Honors prerequisites.

PBL Unit

As noted in Chapter 3, I crafted a comprehensive, 3-week PBL curriculum, integrated with SEL components, for implementation in the context of this study. This specialized curriculum was thoughtfully designed to facilitate learning about molecular genetics by elucidating cancer’s genetic underpinnings. A comprehensive and detailed outline of the unit appears in Appendix A.

SEL skills were a deliberate part of the curriculum, integrated throughout different educational stages. Before delving into the subject matter, I emphasized key SEL competencies, particularly self-awareness and self-management. I administered an
identity inventory to encourage students to explore their self-awareness and work
tendencies within groups, aiding their collaborative efforts in the subsequent PBL unit. I
intentionally formed student groups to mix students and minimize close personal
connections.

Each group created a PBL Group Contract, fostering open discussions about
individual strengths and weaknesses within the group dynamics and promoting conflict
resolution strategies. To sustain SEL skill development, I introduced a daily reflection
journal and prompted students to reflect on various SEL competencies, such as evaluating
their contributions to group work, enhancing self-management skills in collaborative
tasks, and fostering empathy by considering the emotions of patients with specific cancer
diagnoses during genetic counseling sessions.

**RQ1 Findings**

**Quantitative Data**

To quantitatively evaluate the participants’ development of SEL skills, I
administered a pre–post unit survey, the WCSD-SECA in Appendix D. The robust, self-
report tool was designed to gauge eight distinct SEL competencies in fifth- to 12th-grade
students, drawing from the widely accepted CASEL 5 model (Crowder et al., 2019). The
survey comprises a total of 40 items with a Likert-type scale for students to rate the
perceived difficulty level of each statement: 1 = Very Difficult; 2 = Difficult; 3 = Easy; 4
= Very Easy. Consequently, a participant’s choice for each statement reflects their self-
assessment regarding their own proficiency in each of the eight SEL competencies. The
aggregate score ranges from a minimum of 40, indicating an individual perceives
themselves as encountering significant challenges across all competencies, to a maximum of 140, which implies mastery of every competency at the highest possible level.

Administration of the WCSD-SECA occurred prior to the PBL unit and immediately upon its conclusion, capturing the impact of the educational intervention. Despite having 53 willing student participants who consented to participate in the study, the final dataset for analysis consisted of 47 fully completed and appropriately matched pre–post surveys, due to some surveys’ being incompletely filled out and students’ occasional absence.

I entered the information from these 47 matched survey pairs into IBM SPSS Statistics software to comprehensively analyze the collected data. Through robust descriptive and inferential analysis, I derived valuable insights into the impact of the SEL-focused PBL unit on the participants’ SEL skill development. Descriptive analysis allowed for the examination of central tendencies and variability in the data, providing an initial overview of the changes in SEL competencies among the participants. Inferential analysis, on the other hand, enabled exploration of the statistical significance of these changes and whether they were attributable to the intervention.

The median overall score on the assessment at the start of the unit was 118, out of a maximum score of 140. At the end of the unit, the median score increased to 122. A Wilcoxon signed-rank test revealed a statistically significant increase in total SEL score following participation in the PBL unit, $Z = -4.461$ and $p < 0.001$, with a moderate effect size ($r = 0.46$). I also observed statistically significant improvements in each subscale. Although each subscale showed statistically significant improvements in scores, effect size calculations suggest the PBL unit had a large effect in only four SEL competency
areas: responsible decision-making ($r = 0.57$), relationship skills ($r = 0.57$), self-management: school work ($r = 0.55$) and self-management: goal management ($r = 0.49$).

Effect size calculations show the PBL unit had moderate effects for the SEL areas of emotion regulation ($r = 0.44$), and social awareness ($r = 0.39$), and low-moderate effects for the SEL areas of emotion knowledge ($r = 0.22$), and self-concept ($r = 0.26$). Data appear in Table 4.1.

Table 4.1 WCSD-SECA Pre–Post Data With Statistical Significance and Effect Size

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Wilcoxon Signed-Rank Test</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>SD</td>
<td>Median</td>
<td>SD</td>
</tr>
<tr>
<td>SEC Overall Score</td>
<td>118</td>
<td>13.37</td>
<td>122</td>
<td>14.58</td>
</tr>
<tr>
<td>SEL Competency Subscale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-concept</td>
<td>2.75</td>
<td>0.44</td>
<td>3.00</td>
<td>0.53</td>
</tr>
<tr>
<td>Emotion Knowledge:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social awareness</td>
<td>3.00</td>
<td>0.42</td>
<td>3.20</td>
<td>0.42</td>
</tr>
<tr>
<td>Emotion Regulation</td>
<td>2.50</td>
<td>0.51</td>
<td>2.75</td>
<td>0.51</td>
</tr>
<tr>
<td>Self-management:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goal management</td>
<td>2.75</td>
<td>0.58</td>
<td>3.00</td>
<td>0.55</td>
</tr>
<tr>
<td>Self-management:</td>
<td>2.67</td>
<td>0.56</td>
<td>3.00</td>
<td>0.53</td>
</tr>
<tr>
<td>School work</td>
<td>3.00</td>
<td>0.42</td>
<td>3.33</td>
<td>0.44</td>
</tr>
<tr>
<td>Relationship skills</td>
<td>3.00</td>
<td>0.53</td>
<td>3.60</td>
<td>0.46</td>
</tr>
</tbody>
</table>

*Note. $N = 47$. I calculated $r$ by dividing the z-score by the square root of the total number of observations over the two time points (94). If a $p$-value is less than 0.05, it is flagged with one star (*). If a $p$-value is less than 0.01, it is flagged with 2 stars (**). If a $p$-value is less than 0.001, it is flagged with three stars (***).
Qualitative Data

The study included three sources of qualitative data on SEL skill development: focus group interviews, student reflection journals, and teacher observations. Focus groups reflected purposive representative sampling. I attempted maximal variation when forming groups with four to six students, each representative of my classes (Creswell & Plano-Clark, 2018). The focus group interviews occurred immediately after school or at lunch on days when each participant was willing to attend, and each interview lasted around 45 minutes. I conducted six separate interviews at the end of the PBL unit to assess student perceptions of their social and emotional skills.

I also conducted periodic observations over the course of the 3-week PBL unit, totaling 10 days of observations: 9 days when students were actively engaged in group work and the day designated for the public product presentation, when the groups interacted with their “patients” and conducted a simulated genetic counseling session. I also collected student reflection journals for each student who consented to participate in the study. There were 18 deductive and 54 inductive codes, totaling 72 unique codes.

Deductive and Inductive Analysis

The initial analysis phase included deductive coding, using predefined or a priori codes based on the five CASEL (2022) SEL competencies: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. See Chapter 3 for an elaborate account of the development of these codes. To initiate deductive analysis, I incorporated focus group interview transcripts into NVivo (V14.23). I approached each interview transcript separately, coding them one by one. Afterward, I revisited and adjusted the coding of the first interview transcript after coding the second
one. To ensure consistency, I repeated this method for each interview transcript, observing the emergence of themes as I continually analyzed the data.

Subsequently, I executed two successive rounds of the same coding procedure to ensure comprehensive coverage of all relevant deductive codes within the transcripts. During the third round of deductive coding, I began to discern and manually captured recurring words and phrases that permeated the dataset, visually representing emerging themes and concepts as jottings (Miles et al., 2014). I realized I could have managed this entire process in NVivo, yet I felt more at ease operating manually. The jottings served as the cornerstone for the subsequent phases of analysis.

For the next coding stage, in-depth examination of the jottings paved the way for the first round of inductive coding in NVivo (V14.23). This iterative process captured the essence of the data by assigning codes to sentences that encapsulated unique perspectives, experiences, and conceptualizations. The coding schema encompassed in vivo coding, which entailed using participants’ language to encapsulate their experiences; process coding, which delineated sequential steps or actions; emotion coding, which identified emotional nuances in the data; and value coding, which surfaced underlying values and beliefs in the narratives (Miles et al., 2014).

Next, I incorporated teacher observation notes into NVivo (V14.23), initiating another round of deductive coding using the established codebook. Two rounds of deductive coding of the teacher observation notes, followed by an additional round of deductive coding of the focus group transcripts, enabled the transfer of valuable insights, enhancing the depth and breadth of the information in the latter. Additionally, I applied the inductive codes developed during the initial cycle of coding for the focus group
interviews to the teacher observation notes, incorporating any novel recurring phrases and words in the teacher observation notes into the inductive coding framework.

Finally, I integrated student reflection journal entries into NVivo (V14.23) for analysis. Similar to prior cycles, I executed three rounds of deductive coding. The cyclic approach ensured thorough scrutiny of all data. I then revisited the focus group interviews and teacher observation notes for another coding round, applying the inductive codes developed during the initial phase to all three qualitative data sources and integrating any new recurring words and phrases from the student reflection journals into the inductive coding framework. Appendix O includes a list of the inductive codes for SEL.

A final round of analysis synthesized the collective meaning derived from coding all three data sources. This approach integrated both deductive and inductive coding methods, enhancing the rigor and validity of the analysis. The iterative nature of this process offered several advantages. First, it minimized the influence of preconceived notions and biases, ensuring I approached the data with fresh perspectives in successive coding rounds (Saldaña, 2022). This iterative approach also facilitated continual extraction of new insights and information as coding progressed, ensured no subtleties or critical elements were overlooked, and enabled thorough exploration of the entire dataset’s spectrum of insights. In essence, this systematic coding methodology, facilitated by the flexibility of NVivo (V14.23), permitted comprehensive exploration of the qualitative data. It uncovered not only what participants conveyed but also the underlying emotions, processes, and values that enriched my understanding of the phenomenon.

I integrated the observational data I collected throughout the unit using a checklist with the coded focus group interviews and student reflection journal entries to gain a
deeper understanding of the SEL skills demonstrated during the unit. Pattern coding surfaced recurring patterns and themes within the entire qualitative dataset (Miles et al., 2014). The ensuing themes are presented in Table 4.2, and more detailed descriptions of the students’ experiences during the PBL unit follow.

Table 4.2 SEL Skill Competencies and Identified Themes

<table>
<thead>
<tr>
<th>CASEL SEL Competencies</th>
<th>Themes Identified Using Coding From Interviews and Reflection Journals</th>
<th>Themes Identified Using Teacher Observations</th>
<th>Percent of Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationship skills</td>
<td>Stronger peer relationships, communication, supportive group dynamics, conflict resolution</td>
<td>Group dynamics increased over time, frustrations decreased over time, student communication was frequent</td>
<td>45%</td>
</tr>
<tr>
<td>Self-management</td>
<td>Stress management, organizational skills, goal setting</td>
<td>Goal setting, stress management</td>
<td>19%</td>
</tr>
<tr>
<td>Self-awareness</td>
<td>Personal health awareness, knowing one’s strengths, recognizing emotions</td>
<td>Knowing strengths</td>
<td>15%</td>
</tr>
<tr>
<td>Social Awareness</td>
<td>Becoming bone marrow donor, empathy toward “patients,” not wanting to let peers down</td>
<td>Empathy toward cancer patients and family members</td>
<td>11%</td>
</tr>
<tr>
<td>Responsible decision-making</td>
<td>Time management, problem-solving, making good decisions about personal health</td>
<td>Work on project during class time</td>
<td>10%</td>
</tr>
</tbody>
</table>
Discussion of Themes

Research Question 1 sought to investigate the impact of the PBL unit on SEL skills. Qualitative data analysis unveiled one prominent SEL competency: relationship skills. Among all the codes, a substantial 45% pertained to relationship skills. In contrast, self-management accounted for 19% of the codes, self-awareness for 15%, social awareness for 11%, and responsible decision-making for 10%. Consequently, the ensuing discussion commences with an exploration of the themes related to relationship skills, followed by examination of themes identified within the other SEL competencies, along with supporting evidence from the three qualitative data sources.

Relationship Skills

A recurring theme that emerged from all sources of qualitative data was communication. Effective communication skills were crucial during the PBL unit, especially in group work and interactions with the patient during the counseling session. This is evident in quotes from focus group interviews: “[Communication] is really important, especially in group work. Some of the group members were more introverted and I had to make sure to communicate effectively. Also communication was really important for the genetic counseling session with the patient” (1-FG1) and “We had to collaborate and work on things together. We had to figure out how to interact and work out our differences” (3-FG3).

Other students stated that the PBL unit improved their communication skills: “Typically I am a very shy person and hate group work. Working with my group so far has been very easygoing and helps my communication skills” (12-RJ). A different student stated, “I feel like I’ve gotten better at communicating ideas. Often during group
projects I either do what I’m thinking or just listen to someone else, but during this unit I feel like I’ve voiced my opinions more and it’s helped a lot” (26-RJ).

Students felt communication skills were important for collaborating effectively with their peers. Additionally, students reported developing stronger relationships with their peers during the unit and cited opportunities to get to know classmates with whom they had not interacted before. Student statements include: “We were grouped with people we didn’t necessarily know and it helped me get to know new people” (1-FG5) and “I came in new at the semester and I didn’t know anyone in the class. I really got to know them on a personal level during the 3 weeks since we worked together the entire time. It was nice” (3-FG1).

Disagreements within groups were minimal, and when they occurred, students worked together to reach a consensus. For example, a student said, “It worked out but we weren’t sure what to do so we voted majority, so that we didn’t disagree” (2-FG3). Many students took on leadership roles in their groups, whether by initiating plans or coordinating tasks. Frustration was relatively rare, but when it occurred, it typically resulted from concerns about group members’ not contributing or coordinating effectively. For example, one student said, “When a group member didn’t submit their part on time and did not know what they were doing, it was frustrating. Communication was good most of the time but right then it was hard” (3-FG5). Overall, students felt supported by their group members, and they tried to support others as well.

**Self-Management**

A recurring pattern that emerged involved many students’ (n = 11) being driven by their desire to contribute to their group and avoid disappointing their peers. One
student expressed this sentiment, stating, “I tend to procrastinate, so I felt compelled to complete the task to avoid letting my group members down. If it were just for me, I wouldn’t feel the same level of concern” (2-FG1). Another emphasized, “I’ve personally evolved to become more responsible because my team relies on me to complete the work” (1-FG3). The collaborative nature of group work prompted students to be more self-aware about their responsibilities and deadlines. Additionally, students mentioned that they had to exercise self-discipline to effectively manage their time and overcome procrastination during the project.

**Self-Awareness**

Several discernible themes related to self-awareness emerged during the coding process: personal health awareness, preventative measures, personal responsibility for health, and emotional awareness. Twelve students demonstrated increased self-awareness regarding their personal health, acknowledging the importance of consistent self-care for their bodies. For example, one student wrote in their reflection journal, “I think I have become more aware of my body and that I need to take care of it regularly” (3-RJ).

Six students discussed an enhanced awareness of actions they could take to reduce the risk of cancer. They mentioned measures such as minimizing UV exposure, moderating alcohol intake, and avoiding smoking. One student’s reflection exemplified this theme: “I think I have also become more aware of what measures I can take for myself that can prevent cancer, such as preventing UV exposure, alcohol intake, smoking, etc.” (32-RJ). These entries indicated the influence of the PBL unit on students’ awareness of cancer prevention.
A strong recurring theme centered on personal responsibility for one’s health. Many students \((n = 29)\) acknowledged their capacity to make choices and take action to safeguard their well-being. This theme emphasized the students’ realization of their role in maintaining and promoting their health. For instance, one student pointed out, “I have started to realize my bad habits more…and [because of what they learned] the implications have just become more serious” (1-RJ). Another student expressed a similar idea, stating, “[I need to] make sure that I don’t develop habits that might lead me to developing cancer in the future when I get older” (5-RJ). Yet another student shared, “I have become more aware of my body and that I need to take care of it regularly” (16-RJ).

Additionally, a theme related to emotional awareness emerged, with students recognizing a range of emotions during different phases of the PBL unit. These emotions spanned from nervousness and anxiety to excitement at the outset. For example, students expressed feelings “a little overwhelmed but excited to learn” at the start of the unit (3-FG2). Another was “a little excited but super nervous too” (2-FG5). Still another described the unit as “Intimidating because it was so far removed from what we had done before. Didn’t know what to expect” (4-FG4). By the end of the unit, students reported accomplishment, pride, happiness, and relief. Such responses included, “accomplished and much better!” (2-FG4), “Really proud of myself and our group” (1-FG5), and “Happy that we were successful” (3-FG1). This theme highlighted students’ growing awareness of their emotional responses and transitions throughout the PBL experience.

**Social Awareness**

Students demonstrated enhanced social awareness, notably in the realm of empathy. A considerable number \((n = 16)\) shared their experiences of developing
empathy toward individuals battling cancer and their family members and expressed an increased ability to connect and engage in conversations with them regarding their circumstances. For example, a student said, “I feel I have become more empathetic toward those who are diagnosed with serious disorders because I realize it could happen to anyone. I also feel more comfortable talking to a patient or family member about their cancer diagnosis” (44-RJ). Another student stated, “I feel like I am more aware of how many people are affected by not only having cancer but by knowing individuals who have had it and/or have it” (9-RJ).

Moreover, a subset of students (n = 9) acknowledged their awareness of their fellow group members’ personality traits and described consciously adapting their personal behaviors accordingly. For example, one student observed some group members “were more introverted,” prompting them “to take on more of a leadership role” (2-FG4), and another said, “One of my group members was new to our class and she didn’t know us at all. I made sure to help her feel included” (3-FG1).

As is evident, this unit facilitated students’ recognizing the influence of their personal choices on others. As an illustration, a student expressed a heightened awareness of how their individual actions can affect others: “I have also made more observations and realizations on the identities of other people and how my actions can affect their feelings” (18-RJ).

**Responsible Decision-Making**

Interestingly, but perhaps not surprising, quite a few students (n = 6) noted their intention to make better personal health decisions moving forward to reduce their risk of cancer. One student stated, “I think I have become more aware of my body and that I
need to take care of it regularly. I have also realized how common cancer is for people who have lived healthy lives” (3-FG4). Another stated, “Through this unit I’ve been able to be more thoughtful about the choices I make each day that could potentially increase my chances of developing cancer” (11-RJ). Also, “I think that I have become better at making decisions since environmental conditions can affect the development of cancers, so it is important for me to eat healthy and exercise” (50-RJ). Students also exhibited a tendency to consider the implications for their team before arriving at a choice, as evident from this statement in a reflection journal: “I need to think about the impact on my fellow group members before reaching a decision” (6-RJ).

**RQ2 Findings**

**Science Identity Findings**

To quantitatively measure science identity, I dispensed a pre–post survey, the SSI questionnaire, developed and validated for use in a high school setting (Chen & Wei, 2020). I collected qualitative data via individual interviews at the conclusion of the unit. I sought insight into student perceptions of their socially constructed identities and to understand how their past and current experiences, particularly in the PBL unit, potentially influenced their sense of who they are in science contexts.

**Quantitative Data**

The SSI questionnaire consisted of 24 Likert-type questions where participants rated their agreement with each statement from Strongly Agree (5) to Strongly Disagree (1). The higher the score on the SSI, the more a student identifies as a scientist; conversely, the lower the score, the less a student identifies as a scientist. Of the 52 students who supplied pre- and post-unit survey data, the pre-unit median score was 93.5,
which averages to a 3.89 response between Neutral and Agree. The minimum score was 60, and the maximum score was 116. Post-unit data showed an increase in median score to 103, which averages to a 4.29 response between Agree and Strongly Agree. The minimum post-unit score was 66, and the maximum increased to 118 (see Table 4.3).

Table 4.3 Descriptive Statistics for Science Identity Pre- and Post-Unit SSI Scores

<table>
<thead>
<tr>
<th></th>
<th>$N$</th>
<th>Median</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Identity Pre</td>
<td>52</td>
<td>93.5</td>
<td>13.04</td>
<td>60.00</td>
<td>116.00</td>
</tr>
<tr>
<td>Science Identity Post</td>
<td>52</td>
<td>103.00</td>
<td>13.21</td>
<td>66.00</td>
<td>118.00</td>
</tr>
</tbody>
</table>

I used a stacked bar chart (Figure 4.1) to visually represent the alterations in responses from the pre-unit to the post-unit science identity survey. A notable shift in responses is evident: initially, 20% of students strongly agreed, whereas in the post-unit survey, this number increased to 38%. Furthermore, there was a decrease in the number of students selecting Strongly Disagree and Disagree in the post-unit survey.

Note. $N = 52$

Figure 4.1 Stacked Bar Chart for Science Identity Pre and Post-Unit SSI Responses
I conducted a Wilcoxon signed-rank test to determine whether the PBL unit affected the science identity survey score. The results indicate a statistically significant difference between the science identity survey score before the PBL unit (Median = 93.5; SD = 13.04) and after the PBL unit (Median = 103; SD = 13.21), [Z = -4.999, p < 0.001]. An effect size calculation found that $r = 0.49$, indicating the PBL unit had a moderate to large effect on the science identity score improvement.

**Qualitative Data**

Individual interviews facilitated qualitative assessment of identity, given that students may be more likely to disclose personal feelings in a one-on-one situation (Kruger et al., 2018). After interviewing the 15 students who agreed to participate in individual interviews, I loaded the transcripts into NVivo (V14.23) software and then coded and analyzed for themes and connections. A priori coding followed Caroline and Johnson’s (2007) description of the major influences for science identity: recognition of self as a science person, recognition by others as a science person, competence, and performance. I applied initial coding to all 15 transcripts using predefined deductive codes in the first round and repeating this deductive process three times. Subsequently, I conducted three rounds of in vivo coding to capture fresh insights in the students’ own words, as suggested by Miles et al. (2014).

Moving to the next stage of qualitative analysis, the student reflection journal entries, which I had previously uploaded into NVivo (V14.23), underwent initial coding using the preestablished a priori codes for science identity. Three complete rounds of deductive coding ensured data validity and identified all potential occurrences of the
codes. Following this, three rounds of in vivo coding captured additional novel insights expressed in the students’ own language.

Once first-cycle coding was complete with both individual interviews and reflection journal entries, second-cycle pattern coding enabled me to identify recurring themes within the qualitative dataset. The themes that surfaced during the pattern coding phase resembled certain preestablished a priori codes from deductive coding. These encompassed themes like the acknowledgment of oneself as a science enthusiast, acknowledgment by others as someone interested in science, and themes related to competence and performance.

However, alongside these familiar themes, a number of novel themes also emerged. These included the concept of interconnectedness, the fundamental nature of science, the integration of science into everyday life, a strong desire for continuous learning, and a keen interest in pursuing a career in science in the future. The subsequent sections provide an in-depth exploration of these themes, featuring direct quotations from the students to elucidate their perspectives.

**Recognition of Self as a Science Person.** Qualitative analysis revealed that some students \((n = 5)\) expressed a strong interest in science, with a curiosity about how things work and a belief that there is always more to learn. Others \((n = 6)\) shared their varying degrees of interest in science, with some feeling curious and excited about it, while others \((n = 4)\) saw themselves as science enthusiasts but not necessarily scientists. A few students \((n = 3)\) did not consider themselves scientists at present but were interested in possibly becoming one in the future. Student responses indicate they believe being good at science requires critical thinking skills, understanding concepts, and the ability to apply
scientific knowledge to real-life situations. When asked, “Do you think of yourself as
good at science?,” one student said, “I am better now; this class has made me better at it!”
(2-II), and another said, “This class, for sure. Not physics [laughs]. But definitely
biology…it makes sense” (5-II). Several students who self-identified as individuals with
a strong affinity for science elaborated on the reasons behind their self-perception. They
cited their high academic performance and their ease in assuming leadership positions
within laboratory settings and group work as key factors contributing to their self-
identification as “science people.”

Overall, the PBL unit positively influenced students’ views of themselves as
learners of science. One student said, “I realize that if I don’t understand something, I can
figure it out. This has helped me realize that” (11-II). Another stated:

When we first heard about what we were going to do, I was really intimidated and
I didn’t know how we would do this. I thought it was going to be really
challenging. But through the unit I realized that I can learn this and it’s not as
hard as I thought it would be. I underestimated myself. When we figured out what
cancer it was by ourselves, I was really proud of myself. The entire unit helped
me not underestimate myself so much with science. (14-II)

Still another student said, “[This unit] made me understand that there are other ways to
learn and that I can figure out things on my own” (13-II).

**Recognition by Others as a Science Person.** Asking, “Do you believe that others
might perceive you as proficient in science? If so, who might these individuals be, and
what do you think leads them to hold this perception?” yielded a range of responses. Nine
students mentioned that their peers considered them to be adept in science. One student
articulated, “In this class, yes, but not so much last year. I’ve taken on leadership roles in labs and class activities, particularly in the cancer unit, which has contributed to this perception” (1-II). Another student noted, “Yes, my friends and classmates view me this way. I’m known for asking questions frequently and consistently achieving good grades” (8-II). Other factors students cited included their accomplishments in biology, their academic grades, their leadership roles in laboratory work, and their active participation by asking numerous questions during class.

In response to the same set of questions, another student had a different perspective, stating, “Not really because I don’t really show it” (7-II). When asked to elaborate, the student explained, “I’m not sure. I mean, if you look at me, I’m pretty shy and don’t talk too much. I guess that’s why.” This student attributed their perception of not being seen as proficient in science to their shy, relatively quiet demeanor.

The concluding product presentation, during which student groups conducted genetic counseling sessions, may have also played a role in how others perceived them as individuals with a strong connection to science. To illustrate, one student shared that their “patient” had “said I acted like a REAL doctor! I feel a great sense of achievement” (32-RJ). Another student mentioned, “Mrs. XX mentioned that she felt as if she were in a real doctor’s office with actual genetic counselors” (17-RJ). Comments of this nature could have boosted students’ confidence in being acknowledged as individuals with a strong affinity for science.

**Competence.** The PBL unit notably impacted students’ competence, their knowledge of science skills, concepts, and practices. Insights from individual interviews and students’ reflection journals indicated a substantial influence. Many students ($n = 45$)
expressed a sense of accomplishment and a successful grasp of genetic and cancer-related concepts. For instance, one student mentioned, “I feel confident in my ability to explain difficult subjects like this” (15-II). In a reflection journal entry, another student shared, “I find it interesting that these mutations occur. Even though our body has all these fail-safes, cancer still occurs, and mutations are still not caught” (34-RJ). Another journal entry reflected:

I have learned so much since I started this unit. I would say that the thought of a cancer diagnosis scares people so much since they know so little about cancer and automatically think that it is a death sentence when most of the time it isn’t when caught at the right time. (50-RJ)

Furthermore, some students believed they acquired valuable insights into how to excel in their science education. For example, one student advised, “Keep confidence in yourself and tell you that you can learn!” (7-II), and another credited the PBL unit for “show[ing] me that if I researched enough on my own and spent some time learning it, I can understand!” (1-II). Another student commented, “The entire unit helped me not underestimate myself so much with science” (13-II).

**Performance.** The component of science identity referred to as performance encompasses the successful execution of scientific practices in a social context. Throughout the unit, students had the opportunity to experience and demonstrate their competence, with a notable highlight being the public presentation of genetic counseling sessions toward the end of the unit. A substantial number of students \( n = 25 \) expressed a sense of accomplishment both during and after these sessions. In their reflection journals,
students recorded instances such as, “I was good at explaining treatment options for the cancer to the patient” (12-RJ), and:

I feel like our group did well on the products as well as how we presented information to our patient. I say this because our products like the pamphlet came out looking really nice. Also, our delivery to the patient while talking to them went well because of the empathy we expressed and how we presented the information. (23-RJ)

Still another said:

My group did well on the research part as we didn’t need to look back at the script for help during the counseling session and also that we were able to answer questions that weren’t part of the script from the research we did. (26-RJ)

Additionally, one student mentioned in an interview, “My group performed well in the research aspect; we didn’t need to refer to the script for guidance during the counseling session, and we could answer questions beyond the script thanks to our research” (49-RJ). This demonstrates that the students felt their performance in the unit had enhanced their confidence and competence in engaging with scientific practices and communicating scientific information effectively.

**Interconnectedness.** Another thematic aspect that surfaced during the coding process was the idea of interconnectedness. The PBL unit expanded students’ views regarding the interrelatedness of scientific principles. Students conveyed that the unit led them to recognize that science is more intertwined with daily existence than they had previously perceived. To illustrate, one student remarked during their interview, “I like thinking about how we all do science by how we think and live our lives. This unit really
showed me that” (3-II). Another student remarked, “I really see now how science affects our everyday lives” (9-II). Yet another student said the unit helped them “understand how all the units are correlated and how science is all interconnected. Everything is more connected than I initially think it is” (2-II). Another student said, “There is a lot that hasn’t been discovered” (11-II), and yet another stated, “I think I have become more confident in applying science to real-life situations and connecting what I learn to previous information” (6-II).

**Nature of Science.** Another prominent theme that emerged during the coding process was the concept of the ever-evolving nature of science and its inherent incompleteness. Students conveyed a newfound awareness of how science, by its very essence, is a perpetual journey of discovery. For instance, one student credited the unit for illuminating the “layers to all aspects of science,” adding, “It’s crazy how specific you can get with biology and science in general. The unit helped to show how much is out there to know. And yet to know! It helped broaden my understanding” (7-II). Another student said, “It gave me insight as to why scientists do what they do” (2-II), and yet another stated, “It was eye-opening and I learned a lot. This is something that should be better funded” (14-II).

**Desire to Learn More.** The theme of students’ expressing a strong desire to continue their learning journey was evident in both the reflection journal entries and individual interviews. This theme pertains to students’ natural inclination and motivation to further their knowledge and experiences in the field of science. It underscores the degree to which individuals are motivated to delve deeper into scientific concepts and subjects. Some students expressed sentiments like “[The unit] made me want to do it
more” (4-II) and “I wish it would go on!” (12-II), while others conveyed, “I’m excited to keep working at understanding and learning more” (17-RJ).

**Future Possible Selves.** This component of science identity pertains to how students envision their prospective roles and identities within the realm of science (Chemers et al., 2011; Vincent-Ruiz & Schunn, 2018). It encapsulates the degree to which students perceive themselves as potentially embarking on a career or life path intertwined with science. Individual interviews and student reflection journals surfaced several ($n = 4$) expressions of genuine interest in pursuing a future in science. For instance, one student shared, “Having the opportunity to step into the shoes of a genetic counselor truly made me believe that I can aspire to be one someday!” (13-II). This illustrates how students’ engagement in the unit fueled their aspirations and led them to consider science-related careers as part of their future selves.

**Self-Efficacy Findings**

To quantitatively measure science self-efficacy, I administered a third pre–post survey, the SELDS in Appendix L (Cornell University, n.d.). Qualitative data derived from focus group interviews as open-ended questions guided discussion into how confident students feel with their ability to engage in science practices and their ability to understand and do science. The interview questions reflected the following categories: general background, mastery experiences, vicarious experiences, verbal persuasion, and affective states (Appendix M).

**Quantitative Data**

The SELDS instrument measures an individual’s confidence in learning science topics and engaging in scientific activities. It contains eight items and a Likert scale of 1–
5, where 1 is Strongly Disagree and 5 is Strongly Agree (Porticella et al., 2017). The higher the score on the SELDS, the more a student feels confident in their ability to do science; conversely, the lower the score on the SELDS, the lower confidence a student has in learning and doing science. The survey also has two subscales: learning and understanding science and doing science activities. Although 52 students participated in the survey, only 47 provided complete datasets for analysis.

The median score for the entire pre-unit survey was 30, which averages to a 3.75 response between Neutral and Agree. The minimum score was 18, and the maximum score was 40. Post-unit data showed an increase in mean score to 33, averaging to a 4.125 response between Agree and Strongly Agree. The minimum post-unit score was 25, and the maximum score was 40 (see Table 4.4 and Figure 4.2).

<table>
<thead>
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<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
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<tr>
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<td>5.33</td>
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<td>30</td>
</tr>
<tr>
<td>Self-efficacy Post</td>
<td>47</td>
<td>4.06</td>
<td>25</td>
<td>40</td>
<td>33</td>
</tr>
</tbody>
</table>

Figure 4.2 shows the stacked bar chart constructed to visually represent the changes in responses observed between the pre-unit and post-unit science self-efficacy survey. The chart clearly illustrates a significant shift in responses. Initially, only 16% of students strongly agreed with the statements, but in the post-unit survey, this percentage increased substantially to 45%. Conversely, there was a noticeable decrease in the number of students who chose Strongly Disagree and Disagree in the post-unit survey, dropping from 14% to just 2%.
Note. *N* = 47

Figure 4.2 Stacked Bar Chart for Pre–Post Science Self-Efficacy by SELDS Responses

I conducted a Wilcoxon signed-rank test to determine whether the PBL unit affected the science self-efficacy instrument score. The results indicate a statistically significant difference between the science self-efficacy survey score before the PBL unit (Median = 30; SD = 5.331) and after the unit (Median = 33; SD = 4.055), [Z = -4.870, *p* < .001]. An effect size calculation found that *r* = 0.50, indicating the PBL unit greatly affected the science identity score improvement.

To further examine student performance on the SELDS subscales, I separately analyzed the Learning and Understanding and the Doing Scientific Activities subscale scores. The median score for the pre-unit Learning and Understanding Science sub-scale was 3.75, correlating to a response between Neutral and Agree. The minimum score was 1.5, and the maximum score was 5. Post-unit data showed an increase in mean score to
4.00, correlating to a response of Agree. The minimum post-unit score was 2.25, and the maximum score was 5 (see Table 4.5).

Table 4.5 Descriptive Statistics for Pre–Post Learning and Understanding Subscale

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Median</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Learning &amp; Understanding</td>
<td>47</td>
<td>3.75</td>
<td>0.75</td>
<td>1.50</td>
<td>5.00</td>
</tr>
<tr>
<td>Post Learning &amp; Understanding</td>
<td>47</td>
<td>4.00</td>
<td>0.66</td>
<td>2.25</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Figure 4.3 depicts the stacked bar chart constructed as a visual representation of the changes in responses between the pre-unit and post-unit learning and understanding science subscale. It shows students felt more confident in their ability to learn and understand science after the PBL unit. The chart clearly illustrates a significant shift in responses. Initially, only 16% of students strongly agreed with the statements, but in the post-unit survey, this percentage increased substantially to 42%. Conversely, there was a noticeable decrease in the number of students who chose Strongly Disagree and Disagree in the post-unit survey, dropping from 10% to just 1%.

Figure 4.3 Stacked Bar Chart for Pre–Post Learning and Understanding SELDS Subscale
I conducted a Wilcoxon signed-rank test to determine whether the PBL unit affected the science self-efficacy learning and understanding science subscale score. The results indicate a statistically significant difference between the science self-efficacy survey score before the PBL unit (Median = 3.75; SD = 0.75) and the science identity survey score after the PBL unit (Median = 4.00; SD = 0.66), [Z = -4.923, p < 0.001]. An effect size calculation found that $r = 0.51$, indicating the PBL unit greatly affected the Learning and Understanding subscale score improvement.

The median score for the pre-unit Doing Science Activities subscale was 3.75, correlating to a response between Neutral and Agree. The minimum score was 2.00, and the maximum score was 5. Post-unit data showed an increase in median score to 4.25, correlating to a response between Agree and Strongly Agree. The minimum post-unit score increased to 3.25, and the maximum was 5 (see Table 4.6).

Table 4.6 Descriptive Statistics for Pre–Post Doing Science Activities Subscale

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Median</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Doing Science</td>
<td>47</td>
<td>3.75</td>
<td>0.75</td>
<td>1.50</td>
<td>5.00</td>
</tr>
<tr>
<td>Post Doing Science</td>
<td>47</td>
<td>4.25</td>
<td>0.66</td>
<td>2.25</td>
<td>5.00</td>
</tr>
</tbody>
</table>

In Figure 4.4, a stacked bar chart constructed to visually represent the changes in responses between the pre-unit and post-unit doing science activities subscale shows students felt more confident in their ability in doing science activities after the PBL unit. The chart clearly illustrates a significant shift in responses. Initially, only 17% of students strongly agreed with the statements, but in the post-unit survey, this percentage increased substantially to 49%. Conversely, there was a noticeable decrease in the number of students who chose Strongly Disagree and Disagree in the post-unit survey, dropping from 18% to just 2%.
Note. \( N = 47 \)

Figure 4.4 Stacked Bar Chart for Pre–Post Doing Science Activities SELDS Subscale

I conducted a Wilcoxon signed-rank test to determine whether the PBL unit affected the science self-efficacy doing science activities subscale score. The results indicate a statistically significant difference between the doing science activities subscale score before the PBL unit (Median = 3.75; SD = 0.77) and after the PBL unit (Median = 4.25; SD = 0.49), \([Z = -5.282, p < .001]\). An effect size calculation found that \( r = 0.54 \), indicating the PBL unit greatly affected the subscale score improvement.

**Qualitative Data**

I gathered qualitative data on science self-efficacy from focus group interviews, student reflection journals, and teacher field notes. The focus groups for gauging science self-efficacy differed from those for evaluating SEL skills. Nevertheless, there was an overlap in participation. At the end of the PBL unit, I conducted six separate focus group
interviews to evaluate students’ perceptions of their science self-efficacy. A total of 20 students participated in these interviews.

I imported the transcripts into NVivo (V14.23) software for subsequent coding and analysis to uncover themes and connections. Initially, I applied a priori coding, drawing upon the four primary sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and affective states (Bandura, 1997). I repeated the deductive process of using predefined codes three times to ensure comprehensive coverage. Next, three rounds of in vivo coding captured fresh insights using the students’ own expressions, following the guidance of Miles et al. (2014).

Transitioning to the subsequent qualitative analysis phase, the student reflection journal entries and teacher field notes, previously uploaded into NVivo (V14.23), underwent initial coding using the established a priori codes specifically designed for exploring science self-efficacy. Three complete rounds of deductive coding enhanced data validity and identified all possible instances of the predefined codes. Subsequently, I implemented three rounds of in vivo coding with the objective of capturing additional, unique insights expressed in the students’ own words. Upon completing the initial coding rounds for focus group interviews, reflection journal entries, and teacher observation notes, I conducted second-cycle pattern coding to identify recurring themes in the qualitative dataset. In this section, I describe each source of self-efficacy as it relates to the PBL unit and discuss what students identified as the effect of participation in the unit for each source, incorporating student statements to exemplify each source.

Mastery Experiences. Most science classes at Archer High School are typically lecture-based, with wet and dry lab activities interspersed throughout the course. Science
teachers at Archer High have yet to implement PBL into their classes. Thus, the students in the AP Biology classes experienced PBL for the first time in this unit. Overall, students showed increased interest and engagement during the PBL unit. In a focus group interview, one student said the unit “was really helpful in understanding cancer better. Through the unit, I realized that I can learn about science and it was not as hard as I thought it would be” (3-FG2). Another student shared in their reflection journal,

Throughout this unit, we’ve had to work together to find out what causes our cancer and the why and many more things. Not always when we looked for an answer were we right, so seeing that has helped us persevere and eventually succeed. (18-RJ)

Another student expressed in a focus group interview, “I really liked this unit. I definitely learned a lot and honestly found it really interesting” (4-FG5).

These students’ responses suggest that, despite their initial reservations, they delved into the content at a deeper level than they had expected. One student remarked,

I was surprised at how much I learned. I like how balanced the unit was. I really liked how we worked in our groups but then you taught new concepts and then we applied the concepts to our project. I didn’t feel like we were just left for the entire unit to do it on our own. (2-FG1)

Another student admitted, “I underestimated myself. When we figured out what our cancer was by ourselves, I was really proud. The entire unit helped me not underestimate myself so much with science” (2-FG4), and yet another shared, “I was surprised with how much I learned about cancer and genetics. It wasn’t as hard as I thought it would be to learn new topics on our own” (3-FG6).
**Vicarious Experiences.** For the PBL unit, I placed students into groups of three to four, keeping non-participants together in a separate group. I also reorganized the classroom for the duration, placing desks into groups instead of the typical straight rows. This seating arrangement fostered an environment where students could converse in groups more frequently and directly. Thus, vicarious experiences resulted from the unit itself as well as the classroom organization. Teacher observations and field notes revealed several instances when students had vicarious experiences. One field note, for instance, documented a scenario in which Student A approached a neighboring group to inquire about their progress. She discovered that they had already identified their cancer type and then returned to her own group, exclaiming, “They did it... we can too... let’s continue our research.”

[Student A] appeared excited and more motivated to uncover their own group’s cancer type after witnessing another group’s success.

Another field note said,

While completing their Big6 (n.d.) document, one group got a bit frustrated at their lack of progress. [Student B] asked me if he could go talk to another group about how they were approaching the Big6. I said of course and then I proceeded to watch [Student B] observe the other group’s document and discuss with them some of the websites they were using. He then went back to his group and shared what he learned, and said, “We need to regroup and try again. We got this.”

These instances suggest students were influenced and inspired by their peers’ achievements, which positively impacted their own learning and determination.
Most of the vicarious experiences students explicitly mentioned in the focus group interviews did not occur during this unit; instead, they seemed independent of this particular unit. Student responses to focus group interview questions regarding who they identify as role models for how well students did in this course included previous teachers, peers, and family members. For example, one student said, “My biology teacher from Palestine. She kept telling me I should be a biology major in college and that I need to take AP Bio. She was really great and could explain anything” (3-FG3). Another student shared, “My mom because she supports me and helps me when I don’t understand something” (1-FG6). Yet another mentioned a peer who “does so well in this class and . . . can explain things. She helps me check my understanding” (2-FG5). At least five students mentioned their parents as role models for their science class performance. A few students (n = 5) mentioned their siblings who both took this course from me in previous years. Only two students mentioned peers who were in their own AP Biology class, but in both cases, the peers were not in their PBL groups. When asked how these role models have influence, students mainly mentioned that they gain support and help from their role models.

**Verbal Persuasion.** Feedback played a crucial role in the PBL unit. Student groups actively engaged in a feedback loop that involved input from various sources, including their peers, community partners, and me. Within individual groups, members naturally provided feedback to one another as they collaborated on identifying their assigned cancer type, conducting research, and preparing the required materials for the genetic counseling session. Formal feedback sessions occurred twice during the unit. First, each group exchanged their two products with another group to receive and offer
feedback on their initial drafts. They repeated this process a week later for the second drafts of their products, facilitating iterative improvement. The genetic counseling students, who served as community partners, were accessible for feedback through email, further enhancing the feedback avenues available to the student groups. Additionally, teacher feedback was a continuous aspect of the unit, encompassing group discussions and individual comments. This multipronged approach enriched the students’ learning experience during the unit.

Continuous feedback incorporated verbal persuasion, which likely impacted the students’ feelings of self-efficacy, as evident in the focus group interviews, when I asked students about the feedback they received during the unit. Over half of the respondents ($n = 13$) noted positive feedback from peers, community partners, and me. For example, one student said,

You were very encouraging. You kept telling us that we could figure it out even though it was hard. The karyotype we had was so crazy and we kept getting stuck, but you believed in us and eventually we figured it out. (2-FG3)

Another student mentioned, “When [Student X] read over my pamphlet, he gave me a fist bump and said it was awesome. That really made me feel good about what I had done” (1-FG2), adding, “The genetic counselor was very complimentary and made me feel more confident in our work” (1-FG2). A different student said,

At the genetic counseling session at the end, our patient was very nice and told us we seemed like professionals. He said he felt like he was at a real appointment with professionals. I felt really awesome about that and now I feel like I can really do this one day. (4-FG4)
Another student shared how their patient “said we were naturals at fitting into the role of genetic counselors and she said it was not like we were just playing a part. That made us feel good about what we did” (2-FG6).

Word frequency analysis for responses corresponding to social persuasion showed prominent references to peers, patients (i.e., administrators at the school), and me. The words confidence, professional, and compliments also appeared at a higher frequency.

**Affective States.** At the outset of the PBL unit, students displayed elevated levels of concern and anxiety, primarily stemming from their unfamiliarity with this new learning approach. None of the students had prior experience with PBL, which involved creating a public product and delivering a presentation to a professional audience. When questioned about their initial feelings at the start of the unit and upon learning about their public product requirements, the students underscored their apprehensions.

For instance, one student stated, “I was overwhelmed. I didn’t know what to expect and was worried about having a session with a patient, even though it wasn’t an actual patient” (1-FG3). Another student conveyed a mix of emotions, saying, “I was excited but also nervous. I was excited to learn about cancer and genetics, but I was also nervous about the amount of work we would have” (3-FG5). Some students mentioned their anxiety was compounded by personal connections to cancer, with one stating, “I was a bit indifferent. I was also worried since a lot of people in my family have cancer and I was scared to learn about it” (2-FG3). Others emphasized how different this learning method was compared to their accustomed approach, with one student acknowledging, “It was intimidating because it was so far removed from what we had ever done before. I didn’t know what to expect” (2-FG2). Word frequency analysis for
responses corresponding to affective states before the unit showed the prominence of words like nervous, excited, worried, scared, and intimidated. These words collectively underscored students’ complex emotional responses to the unfamiliar PBL experience.

During the focus group interviews at the conclusion of the unit, students shared markedly more positive sentiments about their experience. Common themes included feelings of accomplishment, pride, and a strong desire to continue learning. For instance, one student expressed a sense of pride in themselves and their group, stating, “I was really proud of myself and our group. We worked hard and we worked together to accomplish this. We became really knowledgeable about cancer and were able to speak confidently to our patient” (1-FG4). Another student noted, “I was so proud of our group despite the difficulties we had. Our patient learned something and we all learned so much. I wanted to keep going with the unit” (3-FG4). Yet another student shared, “I definitely felt a sense of accomplishment, and I was proud of our group since we were able to come together and complete the project at such a high level” (1-FG6). Notably, one student was so motivated by the experience that they decided to take action, saying, “I felt like I learned a lot, and our group focused on leukemia for our cancer. I felt like I needed to keep helping so I ended up going to get swabbed for a bone marrow match program” (4-FG5). A word frequency analysis of responses regarding emotional states at the end of the unit highlighted prominent words such as proud, accomplished, confident, happy, learning, and knowledge. These words collectively reflected the overwhelmingly positive emotions and growth students experienced as they completed the PBL unit.
Combined Qualitative Data

In NVivo (Version 14.23), I employed cluster analysis to investigate patterns in the qualitative data. This analysis involved creating dendrograms using measures of word similarity and coding similarity. Sources or nodes positioned close to each other indicate a higher degree of similarity, whereas those farther apart indicate less similarity.

The cluster analysis specifically concerned two primary aspects: science identity and the four primary sources contributing to science self-efficacy. Utilizing both coding and word similarity measures, the resulting dendrograms illuminate the relationships between these factors. Notably, the dendrograms suggest science identity exhibits a closer association with affective states and mastery experiences when compared to its relationship with verbal persuasion and vicarious experiences. Figure 4.5 presents a visual representation.

![Dendrograms Comparing Science Identity to Science Self-Efficacy](image)

Figure 4.5 Dendrograms Comparing Science Identity to Science Self-Efficacy

Analysis of Data Based on Research Questions

Research Question 1

Data support that incorporating PBL in a science classroom positively affects high school students’ SEL skills, which improved over the course of the unit. Both the
quantitative and qualitative data support this finding. Student participants showed statistically significant improvements in their overall scores on the WCSD-SECA \([Z = -4.461, p < 0.001]\). Although each subscale showed statistically significant improvements, the areas of self-concept and emotion knowledge showed the fewest gains \([Z = -2.487, p = 0.013\) and \(Z = -2.145, p = 0.032\), respectively].

Qualitative data suggest PBL strongly impacts SEL skill development. Overall, there are several noteworthy themes regarding the influence of the PBL unit on students’ SEL skills. Foremost among these themes is the cultivation of positive peer relationships and collaboration. Furthermore, the PBL unit encouraged self-motivation and accountability. Students reported that their autonomy and responsibility during the project instilled a sense of ownership over their learning journey. Resilience and problem-solving skills emerged as critical skills honed through the PBL unit. Students encountered challenges and setbacks but learned to persevere. Additionally, the data indicate the PBL unit played a role in developing emotional regulation skills. Empathy and perspective-taking were evident as important SEL skills influenced by the PBL unit. Interacting with community partners and patients during the genetic counseling sessions deepened students’ understanding of empathy and their ability to see issues from others’ viewpoints. These experiences broadened their horizons and encouraged them to consider the emotional aspects of science and healthcare.

In conclusion, the PBL unit had a multifaceted influence on students’ SEL skills. It fostered positive peer relationships, effective communication, self-motivation, and accountability. Additionally, it contributed to improved resilience, emotional regulation, and increased self-confidence. Empathy and perspective-taking skills were also
enhanced, along with heightened engagement, intrinsic motivation, and long-term career aspirations. Overall, the PBL approach proved instrumental in nurturing students’ SEL skills, equipping them with valuable abilities for both their academic and personal lives.

**Research Question 2**

Data from this study also support that PBL can yield positive outcomes in the areas of student science self-efficacy and science identity. Science identity refers to the extent to which individuals see themselves as belonging to the world of science and how they perceive their role in it. Student scores on the SSI questionnaire showed a significant difference between the Science Identity survey score before the PBL unit (M = 93.25; SD = 13.04) and after the PBL unit (M = 99.44; SD = 13.21), [Z = -4.999, p < .001], thus indicating student science identity increased during the PBL unit.

Qualitative data analysis supported these findings and also provided more nuanced insights as to why students may have increased their scores on the SSI survey. First, many students expressed a heightened interest in science as a result of their participation in the PBL unit. They found the real-world applications and hands-on experiences engaging and inspiring. Students also frequently mentioned feeling curious and excited about science, particularly when exploring new topics or conducting experiments. The PBL unit encouraged their inquisitive nature. Some students identified themselves as individuals interested in science; they saw science as a subject that piqued their curiosity and made them eager to learn more. The PBL unit contributed to the growth of students’ curiosity and passion for science. Students clearly enjoyed delving deeper into scientific concepts and understanding how they applied to real-life situations. Additionally, students described a shift from being passive learners to actively engaging
with scientific content. They felt more involved in the learning process, contributing to their evolving science identity. Over the course of the PBL unit, students began to see themselves as individuals who actively engaged in the process of learning science. They no longer viewed science as a subject reserved for experts but as something they could embrace. Students mentioned how the PBL unit helped them connect science to their daily lives. They could relate scientific concepts to real-world scenarios, reinforcing their sense of science identity. Some students identified role models or influential figures who further fueled their scientific identity—whether teachers, family members, or peers who inspired them to pursue science-related interests. Many students recognized personal growth in their scientific knowledge and abilities. They felt a sense of accomplishment and acknowledged that they were becoming more proficient in science. Collaborative work with peers within the PBL unit significantly impacted students’ science identity. Interactions with classmates who shared their interest in science reinforced their sense of belonging. The practical and applied nature of the PBL unit helped students perceive science as relevant to their lives. They realized scientific knowledge had tangible applications, strengthening their science identity. Some students admitted to having initial doubts about their ability to excel in science. However, their participation in the PBL unit helped them overcome these doubts and gain confidence in their science identity.

In summary, the PBL unit influenced students’ science identity by fostering an increased interest in science, promoting curiosity, and encouraging active participation in scientific learning. Students began to identify themselves as science enthusiasts and learners, recognizing personal growth and the relevance of science to their lives.
Collaborative interactions with peers and the practical applications of science further solidified their sense of belonging to the world of science.

Science self-efficacy refers to a person’s belief in their ability to succeed in science-related tasks and challenges. One prominent theme is the increased confidence in students’ scientific abilities. Some students who initially doubted their scientific skills underwent a transformation, shifting from self-doubt to a more positive belief in their capabilities. Additionally, students acknowledged developing their problem-solving skills through the PBL unit, enabling them to confidently approach scientific challenges.

Positive feedback and encouragement from me also played a significant role in enhancing students’ self-efficacy. Students appreciated my guidance and the reinforcing feedback they received, which contributed to their growing belief in their scientific abilities. Furthermore, collaboration with peers proved invaluable. Working with classmates provided students with support and validation, further fueling their self-efficacy in science. Effective teaching methods and successfully completing challenging tasks also increased students’ confidence. The PBL unit challenged them with complex scientific problems, which they successfully tackled. This sense of accomplishment reinforced their belief that they could overcome difficult scientific obstacles. Furthermore, adopting a growth mindset was a common theme. Students began to view challenges as opportunities for growth and learning, a mindset shift that positively influenced their self-efficacy. Independence and autonomy in the learning process empowered students to take ownership of their scientific education, fostering a sense of control and increasing their self-efficacy. The PBL unit provided a safe environment for students to make and learn from mistakes, helping them overcome their fear of failure. It also impacted their future
goals and aspirations, as many students expressed increased confidence in pursuing science-related careers and educational paths.

In conclusion, the PBL unit positively impacted students’ science self-efficacy by fostering confidence in their scientific abilities. Through practical application, positive feedback, peer collaboration, effective teaching, and the successful completion of challenging tasks, students transformed from doubters to believers in their scientific abilities. They embraced a growth mindset, learned to overcome fear, and took control of their scientific learning. As a result, the PBL unit played a pivotal role in reinforcing students’ self-efficacy and self-confidence in the realm of science.

Summary

For my action research study, I wanted to see if implementing a PBL unit, specifically including SEL skills, could increase student SEL skill development, science self-efficacy, and science identity. I implemented a 3-week PBL unit revolving around cancer genetics and collected both quantitative and qualitative data for triangulation. The findings indicate the PBL unit did, indeed, positively influence all three areas of interest.

In Chapter 5, I reflect on these results and discuss how I plan to use these findings to implement changes in my classroom and, potentially, at my school to improve SEL skill development, science identity development, and student science self-efficacy. I also discuss how the findings from this study are transferable to other settings with students similar to mine.
CHAPTER 5: IMPLICATIONS

Although scholars have individually examined PBL and its impact on the development of social and emotional skills, science identity, and self-efficacy, there has been no comprehensive investigation into their interplay in a high school environment. This action research study aimed to explore the influence of PBL on the development of SEL skills, science identity, and self-efficacy among AP Biology students. Thus, the research questions were:

1. How does the incorporation of PBL in a science classroom affect SEL skills among high school students?
2. How does the incorporation of PBL in a science classroom affect students’ science self-efficacy and science identity?

A convergent mixed-method approach combined quantitative and qualitative data to yield the most complete, clear picture of PBL’s influence on SEL skill development, science self-efficacy, and science identity (Creswell & Creswell, 2018). Specifically, this study used a longitudinal survey design, where pre–post surveys of all participating students provided baseline data and outcome data to demonstrate whether the PBL intervention affected students’ SEL skill development, science self-efficacy, and science identity. The surveys provided quantitative data, yet they had inherent limitations in that students could have misconstrued the close-ended questions.
To lessen potential shortcomings, I collected qualitative data via teacher observations, focus group interviews, and individual interviews. The interviews supplemented and validated observation data (Efron & Ravid, 2020), as open-ended and unscripted questioning allowed participants to talk openly and honestly about a specific topic (Creswell & Creswell, 2018). Interviews also grounded the findings in students’ experiences. Triangulation of quantitative and various sources of qualitative data shows this PBL unit’s strong positive influence on students’ confidence in their science capabilities, science identity, and social–emotional skills. This chapter further discusses these findings and their implications for my practice. I also consider the findings in relation to existing literature. Furthermore, I examine other settings that may benefit from the findings of this action research study.

**Discussion of Findings**

PBL positively influenced students’ science self-efficacy, identity, and social–emotional skill development. PBL is an educational approach that fosters an environment where students actively engage in authentic scientific inquiries, collaborate with peers, and address real-world problems, resulting in multifaceted growth across these dimensions.

**Science Self-Efficacy**

One of the most prominent impacts of PBL is its influence on students’ science self-efficacy or their belief in their ability to succeed in scientific tasks and challenges. The PBL unit tasked students with conducting in-depth research, presenting their findings, and interacting with community partners, all of which significantly boosted their self-efficacy. The findings reveal students initially had varied confidence levels in
their scientific abilities. A few students ($n = 3$) entered the unit with strong self-confidence in science, while others entered with self-doubt, perceiving science as challenging or feeling unsure about their competence. However, as the PBL unit progressed, the students with lower self-confidence in science began to witness their capacity for learning and problem-solving in a real-world context. The increases in self-efficacy in this study corroborate previous research showing statistically significant increases in self-efficacy for college students who experienced a project-based curriculum (Krsmanovic, 2021; Rezvanifar & Amini, 2020; Schaffer et al., 2012). These findings also align with research by Samsudin et al. (2020) indicating STEM PBL had a significant influence on increasing the confidence levels of high school physics students.

The heightened sense of self-efficacy among students primarily stemmed from their mastery experiences during the unit, particularly during the genetic counseling session. These mastery experiences accounted for 42% of all codes related to learning during the unit, with 59% of these codes directly tied to the counseling session. As students successfully created patient pamphlets and delivered effective presentations to their patients, they encountered a confidence boost. This success, coupled with the verbal feedback and praise from patients, significantly contributed to their perception of having mastered the material and feeling like authentic scientists. These results support prior findings that mastery experiences have a strong, significant effect on self-efficacy (Capa-Aydin et al., 2018; Bandura et al., 1977; Samsudin et al., 2020; Usher & Pajares, 2008).

Other factors also facilitated the transformation, including the hands-on nature of the unit, the opportunity to grapple with complex scientific concepts, the social nature of the group work, and guidance from the community partners and me. Research has
demonstrated that when students collaborate, social interactions enable them to observe and learn from their peers (Samsudin et al., 2020). This observation is consistent with SCT (Bandura, 1997), which posits that vicarious experiences can impact self-efficacy beliefs. In fact, in this study, some students explicitly conveyed having positive vicarious experiences stemming from the collaborative nature of the PBL approach.

Constructive feedback played a vital role in enhancing students’ self-efficacy in this study. Encouragement, positive reinforcement, and recognition of their efforts validated their belief in their scientific abilities. This feedback was particularly valuable during the genetic counseling sessions, where students had to convey intricate genetic information to patients. Overcoming this challenge and receiving praise for their performance had a substantial impact on their self-efficacy. These results align with Bandura’s (1997) self-efficacy sources framework and reinforce the body of research indicating that verbal persuasion can substantially influence students’ science self-efficacy (Arslan, 2013; Chin & Kameoka, 2002). However, there are conflicting results in the literature, as some studies indicate verbal persuasion does not strongly affect science self-efficacy in high school students (Capa-Aydin et al., 2018). Self-efficacy in this study may stem from the synergy among the mastery experiences of identifying the cancer type, preparing the materials, and participating in the genetic counseling session, along with the verbal praise from the patients and me, commending the students’ hard work.

Furthermore, the autonomy and responsibility afforded by PBL encouraged students to take ownership of their learning. They developed self-discipline, learned to manage their time effectively and set personal goals for their research and presentations. These newfound skills were not only relevant in the context of the PBL unit but also had
a ripple effect on their overall self-efficacy as they realized they could tackle complex tasks independently. This aligns with earlier research, such as Edelson’s (2001) suggestion that students excel when the information they are learning addresses self-posed questions or problems. Furthermore, as Berland et al. (2015) asserted, students thrive in learning environments where they can make sense of issues and establish connections between their learning, the classroom community, and the broader scientific community rather than solely aiming to please the teacher.

In summary, PBL substantially increased students’ science self-efficacy by providing opportunities for hands-on learning, constructive feedback, autonomy, and overcoming real-world scientific challenges. As students witnessed their own growth and accomplishments, their belief in their scientific abilities flourished.

Science Identity

The PBL unit also positively influenced students’ science identity, shaping how they perceive themselves in relation to the field of science and their roles as scientists. This transformation was multifaceted, encompassing changes in their interest, curiosity, and sense of belonging in the scientific community. Initially, students had varying degrees of interest in science, with some motivated by personal curiosity and others driven by external factors such as course requirements or career aspirations. However, as they delved deeper into the PBL unit, their interest in science became more pronounced. Hazari et al. (2010) proposed that interest plays a vital role in shaping one’s science identity, which Vincent-Ruiz and Schunn (2018) echoed. This action research study further substantiates the significance of this construct.
The focus of the PBL unit on real-world issues, such as genetic counseling for cancer, also engaged students’ curiosity and highlighted the relevance of scientific knowledge to everyday life. The hands-on and inquiry-based nature of PBL prompted students to view themselves as active participants in the scientific process. They no longer saw themselves solely as passive recipients of scientific information but as individuals capable of conducting research, formulating hypotheses, and drawing conclusions based on evidence. This shift in perspective contributed significantly to their science identity and supports previous research suggesting competence and performance in science are important parts of developing a strong science identity (Carlone & Johnson, 2007; Hazari et al., 2010; Luehmann, 2007; Robinson et al., 2018).

Moreover, students’ sense of belonging in the scientific community was reinforced through their interactions with community partners, scientists, and patients. These experiences demonstrated the interconnectedness of science with real people and real problems, fostering a sense of responsibility and empathy. As they engaged in genetic counseling sessions and communicated complex scientific information to patients, they felt like genuine contributors to the field of science. The numerous positive comments and feedback they received, including from me as their teacher, likely played a significant role in shaping the students’ science identity. This may be attributed to the students’ perception of support when confronting the demanding aspects of the PBL unit. Consequently, they were more inclined to exhibit resilience and confidence when encountering setbacks, a phenomenon in line with the findings of Aschbacher et al. (2010). This aligns with prior research suggesting influential figures like teachers, parents, and other adults play a pivotal role in science identity development (Aschbacher
et al., 2010; Carlone & Johnson, 2007; Vincent-Ruiz & Schunn, 2018). Furthermore, the genetic counseling student speaker may have played a part in influencing the formation of certain student identities. Research has indicated that adults outside the traditional teaching role can significantly mold students’ science identities by fostering their science learning and kindling their enthusiasm for STEM careers (Aschbacher et al., 2010).

The PBL unit also highlighted the multifaceted nature of science (NOS). Students realized that being a scientist involved not only conducting experiments but also effectively communicating scientific findings and collaborating with others. Moreover, students realized a wealth of knowledge has yet to be constructed in the realm of cancer genetics and that the scientific community continues to grapple with the intricate nuances of cancer biology. In essence, the PBL unit played a role in enhancing students’ understanding the NOS. These findings corroborate research demonstrating that PBL in a first-year college biology course significantly enhanced students’ appreciation and understanding of the NOS (Sukaesih et al., 2022).

As a result of the PBL unit, students were able to visualize their potential for success in the social implementation of scientific procedures, aligning with a critical components of science identity development: performance (Carlone & Johnson, 2007; Hazari et al., 2010). My students effectively showcased their proficiency in executing scientific duties, such as conducting research, synthesizing information to reach informed conclusions, and effectively presenting scientific information to an audience; their performance in these tasks was indeed successful. Upon completing the PBL unit, numerous students reported a feeling of achievement, reflecting positive emotions associated with their performance in these scientific activities. This prevailing sense of
achievement likely played a substantial role in elevating students’ comprehension of not
only scientific principles but also the fundamental essence of science itself and how it
intertwines with their evolving science identities.

Prior research suggests a significant correlation between science self-efficacy and
directly enhances science identity, emphasizing its constructive role. Therefore, the
enhanced science self-efficacy resulting from the PBL unit likely contributed to students’
developing more robust science identities. Likewise, Jiang et al. (2022) found STEM
PBL experiences positively impacted high school students’ science identities.

**Social and Emotional Skills**

Beyond science-specific outcomes, the PBL unit positively impacted students’
social–emotional skill development. SEL skills are vital for personal and academic
accomplishments, and PBL was a conducive environment for nurturing them. There was
a statistically significant increase in total SEL assessment score following participation in
the PBL unit ($Z = -4.461, p < 0.001$) with a moderate effect size ($r = 0.46$). Statistically
significant improvements were also evident in each subscale, although effect sizes varied.
Effect size calculations suggest the PBL unit had a large effect in only four SEL
competencies: relationship skills ($r = 0.57$), responsible decision-making ($r = 0.57$), self-
management: school work ($r = 0.55$), and self-management: goal management ($r = 0.49$).

One of the most salient results of the PBL unit was the enhancement of
interpersonal skills, including teamwork and effective communication. I implemented a
few strategies throughout the unit to promote relationship skills. First, I had every group
create a group contract right at the outset of the unit. This team agreement provided an
opportunity for group members to openly converse about their individual strengths and weaknesses and deliberate on strategies for collaborating in the most efficient manner, ensuring they considered everyone’s strengths and weaknesses. Additionally, the group contract facilitated discussions among the groups on how they would effectively address and manage frustrations and conflicts in a constructive and healthy manner. The groups reviewed and revisited their contracts on two occasions to verify adherence to their initial agreements. Furthermore, I incorporated specific journal prompts to invite students’ reflection on their personal contributions to the group work and assessment of the dynamics within their respective groups.

In conjunction with the targeted interventions I implemented to enhance relationship skills, the structure of the PBL unit proved beneficial, as it required students to collaborate while conducting research, devising plans, and delivering their findings. Students experiencing PBL have reported that communication and collaboration are especially important to their success (Vogler et al., 2017). Over the course of the PBL unit in this study, students reported an improved ability to communicate ideas clearly, actively listen to their peers, and resolve conflicts constructively so they could achieve their PBL project goals. Students emphasized that the PBL unit also provided ample opportunities to improve other communication skills, such as asking questions and articulating their thoughts in written and oral forms. This enhancement in communication not only improved their presentation abilities but also bolstered their confidence in conveying scientific concepts to others. This echoes Aifan’s (2022) research with undergraduates participating in PBL, which found statistically significant increases in 21st-century skills such as communication, collaboration, and leadership.
The PBL unit played a pivotal role in fostering an essential SEL skill: responsible decision-making. Students’ reflections shed light on the transformation in their attitudes and behaviors throughout the unit. Notably, a significant number of students expressed a heightened awareness of the importance of making healthier lifestyle choices to reduce their risk of developing cancer. This newfound health consciousness signifies a growing sense of responsibility for their own well-being. They realized their daily choices significantly impact their overall health and susceptibility to diseases. Furthermore, students displayed an emerging tendency to consider not only their own interests but also the implications of their decisions on their team members. This collaborative approach to decision-making is a testament to their improved interpersonal and teamwork skills. It indicates the PBL approach not only heightened their awareness of health-related matters but also nurtured their ability to make responsible decisions within a group context.

These findings underscore the multifaceted benefits of incorporating real-world, problem-based learning experiences into the curriculum. Beyond acquiring subject matter knowledge, students experienced personal development and gained interpersonal skills. Cultivating responsible decision-making skills holds promise for their future endeavors, emphasizing the practical implications of SEL in preparing students for success in both academic and real-life situations.

Students in this study also reported increases in areas of self-management such as self-motivation, self-discipline, and goal setting. They recognized the importance of setting goals, managing their time efficiently, and holding themselves accountable for their work. This newfound autonomy and responsibility benefited their performance in the PBL unit and equipped them with essential life skills that will extend beyond the
classroom. Resilience and problem-solving skills emerged as prominent themes. Students faced challenges and setbacks during the unit, including the need to adapt their research approaches or address unexpected issues during the genetic counseling sessions. They learned to persevere, seek solutions, and view challenges as opportunities for growth. This capacity for resilience was likely a result of the PBL approach, which encourages students to confront real-world problems that often entail unforeseen obstacles and difficulties (Larmer et al., 2015). Egenrieder (2010) also suggested regular opportunities for authentic student-led inquiry, like PBL, offer the chance to renew or expand interest in scientific explorations that foster necessary resilience for success in STEM fields.

The PBL unit also nurtured another subset of self-management, emotional regulation, although effect size calculations show moderate effects ($r = 0.44$). Throughout the unit, students experienced a range of emotions, from excitement to anxiety and frustration. To assist students in handling these emotions, I provided support at various stages of the PBL unit. For instance, when I observed some groups struggling to identify the type of cancer they were researching, I helped them navigate the complex literature they had gathered and break it down into more manageable sections. This scaffolding intervention alleviated some of the anxiety and empowered the students to recognize their capability to handle the task. Additionally, I guided students in using the Big6 (n.d.) framework, offering an organized plan to approach their research. Effective management of these emotions was essential for them to maintain focus and productivity, which is a valuable skill not only in academic settings but also in various aspects of life.

The social awareness skills of empathy and perspective-taking were also evident as SEL skills potentially influenced by the PBL unit, with low-moderate effect size ($r =$
0.39). Interacting with community partners and patients during the genetic counseling sessions deepened students’ understanding of empathy and their ability to see issues from others’ viewpoints. These experiences broadened their horizons and encouraged them to consider the emotional aspects of science and healthcare. Nevertheless, given the unit’s primary focus on the genetic underpinnings of cancer, and the genetic counseling session’s occurrence toward the conclusion of the unit, students may not have directed most of their research efforts toward understanding the emotional experiences of individuals diagnosed with cancer. Consequently, their development in the realm of social awareness might not have been as pronounced.

The PBL unit had much lower effects for the SEL areas of emotion knowledge ($r = 0.22$), and self-concept ($r = 0.26$). These aspects are part of the broader SEL construct of self-awareness. I attribute the lower effects to the nature of the reflection activities during the unit. While some reflection journal entries prompted students to contemplate their own feelings, many students predominantly expressed their emotions in the context of their group’s progress rather than their personal feelings about the content or project. Furthermore, students had limited opportunities to directly reflect upon their self-concept within the reflection journal. The learning experiences may not have adequately addressed this aspect of self-awareness. As a result, the SEL areas related to emotion knowledge and self-concept did not exhibit as substantial growth as other areas. This highlights the importance of designing reflection activities that explicitly target these aspects of self-awareness to ensure a more comprehensive development of SEL skills.

Lastly, PBL heightened students’ engagement and intrinsic motivation in their learning. The unit’s hands-on, real-world approach sparked newfound enthusiasm for
science. Although engagement and intrinsic motivation are not typically categorized as SEL skills themselves, they are important aspects of a student’s overall emotional and social well-being and can be influenced by SEL skills (Davis et al., 2014). For example, students with strong self-regulation skills might be better at maintaining their motivation and staying engaged in their learning. So, while not classified as SEL skills, they are connected and interrelated with the development of social–emotional competencies.

According to Beisel (2020), PBL offers a natural opportunity to integrate SEL competencies, and many of these skills developed throughout the unit. The observed enhancements in SEL skills also validate Bell’s (2010) perspective that PBL is an effective approach for fostering SEL skills. As both scholars contended, PBL encourages communication, negotiation, collaboration, and responsibility, which are integral to SEL development. Like their work, this study highlights how PBL promotes active learning, engages students in real-world tasks, and prepares them for workforce success by enhancing their 21st-century skills. This study also aligns with research by Culclasure et al. (2019), which attributed similar improvements among middle school students to PBL.

In conclusion, the influence of PBL on students’ science self-efficacy, science identity, and social–emotional skill development is profound and multifaceted. This approach fosters a sense of confidence in scientific abilities, a deepening interest in science, and an expanded view of what being a scientist means. Additionally, it cultivates essential social and emotional skills such as teamwork, communication, resilience, emotional regulation, empathy, and intrinsic motivation. These outcomes underscore the power of PBL in shaping students’ academic success and their holistic development as individuals equipped for future challenges and opportunities.
Implications for Practice

The implications for teacher practice stemming from the influence of PBL on students’ science self-efficacy, science identity, and social–emotional skill development are substantial. Teachers can leverage these insights to enhance their pedagogical approaches and create more enriching learning experiences for their students. First, teachers should actively promote a growth mindset among their students. PBL promotes a growth mindset by valuing effort, emphasizing learning from failures, fostering a supportive environment, encouraging critical thinking and problem-solving, and shifting the focus from outcomes to the learning process (Boss & Larmer, 2018; Seo et al., 2023). Through PBL, students can see challenges as opportunities for growth and believe in their capacity for improvement through dedication and continuous learning. This approach fosters a mindset that values hard work and resilience as key factors in achieving success, aligning with the principles of a growth mindset.

Moreover, the qualitative data underscore the critical role teachers and other adults, such as community members, play in nurturing students’ self-efficacy. Timely and constructive feedback that recognizes effort and highlights areas for improvement should be a cornerstone of classroom practice. Celebrating students’ scientific achievements during the PBL process becomes paramount in boosting their confidence and reinforcing their belief in their capabilities.

Another pivotal insight gleaned from this study underscores the importance of educators’ highlighting the real-world relevance of scientific concepts. One of the primary reasons why students found this specific unit so engaging was its direct connection to a familiar topic: cancer. Although students possessed varying levels of
prior knowledge about cancer, all of them had someone in their lives who had confronted this disease. Consequently, the unit immediately resonated with their personal experiences and the practical world they inhabited. This initial alignment of the curriculum with students’ real-life experiences paved the way for their enhanced engagement with the content and a heightened commitment to their projects.

Furthermore, the culminating products of the unit—a patient pamphlet focusing on the specific cancer and a genetic counseling session featuring a community member in the role of the patient—directly involved and benefitted community members. By design, students approached their work with a heightened sense of seriousness, conducting thorough research and investing substantial effort into creating high-quality products. Knowing their work had real-world applications and would directly engage with the community amplified their sense of purpose and responsibility. Demonstrating how scientific knowledge can practically apply to authentic problems, as the PBL unit vividly exemplified, can power ignite students’ curiosity and motivation. By embedding learning within the context of practical application, educators can effectively bridge the divide between science content and real-world scenarios, making scientific principles more relatable and engaging. This not only enriches students’ understanding but also nurtures a deeper appreciation for the tangible utility of scientific knowledge, fueling their enthusiasm for learning and problem-solving.

This research also unmistakably underscores the advantages of group projects, peer review, and interactions with community partners, all of which were integral components of the PBL unit. In this investigation, these components played a pivotal role in enhancing students’ SEL skills, with a particular focus on improving their abilities in
building relationships. Throughout the 3-week unit, students collaborated closely, affording them daily opportunities to hone their teamwork, communication, and conflict resolution skills. Moreover, students had the opportunity to engage in conversations with members of the community who were previously unfamiliar to them. This experience enabled students to refine their communication skills with adult members of the scientific community, fostering a greater sense of confidence in conversing with adults. The PBL unit also had a positive impact on the SEL skills of social awareness and responsible decision-making. Physically grouped to facilitate their work, students became attuned to their group members’ emotions and navigated various mood dynamics. Additionally, students reported improvements in self-management and responsible decision-making, as they recognized their group members depended on them to complete their tasks on schedule and with a high level of quality. All of these skills will prepare students for the collaborative nature of scientific endeavors in the real world. Teachers can incorporate more collaborative activities into their curriculum to foster a culture of cooperative learning that mirrors the intricacies of authentic scientific inquiry.

Additionally, educators should consider establishing connections with community partners and organizations to facilitate authentic learning experiences. Teachers can further enrich students’ science identity by bringing in professionals from various scientific fields as role models and mentors. Exposure to real-world practitioners broadens students’ horizons and reinforces their capacity to contribute to the scientific community. Having a strong sense of identity in the field of science significantly boosts the likelihood of an individual pursuing a scientific career. Whereas the limited representation of people from marginalized backgrounds within the scientific community
can negatively affect one’s scientific identity, opportunities to observe and interact with career role models who share similar backgrounds tend to boost persistence in STEM careers (Burt et al., 2018; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; Patton, 2016; Villa et al., 2016). Absence of representation essentially acts as a barrier to the retention and persistence of individuals from underrepresented backgrounds in STEM careers, as it denies early-career individuals from these backgrounds the crucial access to role models and mentorship that could bolster their feeling of belonging and connection with the field.

Incorporating these implications into teacher practice enhances the effectiveness of PBL and contributes significantly to students’ holistic development. This study has demonstrated that PBL can nurture and build upon students’ science self-efficacy, science identity, and SEL skills. Thus, by integrating PBL into their classrooms, science teachers empower students to grow into confident, engaged, and adaptable learners who are well-prepared for challenges in the academic and real-world scientific landscapes (Aschbacher et al., 2010; Chen et al., 2021; Hazari et al., 2010). Ultimately, these practices cultivate a generation of scientifically literate individuals poised to make meaningful societal contributions (Alhaddab & Alnatheer, 2015; Chemers et al., 2011).

Upon examining the data and observing the influence of this PBL unit on students’ SEL skills, science self-efficacy, and identity, I created a model, depicted in Table 5.1, that educators can employ to implement PBL units in their own classrooms. By intentionally aligning SEL skills with the PBL Gold Standards, a teacher can create a learning environment that not only fosters academic growth but also nurtures students’ social and emotional development, preparing them for success in school and life.
Table 5.1 PBL–SEL Model

<table>
<thead>
<tr>
<th>PBL Gold Standard</th>
<th>SEL Competency</th>
<th>Incorporation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenging Problem or Question</td>
<td>Self-Reflection</td>
<td>Have students reflect on how the problem relates to their own lives. How does the problem affect others?</td>
</tr>
<tr>
<td>Collaboration and Communication</td>
<td>Empathy and Perspective taking</td>
<td>Encourage students to work together to define and refine the problem or question. This collaboration fosters teamwork, communication, and active listening skills.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ask students to consider the social and emotional aspects of the problem. How does it affect individuals and communities? What are the emotional implications of different solutions?</td>
</tr>
<tr>
<td>Sustained Inquiry</td>
<td>Self-Awareness</td>
<td>Encourage students to reflect on their own strengths and areas for growth throughout the inquiry process.</td>
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<tr>
<td></td>
<td>Self-Management</td>
<td>Teach them strategies for managing frustration and maintaining motivation when facing challenges. Have students self-reflect on their stress levels at various points throughout the PBL unit. Teach organizational skills or methods.</td>
</tr>
<tr>
<td>Authenticity</td>
<td>Social Awareness</td>
<td>Choose real-world problems that require students to understand and empathize with different perspectives, cultures, and communities. Encourage them to consider the social and emotional implications of the problem on various stakeholders.</td>
</tr>
<tr>
<td></td>
<td>Responsible Decision-Making</td>
<td>Challenge students to make decisions that not only solve the problem but also consider ethical and social consequences. Discuss the emotional impact of their decisions on individuals and the community.</td>
</tr>
<tr>
<td>Student Voice and Choice</td>
<td>Self-Awareness</td>
<td>Allow students to choose project topics that resonate with their interests and values. This choice can boost their self-awareness and motivation.</td>
</tr>
<tr>
<td></td>
<td>Relationship Skills</td>
<td>Provide opportunities for students to negotiate roles and responsibilities within their groups. Guide them in resolving conflicts and building effective working relationships.</td>
</tr>
<tr>
<td>Reflection</td>
<td>Self-Reflection</td>
<td>Incorporate regular reflections where students assess their emotional responses, teamwork, and personal growth during the project. Encourage them to set SEL-related goals for improvement.</td>
</tr>
<tr>
<td>Critique and Revision</td>
<td>Communication and Relationship Skills</td>
<td>Teach students to provide constructive feedback to peers, focusing on empathy and positive communication. Help them build resilience to accept feedback graciously and use it for revision.</td>
</tr>
<tr>
<td>PBL Gold Standard</td>
<td>SEL Competency</td>
<td>Incorporation Strategies</td>
</tr>
<tr>
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</tr>
<tr>
<td>Public Product</td>
<td>Social Awareness</td>
<td>Encourage students to present their findings or solutions in a way that considers the emotional impact on their audience.</td>
</tr>
<tr>
<td></td>
<td>Relationship Skills</td>
<td>Discuss effective communication techniques to engage and persuade.</td>
</tr>
<tr>
<td>Public Audience</td>
<td>Social Awareness</td>
<td>When students present their projects to external audiences, highlight the importance of understanding the needs and perspectives of those audiences. This reinforces social awareness and adaptability.</td>
</tr>
</tbody>
</table>

Within the PBL unit I implemented, I incorporated several strategies for each gold standard. To start, when introducing students to the challenging problem, I initiated self-reflection in their journals, prompting them to consider how cancer personally affected them and its broader community impact. This integration aimed to foster SEL skills such as self-reflection and empathy. For the second gold standard, sustained inquiry, I encouraged students to assess their strengths and weaknesses throughout the unit in their reflection journals. In terms of self-management, I introduced the Big6 (n.d.) framework to enhance their organization and research skills.

Regarding aligning SEL skills with the gold standard of authenticity, I urged students to understand and empathize with different perspectives during the genetic counseling session. To achieve this, I set the context that their sessions would involve a family member of a recently diagnosed cancer patient, requiring them to approach the session from a family member’s viewpoint. When deciding how to present the information, students had to use responsible decision-making and consider the emotional impact of their presentations on their patient.

In terms of student voice and choice, I granted students the autonomy to decide their roles and responsibilities within their groups. They were also empowered to choose
the most effective means of communication with each other and with me. This approach facilitated the development of their relationship and communication skills.

Furthermore, self-reflection was seamlessly integrated into the PBL unit through the use of reflection journals. Students were tasked with daily reflections, considering aspects like their teamwork, communication abilities, emotional state, and personal growth. This inclusion naturally aligned with the gold standard of reflection.

In terms of meeting the gold standard for critique and revision, I focused on enhancing students’ SEL skills in communication and relationship-building. Students were responsible for providing peer feedback, both within their own groups and across groups. I encouraged them to deliver constructive and positive feedback while considering what type of feedback would be most beneficial to their peers. This process encouraged them to view the situation from their peers’ perspective. I also emphasized that this was a learning journey and encouraged students to listen to their peers’ suggestions, take their comments to heart, and avoid taking feedback personally.

In the context of the public products and the public audience aspect of the PBL unit, I integrated SEL skills, specifically social awareness and relationship skills. Initially, I urged students to be mindful of their audience when developing their pamphlets, websites, and presentations. I encouraged them to consider the perspective of their audience, reflecting on their audience’s emotions and the information they would find most valuable and engaging. This approach emphasized the importance of tailoring their work to meet the specific needs and expectations of their audience.

In summary, through strategic alignment with the gold standards of PBL, students were not only challenged to expand their scientific knowledge but also to develop key
SEL competencies. From self-reflection and empathy at the outset to sustained inquiry, self-management, and authentic perspective-taking throughout, students were empowered to enhance their skills. The emphasis on student voice and choice, alongside self-reflection, further amplified their personal and social growth. The constructive feedback and revision process underscored the importance of effective communication and relationship building. In the context of presenting to a public audience, students honed their social awareness and relationship skills, recognizing the value of considering the audience’s perspective. This holistic approach to integrating SEL into the PBL unit not only enriched their scientific understanding but also equipped them with essential life skills, fostering a comprehensive educational experience.

**Action Plan**

This study has encouraged me to continue to use PBL in my AP Biology courses, buoyed by a personal plan of action to ensure future PBL units succeed. First, I will maintain my commitment to gathering data on student outcomes related to science self-efficacy, science identity, and social–emotional skills. Ongoing data collection can monitor progress, pinpoint areas where improvement is needed, and provide robust evidence of the effectiveness of PBL. This data-driven approach will be a valuable tool to substantiate the positive impact of PBL on my students. Crafting a comprehensive long-term plan for PBL implementation is crucial to ensure the sustained integration of PBL in my courses. To do this, I will need additional PBL units that seamlessly align with AP Biology content. To develop such units, I must consider their alignment with academic standards and curriculum requirements. By ensuring the PBL units complement the established College Board curriculum, I can strengthen the rationale for continued
incorporation of PBL into my courses. Moreover, I must maintain records of my PBL implementation, encompassing various aspects such as detailed lesson plans, comprehensive assessment data, and a collection of student work samples. These records can serve as a valuable source of evidence for showcasing the effectiveness of PBL to all school stakeholders.

Additionally, sharing the findings of this study is important for disseminating valuable insights to the education community. I intend to share these findings across multiple levels. Initially, I aim to organize professional development workshops for fellow educators within my school and district. During these workshops, I would like to present the findings, discuss their implications, and provide practical strategies for implementing PBL in the classroom. This includes sharing best practices, offering guidance on designing PBL units, and addressing potential challenges that educators may encounter during the implementation process. While my initial focus is on my immediate educational community, I also aspire to extend the reach of these findings to a broader audience. This may involve presenting at district and state-level meetings or conferences, where educators from different schools and districts can benefit from the insights generated by this study.

To encourage teachers at my school to utilize PBL, I plan to form a professional learning community (PLC) centered on learning about and implementing PBL. I will create a repository of resources related to PBL (e.g., lesson plans, assessment tools, and reference materials) to share with colleagues to ease the implementation process. Through the PLC, I can offer mentorship and support to colleagues who are new to PBL. The PLC will also allow me to schedule regular check-in meetings with colleagues to
monitor the progress of PBL implementation and allow us to discuss challenges, share successes, and make adjustments as needed.

Another avenue I would like to pursue is to present my findings at educational conferences or symposia. This would allow me to reach a broader audience of educators and researchers who are interested in innovative teaching practices and their impact on student development. I will also consider submitting articles or op-eds to educational journals or magazines, sharing the findings with a wider audience of educators.

By employing a combination of these strategies, I can effectively disseminate the findings, promote PBL, and contribute to the professional development of peer educators in and beyond my school. Sharing these insights can lead to more widespread implementation of PBL and ultimately benefit student learning experiences and outcomes. Finally, I can ensure my findings translate into meaningful action and lasting improvements in student science self-efficacy, science identity, and SEL skills.

Reflection

Action research is a systematic, reflective, and collaborative approach to inquiry and problem-solving that involves researchers’ actively investigating specific issues, challenges, or problems in their educational or professional context. This type of research can bring about practical and positive changes in a specific environment or situation. Thus, action research is a valuable tool for practitioners to address real-world challenges, enhance teaching and learning, and contribute to the ongoing improvement of educational or professional practices. I used action research for this study because, as a practitioner, I wanted to see if incorporating PBL could improve my students’ confidence in science, ability to see themselves as scientists, and social–emotional skills.
I chose to implement a mixed-methods study, incorporating qualitative and quantitative approaches for a more comprehensive understanding. Triangulation ensured findings from one approach validated or complemented those from the other, enhancing overall reliability and validity. Moreover, mixed-methods research is particularly valuable in that it facilitates both exploration and explanation. Qualitative data offer rich contextual information that can explain quantitative results, shedding light on the underlying mechanisms and rationales. This dual approach contributes to the increased credibility of research findings, as it acknowledges the multifaceted nature of the research subject. Mixed-methods research can also result in better-informed decision-making processes, offering decision-makers a more nuanced and comprehensive basis for their choices. Researchers can tailor the mix of methods to suit the research question at hand, thus ensuring flexibility and adaptability in the research design. However, successful mixed-methods research requires careful planning, rigorous data collection, and effective integration of qualitative and quantitative components.

As I reflect on my study, I have an overwhelming feeling of accomplishment. Overall, I succeeded in answering the research questions. The PBL unit I designed for my AP Biology classes improved student science identity, self-efficacy, and SEL skill development. Combining survey data with interview and field note data illuminated how and why the PBL unit yielded such results. Thus, I am confident in my research design.

**Limitations**

While the study offers valuable insights into the impact of PBL on students’ science self-efficacy, science identity, and social–emotional skills, I must acknowledge and address its inherent limitations. These limitations provide valuable opportunities for
further research and the refinement of findings, enhancing understanding of the complexities involved.

One notable limitation is the study’s relatively small sample ($n = 53$) of students in a high school from a suburb of a Southeastern state. Almost 37% of the student participants were already enrolled in our high school’s honors or college prep math and science magnet program. Participation in these programs is interest-based, so these students had already demonstrated a base level of enthusiasm in mathematics and science. Additionally, AP courses are optional, so students who chose to enroll in the course already had an interest in biology. Thus, changes in science self-efficacy and science identity observed in this study may not transfer to other settings. The limited sample size inhibits generalizability of the findings to a broader, more diverse population. Potential variation in responses from students in different academic contexts or educational levels underscores the need for future studies with larger, more diverse samples to validate and expand on the results.

Due to restrictions imposed by my school district, I could not collect any personal information linked to individual students, preventing the analysis of data based on demographics. Examining data through the lenses of gender and race would have been particularly insightful, considering the significant variations in the influence of science identity on students' future science choices based on these factors (Collins et al., 2020; Falco & Summers, 2019; Vincent-Ruiz & Schunn, 2018). Unfortunately, the constraints limited the exploration of potential trends in my classroom and the potential impact of PBL on them.
Additionally, despite my efforts to encourage honest responses, students may have provided answers they perceived as socially desirable, especially when discussing their experiences and growth during the PBL unit. This potential social desirability bias could impact the accuracy and objectivity of the self-reported data. Moreover, relying on self-report measures for quantitatively assessing science self-efficacy, science identity, and SEL skills introduces subjectivity into the analysis. Individual perceptions and biases can influence how students assess their abilities and emotional experiences, potentially affecting the reliability of the data. Furthermore, the study occurred in a specific school environment with unique characteristics. These contextual factors can significantly impact the outcomes, which may not universally apply to all educational settings. Future studies can address these shortcomings by employing larger, more diverse samples, utilizing multiple data sources, and exploring the impacts of PBL across various educational contexts. These endeavors will contribute to a more comprehensive and nuanced understanding of the effects of PBL on student learning and development.

The PBL unit in this study underwent comprehensive evaluation and garnered validation from three distinct university professors. Despite this endorsement, there is always potential for enhancement and refinement. To further enhance its effectiveness, one possible step is to collaborate with another experienced AP Biology teacher who is well-versed in the PBL framework. Their insights, grounded in content and design expertise, could provide valuable suggestions for improvement. Moreover, in subsequent implementations of this unit, an additional strategy could involve inviting external educators or professors to partake in classroom observations. Their specific focus would be to assess the adherence to effective PBL protocols in the instructional process. This
external perspective and evaluation would ensure optimal execution of the PBL framework in accordance with its intended principles.

The study occurred in a relatively short timeframe of 3 weeks, thereby providing a focused examination of the immediate effects of PBL on the specified outcomes, whereas long-term effects and the sustainability of these influences on students’ overall development were beyond the scope of the study. By design, the study centered on assessing the immediate impact of PBL on targeted outcomes, offering valuable insights into the initial benefits of this pedagogical approach. Nevertheless, the absence of a long-term perspective limits understanding of how these effects may evolve and endure over time. Future research could adopt a longitudinal approach to gain a more comprehensive understanding of the enduring influence of PBL on students’ development. Such studies would allow for tracking students’ progress and development over an extended period, encompassing not only the immediate benefits observed in this study but also the potential long-term advantages and sustainability of PBL. While this study serves as a valuable exploration of the immediate effects of PBL, it highlights the need for further research that delves into the longitudinal and sustained impacts of this innovative pedagogical approach on students’ learning and development.

The outcomes of the study, while revealing the connections between PBL and the variables under study, underscore the limitations related to attribution. The observed changes in students’ science self-efficacy, science identity, and SEL skills may not be solely attributable to PBL. Several other factors could inform these changes. One notable consideration is the potential influence of teacher expertise and instructional practices. The study does not extensively delve into my role in facilitating the PBL unit. Teachers
bring their unique expertise, teaching styles, and classroom management approaches into the learning environment. These factors can significantly impact students’ learning experiences and outcomes (Ertmer & Glazewski, 2015; Hayes et al., 2020; Stronge et al., 2007). A more comprehensive examination of my influence and pedagogical strategies could provide valuable insights into the changes and their underlying mechanisms.

Furthermore, the classroom environment, including its dynamics and resources, may contribute to the outcomes. Factors such as peer interactions, classroom culture, and available educational materials can shape the effectiveness of PBL. The study did not thoroughly explore these aspects, leaving room for further investigation into their roles and contributions. Another consideration pertains to preexisting student characteristics. Individual student attributes, such as prior knowledge, motivation, and learning preferences, can influence their responses to instructional methods like PBL. These characteristics may interact with the effects of PBL and a deeper examination of how these factors interplay could illuminate the observed changes. Thus, while the study identifies correlations between PBL and the specified outcomes, acknowledging multiple contributing factors is crucial. A more comprehensive exploration of these influences and their interactions can offer a nuanced perspective on the dynamics at play in the context of PBL. Addressing these considerations in future research will yield a more comprehensive understanding of PBL’s multifaceted impact on student development.

Due to the ethical considerations associated with conducting an action research study, exposing one of my AP Biology courses to one pedagogical practice while excluding the other class was not feasible. Consequently, this study lacked a control group, which presents certain limitations. The absence of a control group, specifically
one that did not engage in the PBL unit, complicates the task of isolating and attributing specific effects solely to PBL. Including a control group that did not participate in the PBL unit could have strengthened the evidence and allowed for a more rigorous comparison of the impacts of PBL. A control group serves as a benchmark against which to measure the outcomes of the experimental group—in this case, the PBL participants. It clarifies whether observed changes result from the intervention or other factors. Comparing PBL participants to a non-PBL group would yield insights into the distinct effects of PBL on student outcomes, thereby enhancing the study’s validity and generalizability. While the absence of a control group presents a limitation, the ethical constraints and the commitment to providing equitable educational experiences to all my students understandably guided the study’s design. Nonetheless, acknowledging this limitation is essential, and future research in this area could explore alternative methodologies or contexts to address this challenge and further illuminate the impacts of PBL on student learning and development.

While the study primarily underscores the positive outcomes associated with PBL, exploring the potential challenges, drawbacks, or situations where PBL may not prove as effective is equally vital. Because the merits of PBL are well-established, a balanced examination that encompasses its limitations can offer a more comprehensive understanding of its applicability and nuances. By studying the potential pitfalls and constraints associated with PBL, educators can make informed decisions regarding its implementation and develop strategies to address any hurdles that may arise. This comprehensive approach ensures a more holistic perspective, enabling educators to
harness the strengths of PBL while mitigating its limitations, ultimately optimizing its impact on student learning and development.

In summary, to address these limitations, future research should employ larger, more diverse samples; incorporate control groups; employ mixed methods; and investigate PBL’s long-term effects on students’ science self-efficacy, science identity, and SEL skills. Additionally, exploring potential moderating factors, such as teacher practices and classroom contexts, can provide a more nuanced understanding of the relationship between PBL and student outcomes.

Moving Forward

Expanding upon the findings and exploring related research areas can facilitate a deeper comprehension of the impact of PBL on student outcomes. There are several promising avenues for future research and study expansions that warrant consideration. First, conducting a year-long longitudinal study could offer valuable insights into the long-term effects of PBL on students’ science self-efficacy, science identity, and SEL skills. This extended research approach would involve tracking students over several months, encompassing the implementation of multiple PBL units. Such a study could ascertain the sustainability of the observed benefits over time. Second, comparing PBL with other instructional approaches, such as traditional lecture-based teaching or inquiry-based learning, would be beneficial. This comparative analysis could illuminate which approach yields the most significant gains in science self-efficacy and identity. This could be particularly insightful for practitioners, who may not use PBL in every instructional unit, encouraging assessment of its relative effectiveness.
Because my school has a very diverse student body regarding race, ethnicity, and socioeconomic background, I could benefit from exploring how to tailor PBL to promote equity and inclusion in science education. I would like to explore how to customize PBL to foster fairness and inclusivity in science education and whether PBL can reduce achievement gaps among students from diverse backgrounds and abilities. Furthermore, investigating specific approaches and adjustments within the design of PBL curricula that advance equity and inclusion would be valuable. Earlier research by Krajcik et al. (2022) focused on elementary-level education, where third-grade students, with 78% belonging to minority groups, participated in a multiple-literacies PBL that integrated PBL with SEL, culturally relevant pedagogy, STEM, and three-dimensional learning goals. The third-grade students exhibited statistically significant enhancements in SEL competencies and academic performance, which Krajcik et al. attributed to the culturally relevant approach. In a high school context, future research could include PBL units reflecting diverse viewpoints, culturally pertinent content, and supportive structures, thereby empowering all students to actively participate and excel in science education.

Although quite a few of my students aspire to work in science-related fields already, I did have quite a few who were unsure. For a future study, I could investigate the impact of PBL experiences on students’ career aspirations and their level of interest in STEM fields, which presents a promising avenue for exploration. While studies conducted at the high school and collegiate level have indicated that PBL can have a positive influence on students’ interest in STEM careers, there is a clear need for additional research to delve deeper into how PBL may affect long-term retention in science-related fields and eventual career choices (Beier et al., 2018; Bicer & Lee, 2019;
LaForce et al., 2017). Understanding how PBL can catalyze pursuance of STEM careers, especially for students who may be uncertain about their career paths, is of significant educational and societal relevance.

Engaging in these research directions promises to enrich and refine my PBL practices, ultimately enhancing their impact on my students’ science self-efficacy, science identity, and SEL skills. The insights from these efforts can profoundly inform my instructional strategies, enabling me to better support my students’ development and success. As I explore these research avenues, I can anticipate several tangible benefits: improved PBL design guided by research findings to address achievement gaps and foster diversity and inclusion, refined instructional approaches incorporating real-world STEM applications and diverse STEM role models to inspire a wider range of students, enhanced SEL integration through targeted interventions, promotion of equity by implementing strategies ensuring equitable access to learning opportunities, and a shift toward more student-centered learning experiences aligning PBL with students’ diverse interests and aspirations. In essence, these research pursuits represent a commitment to continuous improvement in my teaching practices, with a particular emphasis on the transformative potential of PBL, fostering an inclusive and supportive learning environment that empowers students from diverse backgrounds to excel in science and pursue STEM careers. Through this research, I not only contribute to the broader educational field but also cultivate an enriching educational experience for my students, ultimately nurturing their growth and success in academic and life endeavors.

Summary
Action research is a cyclical, inquiry-based process that addresses a localized problem (Mertler, 2017). In this study, I considered teaching methods that could enhance students’ social and emotional skills, science self-efficacy, and science identity. Among various research-supported science teaching methods, I decided PBL could be an ideal avenue through which I could accomplish these goals. Thus, I developed a PBL unit, with specific inclusion of SEL skills, to implement in my AP Biology classes to address my problem of practice. Overall, students responded positively to the unit and showed gains in all areas of interest. In completing this action research study, I plan to share my research with colleagues at my school and throughout my school district. I also would like to share with other high school teachers at science conferences and in a national publication. I plan on continuing the action research cycle by implementing PBL in my other courses to see if the results of this study are mirrored in other subjects and with other content. I will continue to reflect on my classroom practices and make the necessary modifications to create the best learning environment for my students.
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APPENDIX A: PBL UNIT PLAN PROJECT PLANNER

"Beyond the Genome: Investigating the Molecular Mechanisms of Cancer and the Role of Genetic Counseling"

M. Spigner

Project Overview

Project Title: "Beyond the Genome: Investigating the Molecular Mechanisms of Cancer and the Role of Genetic Counseling"

Driving Question: "How can genetic counseling help us understand and treat cancer at the molecular level?"

This question is open-ended thought-provoking, and challenges students to explore the role of genetic counseling in cancer prevention and treatment. It encourages students to investigate the genetic and environmental factors contributing to cancer and the molecular mechanisms involved in cancer development and progression. Additionally, it invites students to think critically about the different treatment strategies available and how they can be personalized through genetic counseling to optimize cancer treatment outcomes.

Grade Level/Subject(s): High school / AP Biology, 11th and 12th grade

Standards: The AP Biology standards that will be addressed in this unit are in this google doc. The standards included are comprehensive and will not necessarily be taught during the PBL unit. However, it will be essential for the students to understand them and apply the content to the PBL unit. The specific AP Biology College Board standards that will directly be addressed through this unit are:

IST-4 The processing of genetic information is imperfect and is a source of genetic variation.
IST-4.A. Explain how changes in genotype may result in changes in phenotype.
IST-4.A.1 Errors in DNA replication or DNA repair mechanisms and external factors, including radiation and reactive chemicals, can cause random mutations in the DNA—
a. Whether a mutation is detrimental, beneficial, or neutral depends on the environmental context.
b. Mutations are the primary source of genetic variation.
ST-4.A.2 Errors in mitosis or meiosis can result in changes in phenotype—
a. Changes in chromosome number often result in new phenotypes, including sterility caused by triploidy and increased vigor of other polyploids.
b. Changes in chromosome number often result in human disorders with developmental limitations, including Down syndrome/Trisomy 21 and Turner syndrome.
Time Frame: Three Weeks

Project Summary: Many students are affected by cancer in one way or another; they may have a family member with cancer, they may know a friend who has had a relative with cancer or they may know an adult who has had cancer. However, students don't really understand what cancer is, the genetic causes, and how it can affect a person. This unit will start with students reading about various cancer patients of differing demographics and ages. They will hopefully see that cancer does not discriminate and can affect anyone of any age, race, gender, et cetera. Students will then be tasked with developing a product (website, brochure, poster, presentation, etc.) that will be used around our school community and increase student knowledge regarding cancer.

Community Partner Summary: My community partner is a USC School of Medicine student in the Genetic Counseling program. She will visit my classes and talk about what happens when someone has to go to a genetic counselor when evaluating their risk for cancer and/or they have had a cancer diagnosis and need to evaluate genetic risk factors for relatives. She will also discuss with my students the field of genetic counseling in general (what it entails, the schooling/training required, what the job is like, etc.). This will be an enriching experience for my students to learn about the field of genetic counseling and the role of genetic counseling in evaluating genetic risk for cancer.

Group Public Product(s) & Rubrics: Each group will create TWO products:

1. An informational display of information for classmates and others to view (this could be an informational infographic, video presentation, “science fair” type poster, etc.). The information that you need to include on your display is listed below.

2. The second product is up to each group in terms of format (website, brochure, video, etc.), but the GOAL of the second product is informational for PATIENTS to read. These will be given to the “patients.”

The third major part of this project is that each group will take on the role of genetic counselors and will present this information to their “patients” who have a family member just diagnosed with this cancer. These “patients” will be played by various individuals, including me, your peers, other teachers, administrators, local healthcare professionals, American Cancer Society representatives, and district office personnel.

The rubrics can be found in this document.

Individual Product(s) & Rubrics: The proof-of-learning product each individual student is responsible for producing will be their virtual Google slide reflection journal. This reflection journal will be something that each student will work on as a daily assignment during the entire 2 weeks that the unit will span. The reflection journal will document the progress/work completed by the group and by the individual student EACH day throughout the unit. The student will also include a reflection on what they personally learned and how they feel about their individual and group progress toward the goal.

Learning Goals: Students will learn all about cancer from the genetic basis, demographics, diagnosis, treatments, how to reduce risk, and even the current climate in research and public policy. They will be able to learn the standards and develop communication, research, and collaboration skills.

Specific learning goals are as follows:
• Students will understand a set of basic biological principles related to cancer as a cellular phenomenon.
• Students will experience the process of inquiry and develop an enhanced understanding of the nature and methods of science.
• Students will be able to recognize the role of science in society and the relationship between basic science and personal and public health.

**Challenging Problem or Question:** The driving question "How can genetic counseling help us understand and treat cancer at the molecular level?" is likely to sustain student interest and focus throughout the unit for several reasons:
1. **Relevance:** The question is relevant to students' lives, as cancer is a prevalent disease that affects many individuals and families. Understanding how genetic counseling can help prevent and treat cancer at the molecular level can empower students with knowledge and skills that could impact their own health and that of their loved ones.
2. **Complexity:** The question is complex and multi-faceted, requiring students to integrate knowledge and skills from different areas of biology, genetics, and healthcare. As they work to answer the question, students will engage in critical thinking, problem-solving, and collaboration, which are all important skills for success in the 21st century.
3. **Personalization:** The question invites students to personalize their learning by assuming the role of a genetic counselor and meeting with a hypothetical cancer patient. This hands-on experience will help students see the practical application of their learning and make connections between the different topics covered in the unit.

Overall, the driving question will likely sustain student interest and focus throughout the unit by challenging students to engage in real-world problem-solving and offering a compelling, relevant, and complex topic that will keep students engaged and motivated to learn.

**Sustained Inquiry:** Students must use inquiry at almost every milestone throughout the unit. Students will be the drivers of their own learning in this unit, with me as the teacher as a scaffolding presence but not the primary driver of knowledge acquisition.

Specific examples are as follows:
1. **Exploration:** Encourage students to explore various aspects of the genetic basis of cancer through research and investigation. This can involve exploring cancer's molecular and cellular mechanisms, the genetic mutations that contribute to cancer, and the various diagnostic and treatment options available.
2. **Investigation:** Provide opportunities for students to investigate specific questions related to the genetic basis of cancer. This can involve designing and conducting experiments, analyzing data, and drawing conclusions based on the results.
3. **Questioning:** Encourage students to ask questions throughout the unit and provide opportunities for them to pursue their own lines of inquiry. This can involve developing individual milestone questions that align with the overarching driving question and encouraging students to generate their own questions based on their research and investigations.
4. **Reflection:** Encourage students to reflect on their learning and progress throughout the unit and identify areas where they need further inquiry. This can be achieved through regular journaling or writing assignments that prompt students to consider what they have learned, what challenges they have faced, and how they can apply their learning in the future.

By providing multiple opportunities for exploration, investigation, questioning, and reflection, students can engage in a meaningful and iterative process of learning that leads to deeper...
understanding and long-term retention of knowledge. This process also helps students to develop important skills such as critical thinking, problem-solving, and scientific inquiry.

**Authenticity:** The driving question and overall nature of the PBL unit on the genetic basis of cancer reflect authentic, real, recognizable circumstances and scenarios that students will find familiar and relatable in several ways:

1. Relevance: Cancer is a disease that affects millions of people worldwide, and many students are likely to know someone who has been diagnosed with cancer. The PBL unit provides a relevant and relatable context for students to explore the genetic basis of cancer and its impact on individuals and families.

2. Real-world connections: The unit connects to real-world issues and challenges related to cancer diagnosis and treatment and broader issues related to genetics and healthcare. By exploring these issues in the unit context, students can gain a deeper understanding of the role of genetics in health and disease.

3. Personal relevance: The final proof-of-learning product, which involves assuming the role of a genetic counselor and meeting with a hypothetical cancer patient, is authentic because it requires students to apply their learning to a real-world scenario relevant to their lives and experiences. By assuming this role, students can gain a deeper understanding of the challenges and opportunities associated with genetic counseling and its role in cancer diagnosis and treatment.

4. Collaboration: The PBL unit also provides opportunities for collaboration and teamwork, which are essential skills in many professional settings. By working together to explore the genetic basis of cancer and develop a final product, students can learn how to communicate effectively, share ideas, and solve problems collaboratively, skills that are essential in healthcare and other fields.

Overall, the driving question and final proof-of-learning product in the PBL unit on the genetic basis of cancer reflect authentic, real, recognizable circumstances and scenarios that students will find familiar and relatable. By exploring these issues in the context of the unit, students can gain a deeper understanding of the role of genetics in health and disease and develop important skills essential for success in healthcare and other fields.

**Student Voice & Choice:**

1. Research direction: Students will be encouraged to explore different research directions within the scope of the unit. This can be achieved by allowing them to choose which research articles to read or which molecular techniques to apply in their investigation.

2. Project format: Students will have a choice in how they want to present their research findings. For example, they can choose to create a poster, a video, a presentation, or a written report.

3. Collaboration: Students will be encouraged to collaborate with each other and share ideas. This can be achieved through group discussions, peer reviews, or team projects.

By giving students agency and voice through these various opportunities, they can take ownership of their learning and progress through the unit in a way that aligns with their interests and strengths. As a result, they are more likely to be engaged, motivated, and invested in their work, leading to deeper learning outcomes. Additionally, student voice and choice can inform their work in the unit by allowing them to connect the material and their personal interests and experiences.

**Critique & Revision:** Peer feedback: There will be opportunities for students to give and receive feedback from their peers. This can be achieved through peer review sessions or group
discussions where students can share their ideas, critique each other's work, and provide constructive feedback. Teacher feedback: Regular feedback will be given to students on their work, progress, and learning outcomes. This feedback can be given through individual meetings or group discussions where students can receive personalized feedback and suggestions for improvement. Revision process: Students will be asked to revise their work based on feedback received from their peers and teachers. This can be achieved through a structured revision process that involves multiple rounds of feedback and revision. Reflection and self-assessment: Students will be asked to reflect on their own work and assess their progress. This can be achieved through regular journaling or writing assignments that prompt students to consider what they have learned, what challenges they have faced, and how they can apply their learning in the future.

Collaboration: Collaboration will be encouraged between students to facilitate peer feedback and revision. This can be achieved through group discussions, peer reviews, or team projects. Students can refine their ideas and improve their work throughout the unit by providing multiple opportunities for feedback and revision. Additionally, this process helps students develop important skills such as critical thinking, self-awareness, and metacognition, which are essential for success in academic and professional settings.

**Reflection:**

1. Self-reflection: Encourage students to reflect on their learning and progress through the unit. This can be achieved through regular journaling or writing assignments that prompt students to consider what they have learned, what challenges they have faced, and how they can apply their learning in the future.

2. Peer feedback: Provide opportunities for students to give and receive feedback from their peers. This can be achieved through peer review sessions or group discussions where students can share their ideas, critique each other's work, and provide constructive feedback.

3. Teacher feedback: Offer regular feedback to students on their work, progress, and learning outcomes. This feedback can be given through individual meetings or group discussions where students can receive personalized feedback and suggestions for improvement.

4. Class discussions: Facilitate class discussions that allow students to reflect on the material covered in the unit. These discussions can be based on specific topics or themes, allowing students to share their perspectives, insights, and questions.

5. Trial runs: Provide opportunities for students to practice their genetic counseling skills through role-play scenarios or mock counseling sessions. This can help students identify improvement areas and refine their skills before meeting with a hypothetical cancer patient.

By offering multiple opportunities for reflection informed by critique and feedback, trial runs, data collected from tests, and class discussions, students can engage in a meaningful and iterative process of learning that leads to deeper understanding and long-term retention of knowledge. Reflection also helps students to develop important skills such as critical thinking, self-awareness, and metacognition, which are essential for success in academic and professional settings.

**Public Product:** The group proof-of-learning product, where students assume the role of a genetic counselor and meet with a hypothetical cancer patient, will be communicated to a wider audience in several ways, including:
1. Presentations: Students will present their final products to the class, as well as to other classes and school staff. This will be done as a simulation of a genetic counseling session.

2. Virtual platform: Student groups will also create a virtual platform, such as a website or blog, to showcase their final products. This can include video recordings of their genetic counseling session, written reports, or other materials.

3. Community outreach: Students will also collaborate with local healthcare providers, advocacy groups, or cancer support groups to share their final products and raise awareness about the role of genetics in cancer diagnosis and treatment.

The group proof-of-learning product serves as evidence that students have accomplished the learning goals aligned to the unit in several ways:

1. Application of knowledge: By assuming the role of a genetic counselor and meeting with a hypothetical cancer patient, students are applying the knowledge and skills they have gained throughout the unit.

2. Critical thinking: In developing their final product, students must demonstrate critical thinking skills, such as problem-solving, decision-making, and analysis of complex information.

3. Collaboration and communication: By working in groups and presenting their final products, students demonstrate collaboration and communication skills, which are essential for success in healthcare and other fields.

4. Reflection: The final product also provides an opportunity for students to reflect on their learning and receive feedback from peers and instructors, which can help them further develop their knowledge and skills.

Overall, the group proof-of-learning product comprehensively demonstrates the student's learning and ability to apply their knowledge and skills to real-world scenarios. By communicating their final products to a wider audience, students can raise awareness about genetics’ role in cancer diagnosis and treatment and showcase their learning to the broader community.
APPENDIX B: PARENT AND STUDENT CONSENT FORM

January 17, 2023

Dear AP Biology student and parent / guardian,

Hello! My name is Michelle Spigner, and your child is enrolled in my AP Biology class this year.

I am a doctoral candidate in the Education Department at the University of South Carolina. I am conducting a research study as part of the requirements of my Doctor of Education degree in Educational Practice and Innovation with a concentration in STEM Education. For my research study I would like to utilize my students and I am seeking your permission for your child to take part in my research study.

The working title for this study is: The Use of Project-based Learning to Scaffold Student Social and Emotional Learning Skill Development, Student Science Identity and Science Self-Efficacy.

This is a very technical way of saying that I want to understand if project-based learning can affect student social and emotional skills, their feelings of confidence in science and / or their personal identification as a “science person”. The overall goal for this study is to help me become a better teacher by understanding if project-based learning can positively affect my students in AP Biology.

To help me carry out this research, students will have to complete three short surveys in class twice during February. The surveys will be administered before a project-based learning unit is started and then after the completion of the two-week unit. The surveys will be administered at the beginning of the class on February 10 and then at the beginning of class on February 27th. Additionally, some students will be asked to participate in small-group and/or individual interviews that will take place during lunch or at a time most convenient for the student(s).

In particular, students will be asked questions about social and emotional skills, science identity and science self-efficacy. If a student ever feels uncomfortable answering some of the questions, they can choose not to answer. Students do not have to answer any questions that they do not wish to answer. All group discussions and individual interviews will take place in my classroom, room E312, during lunch or at a time most convenient for the student(s) and should last about 25 minutes. The group discussions and interviews will be audio recorded so that I can accurately transcribe what is discussed. The recordings will only be reviewed by myself and one other teacher (to help prevent bias on my part) and they will be deleted upon completion of the study. For the group discussions, others in the group will hear what other students say, and it is possible that they could tell someone else. Because we will be talking in a group, I cannot promise that what students say will remain completely private, but I will ask that all students and all other group members respect the privacy of everyone in the group.
I wish to alleviate any concerns you may have about allowing your child to be a part of this study.

- Participation is confidential. Study information will be kept in a secure location at Spring Valley High School and my personal residence and will all be destroyed upon completion of the study. The results of the study may be published or presented at professional meetings, but student identity will not be revealed.
- Student information will be identifiable to me for the purposes of charting changes within the surveys over time. Personally identifiable information will not be shared in the data analysis or final writing of the dissertation.
- There is no anticipated risk to participants (physical, psychological, legal)
- **I will not analyze any data until after your child has completed the class.**
- You have the right to inspect materials before consenting, if you wish.
- While Richland School District Two has given me permission to conduct this research, Richland School District Two itself is not conducting or sponsoring this project.
- There is no penalty to your child for not participating in this study.
- There is no penalty to your child for withdrawing from the study at any time.

If there are any questions or concerns, you may email me at USC email address, or contact me via phone. You can also contact my advisor, Dr. Christine Lotter.

Thank you for your support and consideration!

With kind regards,

Michelle Spigner

Please choose an option below. If you give consent, please sign and have your child sign the document as well, as that will indicate that your child understands that they recognize the purpose of the research and will participate in filling out the surveys in class and possibly participate in group discussions and/or interviews.

__________ Yes, I give permission for my child to take part in this study.

Parent Signature __________________________ Student Signature __________________________

Student Printed Name __________________________

__________ No, I do not give permission for my child to take part in this study.

Parent Signature __________________________

Student Printed Name __________________________
APPENDIX C: IRB LETTER

OFFICE OF RESEARCH COMPLIANCE

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
DECLARATION of NOT RESEARCH

Michelle Spigner
820 Main Street
College of Education
Wardlaw College
Columb, SC 29208

Re: Pro00126158

Dear Mrs. Michelle Spigner:

This is to certify that research study entitled The Use of Project-based Learning to Scaffold Student Social and Emotional Learning Skill Development, Student Science Identity and Science Self-Efficacy was reviewed on 1/23/2023 by the Office of Research Compliance, which is an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). The Office of Research Compliance, on behalf of the Institutional Review Board, has determined that the referenced research study is not subject to the Protection of Human Subject Regulations in accordance with the Code of Federal Regulations 45 CFR 46 et. seq.

No further oversight by the USC IRB is required. However, the investigator should inform the Office of Research Compliance prior to making any substantive changes in the research methods, as this may alter the status of the project and require another review.

If you have questions, contact Lisa M. Johnson at lisaj@mailbox.sc.edu or (803) 777-6670.

Sincerely,

Lisa M. Johnson
ORC Assistant Director and IRB Manager
# APPENDIX D: SOCIAL AND EMOTIONAL SKILL ASSESSMENT

## FORM

### WCSD Social and Emotional Competency Long-Form Assessment

**Directions:** Please tell us how easy or difficult each of the following are for you.

**Response Options:** 1 = Very Difficult; 2 = Difficult; 3 = Easy; 4 = Very Easy

### Self-Awareness: Self-Concept

1. Knowing what my strengths are.
2. Knowing how to get better at things that are hard for me to do at school.
3. Knowing when I am wrong about something.
4. Knowing when I can't control something.

### Self-Awareness: Emotion Knowledge

5. Knowing when my feelings are making it hard for me to focus.
6. Knowing the emotions I feel.
7. Knowing ways to make myself feel better when I'm sad.
8. Noticing what my body does when I am nervous.
9. Knowing when my mood affects how I treat others.
10. Knowing ways I calm myself down.

### Social Awareness

11. Learning from people with different opinions than me.
12. Knowing what people may be feeling by the look on their face.
13. Knowing when someone needs help.
14. Knowing how to get help when I'm having trouble with a classmate.
15. Knowing how my actions impact my classmates.

### Self-Management: Emotion Regulation

16. Getting through something even when I feel frustrated.
17. Being patient even when I am really excited.
18. Staying calm when I feel stressed.
19. Working on things even when I don't like them.

### Self-Management: Goal Management

20. Finishing tasks even if they are hard for me.
21. Setting goals for myself.
22. Reaching goals that I set for myself.
23. Thinking through the steps it will take to reach my goal.
Self-Management: School Work
24. Doing my schoolwork even when I do not feel like it.
25. Being prepared for tests.
26. Working on assignments even when they are hard.
27. Planning ahead so I can turn a project in on time.
28. Finishing my schoolwork without reminders.
29. Staying focused in class even when there are distractions.

Relationship Skills
30. Respecting a classmate's opinions during a disagreement.
31. Getting along with my classmates.
32. Sharing what I am feeling with others.
33. Talking to an adult when I have problems at school.
34. Being welcoming to someone I don’t usually eat lunch with.
35. Getting along with my teachers.

Responsible Decision-Making
36. Thinking about what might happen before making a decision.
37. Knowing what is right or wrong.
38. Thinking of different ways to solve a problem.
39. Saying "no" to a friend who wants to break the rules.
40. Helping to make my school a better place.

If you have additional questions about this assessment and related research, please contact Laura Davidson, Washoe County School District Director of Research and Evaluation at 775-348-3850 or ldavidson@washoeschools.net.
APPENDIX E: FOCUS GROUP QUESTIONS FOR SEL SKILLS

• How do you feel that your communication skills were used during the PBL unit?
• Do you think you developed stronger relationships with your peers during this unit? Why or why not?
• Was there ever a point in which your group disagreed? Tell me about it.
• Did you feel like you were a leader at some point in this unit? Explain.
• Did you ever get frustrated during the unit? Why? What did you do about it?
• Did you ever feel supported by your group members? Did you support others?
• Did you experience stress during the unit? Can you tell me about it?
• (If yes) What did you do about the stress you experienced? Did it help?
• Do you feel that you had to exhibit self-discipline?
• Do you feel that you had to exhibit self-motivation?
APPENDIX F: IDENTITY INVENTORY

Instructions for Students:

Draw or find an image that represents you and place it in the middle rectangle. Write your name below the rectangle. Use the blanks provided to the sides of the rectangle to write descriptors you consider to be key aspects of your identity. Add more blanks as needed. Then use the questions below to reflect on how your identity factors influence your life.

• What identity factors most shape your worldview?
• Which factors are visible? Invisible?
• How do you resolve conflict when others have opinions diametrically opposed to your perspective?
• How do your identity factors influence your choices and your actions?
APPENDIX G: PBL GROUP CONTRACT

Our Problem Statement

Community Agreements

<table>
<thead>
<tr>
<th>Operational Agreements</th>
<th>Relational Agreements</th>
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Group Communication

<table>
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<th>Contact Info (phone &amp; email)</th>
<th>Availability Outside of School</th>
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Group Member Assets

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<th>Assets</th>
<th>Areas of Growth</th>
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184
Team Member Roles

<table>
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<th>Group Member Name</th>
<th>Project Role(s)</th>
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Decision Making Protocol

Plan for Difficult Conversations
When our group has a disagreement or is having a difficult conversation, we will work through the following questions to help resolve the issue.

- If the disagreement is with a specific group member, have you talked to the person one-on-one? What was the result of that conversation? How might your whole group support you?
- If you continue to have trouble, have you talked about it as a group? What was the result of that conversation? What support might you want from your teacher?
- If you are unable to resolve the issue on your own, have you talked to the teacher? What was the result of that conversation?

Signatures
By signing my name, I agree to hold myself and my group members accountable to the contents of this Project Management Log so that we can achieve our vision.
APPENDIX H: SEL TEACHER CHECKLIST

Student Name: ______________________ Date: ______________________

Self-Awareness:
Demonstrates self-awareness by recognizing and accurately labeling emotions.
Shows an understanding of personal strengths and weaknesses.
Identifies personal interests, values, and goals.

Self-Management:
Demonstrates self-regulation by effectively managing emotions, especially in challenging situations.
Exhibits impulse control and the ability to resist distractions.
Sets and works toward achieving personal and academic goals.

Social Awareness:
Displays empathy by understanding and acknowledging the feelings and perspectives of others.
Shows respect for diversity and individual differences.
Participates in activities that promote a sense of community and belonging.

Relationship Skills:
Demonstrates effective communication skills, including active listening and clear expression of thoughts and feelings.
Collaborates well with peers in group activities or projects.
Resolves conflicts constructively by seeking win-win solutions.
Responsible Decision-Making:

Makes thoughtful and ethical choices, considering potential consequences.
Analyzes problems and evaluates potential solutions.
Demonstrates good judgment and accountability for actions.

Overall SEL Observations:

Engages in self-reflection and self-improvement efforts.
Shows a willingness to learn from mistakes and setbacks.
Actively participates in SEL activities and discussions.
Consistently demonstrates a positive attitude and behavior toward self and others.
Provides peer support and encouragement when appropriate.
Utilizes SEL skills effectively in various contexts.

Additional Comments or Notes:
APPENDIX I: STUDENT REFLECTION JOURNAL

Instructions Given to Students:

For the duration of this unit you will need to reflect on your own personal progress and your group progress daily. There is a slide for each day of the unit as well as an overall reflection slide at the very end. On each slide I have included a few specific questions that I want you to address in your journal entry for each day. You are also free to write anything else that you would like to comment upon.

<table>
<thead>
<tr>
<th>Day of Unit</th>
<th>Question Prompts</th>
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</table>
| 1           | → What did you feel/think when you watched the videos?  
             | → How do you feel about this new unit?  
             | → How do you feel about working in cooperative groups? |
|             | 2 → What cancer will your group research?  
             | → How do you feel right now?  
             | → What have you contributed so far to the group?  
             | → What will you do to ensure that you will fully contribute to the group assignments? |
|             | 3 → How are you feeling today?  
             | → How do you feel about your group?  
             | → How do you feel about your progress? |
|             | 4 → What are your thoughts today about this class and this project? |
|             | 5 → What questions do you have for the genetic counselor?  
             | → What do you hope to gain from hearing the genetic counselor talk?  
             | → What are your general thoughts? |
|             | 6 → What are three takeaways from the genetic counselor’s talk?  
             | → Can you use anything from this talk and apply it to your group project? Why or why not? |
|             | 7 → What are your thoughts today about this class and this project? |
8 → What questions do you have about this project?
    → What do you plan to do to answer your question(s) if you have any?
    → How can you connect what you are learning in this unit to your life?

9 → Do you feel like you have learned anything interesting so far?
    → How do you feel about the effort you put into this so far?
    → Is there anything you can do to contribute more?
    → What about your group members?
    → Do you feel they have contributed enough?
    → If it is an issue, what can you do to help remind them to help more?

10 → What are your thoughts today about this class and this project?

11 → What are your thoughts about your group progress?
    → How do you feel regarding your relationships in this class?
      What about your group specifically?

12 → How do you feel the peer review went? Do you feel that you learned anything? Did your group get good feedback? Why or why not?
    → Do you feel that you gave good feedback? Why or why not?

13 → Are you ready for the genetic counseling sessions with your “patient”?
    → Why do you feel that way?
    → How do YOU feel about Friday?

14 → What are your feelings today? Do you need to do anything else for tomorrow?

15 → What is your overall impression of this unit?
    → What did you learn about yourself?
    → What will you do differently to help our planet?
    → What will you encourage others to do differently to help our planet?
    → Did you enjoy this unit? Why or why not?
    → How do you think this unit can be improved?
APPENDIX J: STUDENT SCIENCE IDENTITY SURVEY

Student ID number: _______________

Please answer each question honestly. There are no right or wrong answers.

1) I think I did well in science classes.
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree

2) I am able to get a good grade in science subjects.
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree

3) I am able to complete my science homework.
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree

4) I am proficient in using tools and operating apparatus in experiments.
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree

5) I can smoothly conduct a science inquiry activity.
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree

6) I can get a good grade in science and technology competitions
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree

7) I think I am good at science.
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree

8) I can understand scientific laws and principles well.
   Strongly agree  Agree  Neither agree  Disagree  Strongly disagree
9) I am able to use science to explain natural phenomena in daily life.
   Strongly Agree  Neither agree  Disagree  Strongly disagree
   nor disagree

10) I believe I can learn a lot of knowledge in science classes.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

11) I believe I will do well in science.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

12) I believe I can learn even the hardest parts of scientific knowledge if I try.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

13) I think of myself as a science person.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

14) My classmates recognize me as a science person.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

15) My science teachers recognize me as a science person.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

16) My family and friends recognize me as a science person.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

17) I will learn more about science through a variety of sources.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

18) I like to participate in various scientific activities.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree

19) I think the science knowledge taught in my classes is important in the real world.
    Strongly Agree  Neither agree  Disagree  Strongly disagree
    nor disagree
<table>
<thead>
<tr>
<th></th>
<th>I like the science equipment in my science classes.</th>
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<tr>
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<td></td>
<td>Agree</td>
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<tr>
<td></td>
<td>Strongly disagree</td>
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<table>
<thead>
<tr>
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<th>I like to attend classes that are related to science.</th>
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<tr>
<td>21</td>
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<tr>
<td></td>
<td>Agree</td>
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<td>Neither agree</td>
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<td>Disagree</td>
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<tr>
<td></td>
<td>Strongly disagree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>I am interested in careers that are related to science.</th>
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<tbody>
<tr>
<td>22</td>
<td>Strongly agree</td>
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<td></td>
<td>Agree</td>
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<td>Neither agree</td>
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<td>Disagree</td>
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<td></td>
<td>Strongly disagree</td>
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<thead>
<tr>
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<th>I plan to pursue science careers in the future.</th>
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<tr>
<td>23</td>
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<td>Strongly disagree</td>
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<table>
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<tr>
<th></th>
<th>I would feel comfortable talking to people who work in science careers.</th>
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<tr>
<td>24</td>
<td>Strongly agree</td>
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<tr>
<td></td>
<td>Agree</td>
</tr>
<tr>
<td></td>
<td>Neither agree</td>
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<tr>
<td></td>
<td>Disagree</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
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</table>
APPENDIX K: INDIVIDUAL INTERVIEW QUESTIONS FOR

SCIENCE IDENTITY

Adapted from Cian & Dou (2022)

• Would you describe yourself as someone who is interested in science?
• Do you ever feel really curious or excited about science?
• Do you think of yourself as a person who does science?
• If yes, What sort of things do you do that make you feel like a person who does science?
• Do you know anyone who does science? If yes, what do they do that is science?
• Can you think of anyone other than (person mentioned) who you know who does science?
• What do you think it means to be good at science?
• Do you think of yourself as good at science?
• When/where do you feel like you’re good at science?
• Can you give me an example of a time when you felt like you were good at science?
• Have you ever felt like you weren’t good at science? When/where do you feel this way? Can you tell me about a particular moment you felt that way?
• Do you think other people might think you’re good at science? Who might they be? What makes you think that they may think you’re good at science?
• What do you like (not like) about science class? What do your friends in science class think about you during class? Do they go to you for help? Do you think of any kids in your class as a science person? If yes, What do they do that makes you think of them like that? 2. Do you think your teacher would agree with them? What makes you think that?
• Do you think of yourself as a scientist? If no, what do you think is the difference between you and a scientist?
• How has participation in the PBL unit changed how you see yourself as a learner of science?
• What are some of the aspects of the PBL unit that have influenced how you think and feel about science?
• Were there some the aspects of the PBL unit that made you feel less like a scientist?
APPENDIX L: SELF-EFFICACY FOR LEARNING AND DOING SCIENCE (SELD, GENERIC) SCALE

STUDENT ID #: __________________________

Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by circling the number in the appropriate column. Please respond as you really feel, rather than how you think “most people” feel.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>These statements are about how you feel about learning and understanding science topics.</strong></td>
<td></td>
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</tr>
<tr>
<td>1. I think I’m pretty good at understanding science topics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. Compared to other people my age, I think I can quickly understand new science topics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. It takes me a long time to understand new science topics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. I feel confident in my ability to explain science topics to others.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</table>
These statements are about how you feel about doing scientific activities.

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<tr>
<td>5. I think I’m pretty good at following instructions for scientific activities.</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>6. Compared to other people my age, I think I can do scientific activities pretty well.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. It takes me a long time to understand how to do scientific activities.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>8. I feel confident about my ability to explain how to do scientific activities to others.</td>
<td>1</td>
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APPENDIX M: FOCUS GROUP QUESTIONS FOR SELF-EFFICACY

Adapted from Arcelay-Rojas, 2018.

General Background Questions
1. Why did you decide to take AP Biology?
2. What do you hope to gain from this course?

Mastery Experiences
1. Describe your experience during the PBL unit.
2. What did you feel that you did well during the PBL unit?

Vicarious Experiences
1. Who do you identify as role models and as an influence in how well you do in this course?
2. In what way(s) have these role models influenced you?

Verbal Persuasion
1. How would you describe the feedback you have received from your teacher during the PBL unit?
2. How would you describe the feedback you received from the community partner(s) during this unit?
3. How would you describe the feedback you received from the school community (other teachers and administration) during this unit?

Affective States
1. How did you feel at the start of the PBL unit?
2. How did you feel when you first learned of the public presentation of the artifact?
3. How did you feel at the end of the PBL unit?
4. How did you feel when immediately after the public presentation of the artifact?
### APPENDIX N: RAW DATA FOR SEL INSTRUMENT

<table>
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<th>SEL PRE</th>
<th>SEL POST</th>
<th>Self concept PRE</th>
<th>Self Concept POST</th>
<th>Emotion Knowledge PRE</th>
<th>Emotion Knowledge POST</th>
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*Note: Each line of the table corresponds to an individual student and their pre and post scores.*
### APPENDIX O: SEL Determined Inductive Codes

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APPENDIX P: RAW DATA FOR SCIENCE IDENTITY ASSESSMENT

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*Note:* Each line of the table corresponds to an individual student and their pre and post scores.
APPENDIX Q: RAW DATA FOR SCIENCE SELF-EFFICACY AND SUBSCALES

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