An Examination of Successes and Challenges of Teacher Professional Development for Project-Based Learning in a STEM School

by

Ni Clark., B.S., M.A.

A Dissertation

In

Educational and Instructional Technology

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

DOCTOR OF EDUCATION

Approved

Sungwon Shin, Ph.D.
Chair of Committee

Fethi Inan, Ed.D.

Joshua Cruz, Ph.D.

Mark Sheridan, Ph.D.
Dean of the Graduate School

May, 2021

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ACKNOWLEDGMENTS

Completion of this dissertation could not be possible without the help and support of many people. First and foremost, I would like to express my sincere gratitude to my committee chair, Dr. Sungwon Shin, for her extraordinary dedication, invaluable support, uplifting encouragement, and immeasurable flexibility to work with me many nights and even weekends during the past few years. She welcomed me with open arms to nurture me with great patience through the pilot study, pilot training, and this study. She graciously offered her time and shared her expertise through this 2.5-year journey. I was privileged to be allowed to work with a wonderful advisor and mentor.

Second, I am very grateful to each of my committee members, Dr. Fethi Inan and Joshua Cruz, for their valuable comments, knowledge, support, and patience. I thank Dr. Fethi Inan who prepared me for research fundamentals and strategies. I thank Dr. Joshua Cruz for being my wonderful mentor, guiding me for qualitative studies, and involving me in his research. I also would like to express my sincere acknowledgment to Dr. Zhanxia Yang, my fellow researchers Guoxiang Wang, Narges Hadi, and Justin Nakhle for sharing their knowledge and time to help shape my research.

Third, I would like to thank my husband, Joshua Clark, who has been patient, understanding, and encouraging throughout this process. Thank you for handling most of the family duties while I worked on my research. Special thanks to my parents, Weidong Wang and Hua Liu, and my sister, Yue Wang, for their endless love and encouragement at the other end of the globe. I am very fortunate to have such great families who are always supportive.

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ABSTRACT

This study addresses a gap in effectively training novice teachers for project-based learning (PBL). Many studies report that teachers face challenges in using PBL strategies in K-12 classrooms due to the complexity of the pedagogy, design, and implementation of PBL. It is even more challenging for novice teachers. The purposes of this study are to explore (a) teachers' perceptions towards the effectiveness of a newly designed PBL training program; (b) how the training affects teachers' perceptions towards PBL; and (c) the factors associated with the successes and challenges of the training. Two middle school teachers at a STEM school were recruited to receive the ten-week training, and their perceptions were examined through multiple data sources. Using an iterative coding process, I found patterns that reflected several factors, such as teacher belief and classroom management, associated closely with the training program's successes and challenges. Also, putting the teachers' learning into practice in this training was found critical to help deepen teacher knowledge and transform teacher belief.

Overall, both teachers perceived the teacher professional development to be effective in training them for PBL, and their perceptions of PBL in terms of understanding PBL and beliefs in PBL evolved over time during the training. The study's findings suggest that teacher belief, classroom management, and teacher workload were closely associated with the training program's successes and challenges. These findings contribute to better PBL training for novice teachers and aim to increase PBL usage at K-12 schools. An effective PBL training for novice teachers recommends scaffolding teacher growth from PBL knowledge to PBL co-design with mentors, then PBL implementation, and finally independent PBL design. Also, the training should provide

the design and use of management documents to increase teachers' self-efficacy in using PBL.

Keywords: project-based learning, teacher professional development, training effectiveness

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CHAPTER I

INTRODUCTION

Science, Technology, Engineering, and Mathematics fields (STEM) have been the focus of governments worldwide to have sustainable development since the 2000s (Gough, 2015). As the world leader, the United States (U.S.) calls for urgent action to work with learners, families, educators, communities, and employers for the development of fluency in STEM, which is well-recognized as a significant strategy to cultivate future world leaders and skillful workforce (U.S. Department of Education, n.d.). Sensibly, STEM education is seen as the powerhouse for U.S. innovation, prosperity, and security (National Science and Technology Council, [NSTC], 2018). The quantity and quality of K-12 STEM teachers play an important role in preparing U.S. students for academic and career pathways in STEM (Wilson, 2016). Therefore, it is critical to provide teachers with quality training in STEM because an effective training program can change the knowledge, beliefs, and attitudes of teachers, which can lead to the acquisition of new skills, new concepts, and new processes related to the teaching practice (Desimone, 2009; Ertmer & Ottenbreit-Leftwich, 2010).

STEM education often incorporates the nontraditional teaching method, project-based learning (PBL), in either a single STEM subject or in interdisciplinary STEM subjects (Corlu et al., 2014). However, STEM teachers have difficulty understanding PBL, designing PBL, and implementing PBL (Aldabbus, 2018; Ertmer et al., 2014; Lesseig et al., 2016). Therefore, it is urgent to provide STEM teachers with a quality training program in learning PBL.

Background of the Study

Project-Based Learning (PBL) is gaining popularity in the education field, especially STEM education, in the previous three decades and inspiring numerous project approaches and studies. Many researchers report that PBL can increase student self-esteem (Doppelt, 2003), interest (Blumenfeld et al.,1991), motivation to learn, self-mastery, learning responsibility, and academic performance (Bell, 2010; Thomas, 2000). Moreover, PBL can help students better understand the content, deeper learning (Bell, 2010; Blumenfeld et al., 1991; Thomas, 2000), and become better team players, independent researchers, problem-solvers, and high-order thinkers (Bell, 2010; Thomas, 2000). Most importantly, PBL connects students to their community and to the real world and prepares students for the 21st century. (Bell, 2010; Buck Institute for Education [BIE], n.d.; Thomas, 2000). Given the numerous studies, students rise to the challenges that PBL brings and discover their potential through PBL.

The PBL utilizing technology makes the environment more authentic to student learning because students can explore and search information, expand interaction, and collaborate online and in the classroom (Howard, 2002; Krajcik et al., 1994). This provides tools for both teachers and students to develop and produce artifacts. Project-based learning has proven particularly effective in involving the use of computer technology (Barron et al., 1998; Edelson et al., 1999; Solomon, 2003). In many studies, students in a technology-enhanced PBL environment outperformed their peers in a control group who performed projects without using technology (Basilotta Gómez-Pablos et al., 2017; Chang & Lee, 2010; Wu et al., 2018). Therefore, teachers are encouraged to develop innovative ways of using technology to enhance the learning environment and

promote knowledge acquistion and deepening (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2011a).

As an educational researcher and K-12 teacher, I noticed extensive uses of PBL in STEM classrooms and other K-12 education and began to study the pedagogy and how PBL is designed and implemented. I visited a nation-wide, well-known PBL school, High-Tech High school in California and observsed how a teacher taught mathmatics via PBL appraoch and how a history teacher empowered students to have a self-directed discussion. Before this study, I shadowed a PBL expert teacher for half a year to learn how PBL was implemented for a national STEM program. Through the experience, I observed a novice teacher resisted using PBL even though she was mentored for two years. I found the strong need of training K-12 novice teachers effectively in PBL. To learn how to design an effective training, I attended an international teacher workshop hosted by authoritative teacher professioanl development (PD) organization, Buck Instruction for Education (BIE). I learned how to train teachers effectively via remote learning and how to deliver instruction via PBL online and in the classroom.To validate my observed need from the pilot study and explore in depth about the effectiveness of a PBL training, I kept reviewing numerious studies on teacher PD and PBL; PD as well as STEM and other K-12 teachers' struggles with PBL. These studies reported common challenges of STEM and other K-12 teachers in using PBL, especially novice teachers struggles the most.

Statement of the Problem

Education in STEM demands quality teachers (Wilson, 2016). However, STEM teachers lack in-depth content knowledge in STEM, professional development, and

understanding of the available teaching methods and strategies (Ejiwale, 2013; Shernoff et al., 2017). These obstacles result in poor content delivery and assessment for STEM teaching. Project-based learning (PBL) provides the means to improve STEM education (Stearns et al., 2012). However, similar to teachers' problems in STEM education, teachers have difficulty mastering PBL because it is considered ill-structured and involves complex processes (Blumenfeld et al., 1991; Miles et al., 2015). Specifically, many teachers struggle in understanding PBL (Chan, 2016; Lesseig et al., 2016), designing PBL lessons (Aldabbus, 2018; Penuel & Gallagher, 2009), and implementing PBL (Ertmer et al., 2014; Smolleck & Mongan, 2011). Furthermore, it was even more challenging for novice teachers to teach via the PBL approach (Chichekian et al., 2016; Rogers et al., 2011).

Purpose of the Study

The purpose of this study was to investigate novice teachers' perceptions towards the successes and challenges of teacher professional development in learning PBL at a STEM school. The training program had two goals: (1) to train teachers in PBL teaching, specifically in PBL pedagogy, PBL design, and PBL implementation, and (2) to inform teachers and teacher educators about (a) the effective design elements in a teacher training program needed to understand PBL, PBL design, and PBL implementation in STEM classrooms and beyond, (b) how the training program affects classroom teachers' perceptions towards PBL, and (c) the factors associated with the successes and challenges of this program.

This study utilized an exploratory case study approach, which was intensively described and analyzed of a bounded real-life phenomenon, such as a person, process, or

program (Merriam, 1998). This case was bounded within a PBL training program to describe and analyze two novice teachers' perceptions and activities throughout the training, implementation of training outcomes, and evaluation of the training effectiveness.

Research Questions

The following research questions guided this study:

1. How do teachers perceive the effectiveness of a PBL training program?
2. How do teachers' perceptions towards PBL change during the training program?
3. What are the factors associated with the successes and challenges of the training program?

Significance of This Study

The study's significance was to discover the factors that might lead to a teacher training program's success in learning PBL. Also, this study presents a potential effective training design to prepare novice teachers in understanding PBL, PBL design, and PBL implementation. If the training is perceived to be effective, researchers and educators can apply the training design to a larger scale to improve STEM teacher quality. Since student achievement improves with STEM teacher quality improvement (Wilson, 2016), this program can better prepare more students in STEM academic and career pathways to meet the gap with other countries and the growing demand of STEM occupations in the U.S. (ACT, 2018; NSTC, 2018; Olson & Riordan, 2012).

Definitions of Terms

This study utilized the following definitions:

- Driving question – the essential question that drives and guides students to solve the problem or produce a product throughout a project (Boss & Larmer, 2018)
- Entry event – the student activity introduced to stimulate student interest when PBL is launched (Boss & Larmer, 2018)
- General pedagogical knowledge (Shulman, 1987) of PBL – the broad principles and strategies of PBL instruction, including what PBL is and is not, the characteristics and misconceptions of PBL, benefits and challenges of PBL, and the essential elements of PBL design and implementation
- Management documents – the digital files to organize and present PBL for the teacher and students, which include a graphic organizer of the timeline, Google Doc of group organizer, Google Doc of student personal workspace, Google Site of narrowed teaching scope, and PowerPoints of milestone planner for preliminary planning
- PBL – an acronym for project-based learning. In this study, PBL is defined as a teaching approach/strategy/pedagogy to provide students with a learning experience in exploring and serving the real-world by designing and organizing projects
- PBL design – a skill to develop PBL lessons
- PBL implementation – a skill to enact PBL lessons with students
- STEM – an acronym for Science, Technology, Engineering, and Mathematics

- TEKS – Texas Essential Knowledge and Skills, Texas state academic standards for K-12 schools
- Teacher attitudes –teachers' disposition that is expressed by evaluating the training program with some degree of favor or disfavor (Eagly & Chaiken, 1993).
- Teacher belief –teachers' evaluation and judgement about PBL and its implementing environment, aligning it with previous experience (Gill & Hoffman, 2009; Pajares, 1992).
- Teacher knowledge - teacher's understanding in PBL pedagogy and related PBL knowledge
- Teacher self-efficacy - teachers' belief in their capacity to successfully perform and complete tasks (Bandura, 1997)
- Teacher professional development- teachers learning, learning how to learn, and transforming their knowledge into practice for the benefit of their students' growth (Avalos, 2011, p. 10)

Chapter Summary

The demand for STEM quality teachers is increasing as the demand for employment in STEM fields is growing in the United States. STEM education demands teachers to undergo training in PBL. However, teachers face challenges in understanding PBL pedagogy, PBL design, and PBL implementation. This study explored novice teachers' perceptions towards the successes and challenges of a designed teacher training program in learning PBL at a STEM school, addressing three main research questions. To address these research questions, Chapter II presents a thorough review of the literature,

followed by a description of the study's research methods in Chapter III. Chapter IV presents the findings. Finally, Chapter V discusses recommendations for future research.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter presents a literature review in which this study is grounded. The purpose of this study was to investigate teachers' perceptions towards the successes and challenges of a designed training program in learning PBL for STEM teachers. To serve the purpose of this study, three major areas were explored and described from the literature review: (1) overview of STEM education and its challenges; (2) overview of PBL, including its key components, principles, technology's role, and the benefits and teacher challenges of using PBL; teachers' belief and self-efficacy; (3) the effectiveness of teacher professional development, including design components such as video use and reflection and factors to assess a teacher training program.

STEM Education

The definition of *STEM education* provided by Gonzalez and Kuenzi (2012) for congressional research service is preferred in this study because it is simple and straightforward:

> STEM education refers to teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels— from pre-school to post-doctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings. (Sec. 1, para. 1)

However, STEM education faces some challenges, including program quality and teacher training.

Challenges of STEM Education

The U.S. demands large STEM employment but falls short in candidates. According to the Bureau of Labor Statistics, employment in STEM occupations in the U.S. grew by 10.5%, or 817,260 jobs, between 2009 and 2015 (Fayer et al., 2017). However, STEM employment outgrows the number of college students with STEM degrees. The nation would need to increase undergraduate STEM degrees by 34% annually to meet the growing demand for STEM professionals based on the report to the Executive Office of the U.S. President (Olson & Riordan, 2012). Also, the Bureau of Labor Statistics has projected that STEM occupations will grow approximately 13% to more than nine million by 2022—an increase of about one million over 2012 (American Immigration Council, 2017).

While K-12 STEM education can serve as a *pipeline* to post-secondary STEM education (National Governors' Association [NGA], 2008), only 20% of high school graduates in 2018 met the American College Testing's [ACT] STEM readiness benchmark (ACT, 2018). Moreover, 15-year-old students in the U.S. scored below the international average in mathematics and slightly above the international average in science, based on the National Science Board's Science and Engineering Indicators between 2006 and 2015 (NSTC, 2018).

To prepare U.S. students for academic and career pathways in STEM, STEM teachers play a critical role. After reviewing multiple studies in measuring the quantity and quality of K-12 STEM teachers in the U.S., Wilson (2016) claimed that teacher quality positively affects student achievement. Three major barriers for teachers in K-12 STEM education were mentioned in multiple articles (Ejiwale, 2013; Hibpshman, 2007;

Shernoff, 2017). First, STEM teachers lack in-depth content knowledge in STEM. Second, STEM teachers lack professional development (PD). Third, STEM teachers lack an understanding of the available teaching methods and strategies, resulting in poor content delivery and STEM teaching assessment. Therefore, multitudes of the U.S. bureaucratic reports published since the 1990s have called for major changes, expansions, opportunities, and improvements in STEM education and STEM teacher preparation (Council on Competitiveness, 2005; Olson & Riordan, 2012; Rutherford & Ahlgren, 1990).

Some solutions to the three challenges described above have been explored in empirical studies. One empirical study done by Shernoff et al. (2017) reported that the STEM PD must include teaching strategies that are constructivist, inquiry-based, and project-based, based on interviews with teachers and administrators. Among these strategies, STEM education often applies PBL in either a single STEM subject or in interdisciplinary STEM subjects (Corlu et al., 2014). Correspondingly, PBL provides the means to improve STEM education (Stearns et al., 2012) because PBL involves students for high-level thinking and develops their potentials through authentic projects (Brush & Saye, 2000; Bell et al., 2005; Kienzler & Fontanesi, 2017). In essence, STEM and PBL are a natural fit (Miller, 2014).

Project-Based Learning

Definition

Researchers have not reached a consensus in defining PBL. Markham et al. (2003) defined PBL as an extended inquiry process starting from complex, authentic questions and ending with carefully designed products. Sidman-Taveau and Milner-

Bolotin (2001) defined PBL as a comprehensive, constructivist-based approach for students investigating authentic problems. Thomas (2000) defined PBL as a learning model organized around projects, while Bell (2010) viewed PBL as a learning approach that is student-driven and teacher-facilitated.

Project-based learning is one type of inquiry-based learning (Lee et al., 2018). Inquiry-based learning is an active learning process in which students answer the research questions through data collection and analysis and reach their conclusions (Bell et al., 2005; Kienzler & Fontanesi, 2017). The goal of inquiry-based learning is consistent with PBL, which is to develop student understanding of subject matter ideas, principles, and thinking skills (Crawford, 2016).

Project-based learning is similar to community-based learning, which is essentially service-based learning. Students participate in a real-world context to raise their awareness of social, political, economic, and historical issues that they are encouraged to improve or solve (Hart & Akhurst, 2017), but not necessarily end up with products. Project-based learning and community-based learning's common goal is that educators must provide learning experiences that enable students to seek knowledge and develop reasoning skills with cultural awareness and civic responsibility (Twible & Henly, 2000).

Project-based learning is also similar to experiential learning, defined as the process whereby knowledge is created through the transformation of experience (Kolb, 1984) and which is based on *learning by doing* (Dewey, 1938). Experiential learning is not product-oriented. In both PBL and experiential learning, students are provided opportunities for the ownership of a real-world project to develop research, critical

thinking, collaborative teamwork, and problem-solving skills (Gilbert et al., 2014).

Project-based learning is slightly different from problem-based learning because it is a subset of project-based learning (Carter, 2016). In problem-based learning, the focus is that students are challenged to solve a real-world problem (Hmelo-Silver, 2004). In project-based learning, the focus is that students conduct projects to learn anything that they are interested in or feel passionate about. These projects do not necessarily target to solve a real-world problem, but usually result in a product or an artifact (Brush & Saye, 2000).

In this study, focusing on teacher perspectives, PBL is defined as a teaching approach/strategy/pedagogy to provide students with a learning experience in exploring and serving the real-world by designing and organizing projects.

Rooted Theory

Project-based learning is rooted in constructivist learning theory, which suggests that knowledge is developed and constructed through collaboration (Vygotsky, 1978; Wenger et al., 2002). Because PBL requires students to create products or artifacts, learners are engaged in a series of higher-level activities, including planning, searching for information, analyzing the information, and making products while sharing ideas with others for real-life applications (Blumenfeld et al., 1991). Three constructivist principles describe PBL well: (1) learning is context-specific, (2) learners are involved actively in the learning process, and (3) learners achieve their goals through social interactions and the sharing of knowledge and understanding (Cocco, 2006).

Key Components of PBL

Many scholars have described PBL with key components in different but similar ways. Thomas (2000) identified PBL's five characteristics as (1) centrality, (2) problem-solving, (3) constructive research, (4) autonomy, and (5) realism. From the lens looking at students, Diehl et al. (1999) recognized that PBL incorporates students in (1) cooperative learning, (2) reflection, (3) incorporation, and (4) adult skills. Similarly, Cocco (2006) believes that PBL involves students in (1) a specific context, (2) active learning, and (3) social interaction to share understanding and knowledge.

From the lens looking at PBL design, Krajcik and Blumenfeld (2006) discerned that PBL should be designed with a broad framework: (1) driving questions, (2) developing artifacts, and (3) peer collaboration. Moursund (1999) believes that PBL design should also include: (1) authentic content, (2) authentic assessment, (3) teacher facilitation, and (4) explicit educational goals. Krajcik and Shin (2014) agreed with these scholars on (1) a driving question, (2) an assessment aligned with discipline, and (3) a product to address the driving question. Also, they added that PBL needs (4) support provided by peers, teachers, community members, and technology.

One promising study, Boss and Larmer (2018), identified seven design elements of PBL that Buck Institute for Education (BIE), a well-known non-profit organization for teacher professional development (PD) on PBL in the U.S., has been promoting:

1. Challenging problem or question
2. Sustained inquiry
3. Authenticity
4. Student voice and choice

5. Reflection
6. Critique and revision
7. Public product (p. 3)

These elements have been exercised in K-12 education and have resulted in positive outcomes (Coyne et al., 2016; Kitagawa et al., 2018; Shernoff et al., 2017). Thus, the researcher used these seven design elements as an essential part of the PBL principles to train teachers.

PBL Principles

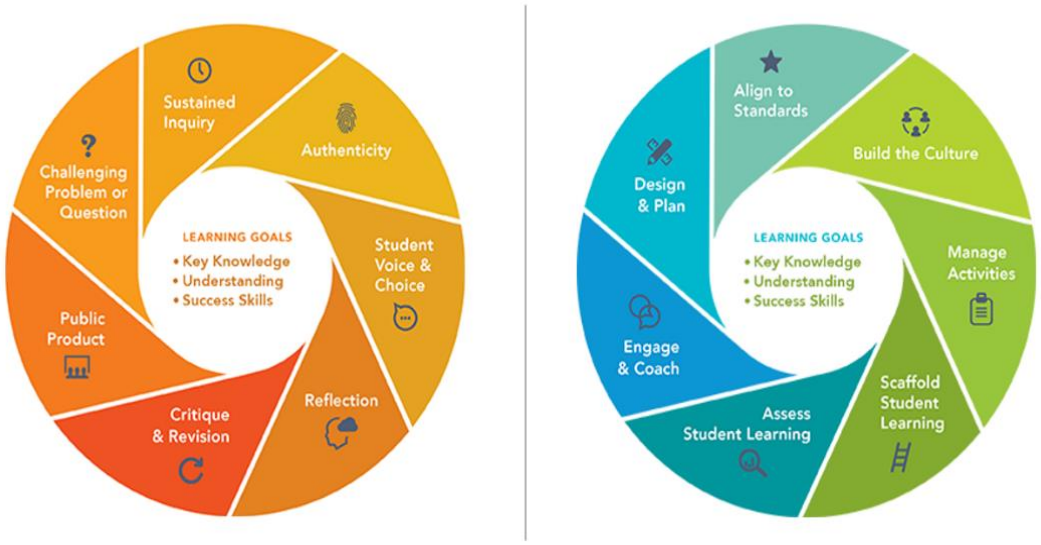
Boss and Larmer (2018) also identified seven essential teaching elements of PBL, promoted by BIE as well:

1. Design and plan
2. Align to standards
3. Build the culture
4. Manage activities
5. Scaffold student learning
6. Assess student learning
7. Engage and coach (p. 5)

The researcher utilized the seven design elements and seven teaching elements as the key components of the PBL principles in the training program. Figure 1 summarizes these two sets of essential elements.

Figure 1

Essential Elements of PBL Design and PBL Teaching



Note. This figure illustrates seven essential elements of PBL design on the left and that of PBL teaching on the right. The elements are aligned with the learning goals shown in the center. From *PBL works*. https://www.pblworks.org/what-is-pbl/gold-standard-project-design and https://www.pblworks.org/what-is-pbl/gold-standard-teaching-practices. Copyright 2019 by Buck Institute for Education.

Technology Role in PBL

Technology makes the PBL environment more authentic to student learning because the digital device supports the exploration and searching of data and information and expands interaction and collaboration with others via networks. The technology use also promotes investigation and provides tools for both educators and students use to produce artifacts (Howard, 2002; Krajcik et al., 1994). PBL has shown to be effective in involving the use of computer technology (Barron et al., 1998; Edelson et al., 1999; Solomon, 2003). In many studies, students in a technology-enhanced PBL environment outperformed their peers in a control group (Basilotta Gómez-Pablos et al., 2017; Chang & Lee, 2010; Wu et al., 2018). Therefore, teachers are encouraged to develop innovative

ways of using technology to enhance the learning environment and promote technology literacy, knowledge deepening, and knowledge creation (UNESCO, 2011a).

Benefits of PBL

Project-based learning has improved student achievement in K-12 education and STEM education (Al-Balushi & Al-Aamri, 2014; Cukurbasi & Kiyici, 2018; Han et al., 2016). Also, PBL has been particularly effective when combined with computer technology in K-12 education (Baser et al., 2017; Novak & Wisdom, 2018). The U.S. Department of Education (2010) has recommended PBL as an effective instruction for differentiated learning. This study focused on reviewing the empirical evidence of PBL.

Gains in Student Academic Achievement

Thomas (2000) reports gains in student academic achievement in many schools in the U.S. (e.g., Expeditionary Learning Schools, three elementary schools in Iowa, a middle school in Boston, a middle school in Maine, Co-Nect schools, and many more). These schools implemented PBL and gained significant improvement in student test scores on standardized tests. Three elementary schools in Iowa gained in reading from 15% to over 90%; a middle school in Maine improved in six subjects three to ten times larger than that of the state as a whole with Maine Educational Assessment battery; Co-Nect schools gained almost 26% more than the control schools in all subject matter areas over the two years.

In several quasi-experimental studies in middle schools, students in the PBL group outperformed the control group in content knowledge gain. In a study by Hernandez-Ramos & De La Paz (2009), eighth-grade students who engaged in the PBL curriculum demonstrated significant gains in history knowledge compared to the control

group's gains with an effect size of 0.47. In a study done by Hsu et al. (2015), seventh-grade students in the PBL group achieved knowledge gain in science with a standard group mean difference of 0.68.

Similar positive evidence of PBL adoption was found in other countries. Karaçalli and Korur (2014) conducted a quasi-experimental study in Turkey with 143 fourth-grade science students who formed a PBL group and a control group from two schools. Comparing the pre- and post-tests, they found a statistically significant effect on academic achievement and knowledge retention for the PBL students. In Oman, Al-Balushi and Al-Aamri (2014) randomly assigned 62 11th grade students in Oman in a PBL group and a control group in the Environmental Knowledge Test and Science Attitudes Survey. They found that the PBL group outperformed the control group in the test, and the students in the PBL group enjoyed learning more. Overall, PBL extends a positive effect to all students, regardless of socioeconomic or linguistic status or special learning needs (Doppelt, 2003; Sutton & Knuth, 2017).

Increase in Students Motivation/Positive Attitudes

PBL motivates and empowers students through complex and open-ended product design challenges in STEM education and K-12 education (Hugerat, 2016; Lesseig et al., 2016). Tiwari et al. (2017) reported that about 74% of students (N = 99) felt motivated by PBL and satisfied with PBL in the questionnaire. Students were allowed to work collaboratively and given choices during the process. In Shin's (2018) study, comparing the pre- and post-survey among 79 college students via *t*-test, she found out that student motivation in the post-survey was significantly greater than the pre-survey. Sixty-nine percent of the students changed their attitudes towards English learning. Over 70% of

students increased their confidence and wanted to continue with PBL as their learning mode. Carrabba and Farme (2018) used independent samples *t*-tests to compare a PBL group and a direct-instruction group across three middle-school grade levels. Through random sampling, over 100 students were selected for each grade level. The study found that the student motivation of the PBL group was significantly higher than the direct-instruction group (PBL $M = 3.09$, Direct instruction $M = 2.78$). In conclusion, PBL can improve students in academic achievement and motivate students to engage in learning actively. Above all, PBL prepares students for academic, personal, and career success and readiness for the 21st century (Bell, 2010; BIE, n.d.).

Challenges of PBL

Teachers in STEM and K-12 Education face challenges in understanding PBL pedagogy, PBL design, and PBL implementation (Aldabbus, 2018; Havice et al., 2018; Lesseig et al., 2016). Therefore, PBL training should address these three challenges.

Teacher Challenge in PBL General Pedagogical Knowledge

Some STEM and K-12 teachers had challenges understanding PBL general pedagogical knowledge (GPK) and struggled to transition from teacher-directed instruction to student-driven instruction (Han et al., 2015; Lesseig et al., 2016; Nariman & Chrispeels, 2016). Teachers must understand the broad principles and strategies of instruction, classroom management, and student learning but not linked to the subject, categorized as GPK (Shulman, 1987). Teachers should have GPK because GPK allows them to prepare, structure, and assess the lessons to teach.

Chan (2016) interviewed 13 PBL facilitators and found out that quality PBL teaching depends on a clear understanding of PBL. Havice et al. (2018) reported that their

successful use of a set of PBL principles for teachers leads to a successful implementation of PBL in STEM classrooms. In a study with 246 in-service teachers in Austria, students rated the teachers higher scores in instructional quality, who also scored higher on the GPK test (König & Pflanzl, 2016). While GPK can increase teacher self-efficacy (Lauermann & König, 2016), GPK was a significant predictor of teachers instructional practice (König & Pflanzl, 2016; Voss et al., 2017).

In this study, the GPK of PBL refers to the broad principles and strategies of PBL instruction, including what PBL is and is not, the characteristics and misconceptions of PBL, benefits and challenges of PBL, the essential elements of PBL design and implementation, and the model of teacher change environment. The GPK of PBL and teacher knowledge in PBL are interchangeable in this study.

Teacher Challenge in PBL Design

Some STEM and K-12 teachers face the challenge of designing PBL lesson plans that are not available from textbooks and their current practice (Lesseig et al., 2016; Penuel & Gallagher, 2009; Reiser et al., 2000; Remillard, 1999; Sherin, 2002). In Aldabbus's (2018) study, two-thirds of the pre-service teacher participants (n = 24) struggle to design meaningful projects because the curriculum was not designed to be taught by PBL. Lesseig et al. (2016) claimed the teacher participants struggled to align their projects with district curriculum and grade-level standards.

Project-based learning (PBL) demands the teacher learn how to design projects that are coherent with school, district, and state requirements (Desimone, 2009). Meaningful projects cannot be handed to a teacher, and they should stem from teacher passion, student interest, and a connection to the world (Bell, 2010; BIE, n.d.). Teachers

should get involved with the curriculum materials design process (Brown et al., 2006), including revising existing curriculum materials or designing and developing new ones (Knight-Bardsley & McNeill, 2016); this requires the teacher to use a substantial amount and a variety of resources (Knight-Bardsley & McNeill, 2016), which this training program intends to provide.

Teacher Challenge in PBL Implementation

The implementation of PBL practice continues to be a challenge for many STEM and K-12 teachers (Dillion, 2008; Han et al., 2015; Smolleck & Mongan, 2011). Understanding and implementing PBL in STEM classrooms and greatly help students understand the content, develop skills, and perform academically (Capraro et al., 2016; Havice et al., 2018). Although designing PBL lesson plans is difficult for many teachers (Basilotta Gómez-Pablos et al., 2017; Girvan et al., 2016; Harrigan, 2014), they undertake professional development; subsequently, their self-efficacy in teaching PBL tends not to improve very much (Ertmer et al., 2014). This statement supports Cantrell et al.'s (2003) observation, who found larger effect sizes in teaching efficacy when pre-service teachers had spent time teaching students. Therefore, this study's training program requires trainees to put what they have learned from training into practice.

Novice Teachers in Using PBL

Many studies report that novice teachers tend to have difficulty in all aspects on of instruction: planning, implementing, and assessing (Ertmer & Simons, 2005; Jung et al., 2005). Also, they tend to feel vulnerable to access school and mentor supports (McLeskey & Billingsley, 2008) and rely on their sole endeavor (Confait, 2015). A positive finding for novice teachers is that teachers' years of experience do not affect

teachers to adopt PBL (Sutton & Knuth, 2017; Xie & Sharif, 2014). In many STEM studies, teachers who used or have been exposed by the traditional pedagogies for many years were found having struggles shifting knowledge-based approach to student-centered approach (e.g., Lesseig, et al., 2016; Odell et al., 2019). Compared to seasoned teachers, novice teachers were found demonstrating a higher transfer level of complex teaching strategies to their practices (Scott, 2003). To help STEM and other K-12 teachers in using PBL and access mentor support, schools should assign mentors to scaffold structures of PBL training and tasks (Ertmer & Simons, 2006).

Mentor's Support for Novice Teachers in Using PBL

Research has provided positive evidence that mentoring supports difficult teaching practices (Hopkins et al., 2013; Teemant et al., 2011; Vogt & Rogalla, 2009). Mentor teachers are hired to instigate significant change in a school system (Hopkins et al., 2013; Thornton, 2014) as expert teachers, especially for novice teachers. Based on the result of a survey on over 1000 first-and second-year teachers, Hong and Matsko (2019) found that novice teachers need mentors to facilitate vast arrays of development, including classroom management and pedagogy, and to inform them about school and district policies and contexts. Successful mentoring can increase STEM and other K-12 teacher retention and improve teachers' competence and effectiveness because novice teachers learn by guided practice instead of trial-and-error alone (Confait, 2015; Jones et al., 2016).

Model of PBL Teacher Training

Kali et al. (2018) notes three stages of training: (1) teacher as a learner, (2) teacher as a designer, and (3) teacher as enactor. In the model, teachers learn inquiry-

based learning, conceptualizing the pedagogy in the first stage. In the second stage, teachers experience learning lesson design. In the last stage, teachers enact what they had learned from the previous stages. This model led to a successful outcome in teacher professional growth.

Knowing that teachers' three major challenges in PBL are PBL pedagogy, PBL design, and PBL implementation, Kali et al.'s (2018) training design is the best match for this study. The three roles of teachers are correspondingly designed in three training components to meet the three challenges.

Also, scaffolding is an excellent support to level up learners' actual capability to potential capability (Vygotsky, 1978). The support needs to be contingent, fading over time, and aiming at transferring the responsibility to the learner (Van de Pol et al., 2010). In this study's context, the learner is the teacher, learning a new teaching pedagogy named PBL. Learners can connect their new learning to their previous knowledge and experience by seeing similarities (Jackson et al., 2019; Lobato, 2003). Provided there are opportunities to develop the transfer, learners can practice transferring by applying what they have learned (National Research Council, 2000).

It is believed that teachers should have a pedagogical design capacity to maneuver instructional resources to design instruction (Brown, 2009). This capacity can be examined by lesson plans (Papaevripidou et al., 2017). Hence, to scaffold the training content and increase the training effect, the researcher co-designed a lesson plan with each teacher participant in the second phase and asked teachers to design a new lesson plan on their own in the four phases, hoping that they connect the new learning to the previous experience by seeing the similarity and make the learning experience

transferred. Therefore, the researcher adopted the training model of Kali et al. (2018) from three teacher roles to four roles: (1) teacher as a learner, (2) teacher as a co-designer, (3) teacher as an enactor and (4) teacher as an independent designer. This training program is designed with four progressive phases and various teacher roles in each phase.

The Use of Video Cases in Teacher Training

Analyzing classroom videos can be a powerful teacher training method (Blomberg et al., 2013; Borko et al., 2011). After observing the implementation of three workshops on video-based teacher training, Borko et al. (2011) found that it is important to select relevant and accessible videos and prompt guiding questions to provoke discussion at a deeper level. Gartmeier et al. (2015) designed a study to investigate the effect of video cases and role play in e-learning by factorial experiment. They concluded that video-based e-learning is more effective. Videos provide graphic and immediate context for a descriptive story in reality (Perry & Talley, 2001) and allow viewers to see the subtle non-verbal expressions and interactions between teachers and students that are difficult to capture by texts (Brophy, 2003). From the perspective of observational learning (Bandura, 1977), a second-hand experience fosters an analytical standpoint to examine a teaching method without being pressured to teach (Kleinknecht & Schneider, 2013).

To be effectively used in teacher training, the analysis of video cases should be embedded within tasks that engage teachers in a deeper level of learning (Gartmeier et al., 2015). They recommended using video cases in multimedia e-learning environments that provide (a) conceptually structured and elaborative instruction, (b) exemplary videos

that represent targeted communicative behaviors, and (c) tasks based on the videos to bridge the theoretical knowledge and practice.

Reflection

Since Dewey (1933) and Schön (1983) established the importance of reflection in developing teachers' expertise in their practices**,** reflection has been used to improve student learning and teacher professional development in many studies (e.g., Brears et al., 2011; Holen, 2000; Kintz et al., 2015). Reflection is defined as the process of engaging the self in attentive, critical, exploratory and iterative interactions with their own thoughts and actions that reflecting their conceptual framework including knowledge and belief, with a view to changing them (Nguyen et al., 2014). Reflection facilitates teachers in developing their teaching expertise (Darling-Hammond et al., 2017; Hoffman-Kipp et al., 2010) because reflection enables teachers to activate and take ownership of their learning (Dewey, 1933) and the learning becomes explicit through reflecting (Hoffman-Kipp et al., 2010). Therefore, this study uses reflection as part of the training strategy to change teachers' knowledge and belief in PBL.

Transferring of Learning

When the training is effective, the learning will be transferred (Shoobridge, 2002). A training program's positive outcome is the effective application, generalizability, and maintenance of new knowledge, skills, and abilities in the workplace (Holton et al., 2000). Many scholars have studied the transferring of learning. They have reached a consensus that learners can connect their new learning to their previous knowledge and experience by seeing similarities (Jackson et al., 2019; Lobato, 2003). Provided opportunities to develop the transfer, learners can practice the process of transferring by

applying what they have learned (National Research Council, 2000). Teachers should have the pedagogical design capacity to maneuver instructional resources to design instruction (Brown, 2009), and this capacity can be examined by lesson plans (Papaevripidou et al., 2017). Therefore, this training asked trainees to independently design a PBL lesson plan after being guided and facilitated from the training, targeting whether trainees had transferred the learning from the training.

The Effectiveness of a Teacher Professional Development

Based on many studies (Garet et al., 2001; Jeanpierre et al., 2005; Johnson et al., 2007; Penuel et al., 2007), Desimone (2009) summarizes five characteristics of teacher professional development (TPD) that are critical to increase teacher knowledge and skills and improve their practice: (1) content focus, (2) active learning, (3) coherence, (4) duration, and (5) collective participation. Content focus refers to TPD activities' concentration on subject matter content and how students learn the content. Active learning involves non-passive learning, which should inform how teachers engage in TPD. Coherence pertains to the consistency of learning concerning teachers' knowledge and beliefs, as well as with school, district, and state reforms and policies. Duration deals with the sufficiency of time for TPD to complete the activities. However, the optimal duration for TPD has not been determined. According to Van Veen et al. (2011), teachers need to change their behavior from 14 to 80 hours. Collective participation refers to interaction and discourse among the teachers during TPD.

Like Desimone's (2009) conceptual work, an effective TPD model was proposed by Darling-Hammond et al. (2017). They believe that an effective TPD should (a) focus on content, (b) incorporate active learning, (c) support collaboration, (d) use models of

effective practice, (e) provide opportunities for coaching and expert support, (f) offer feedback and reflection, and (g) have a sustained duration.

The common characteristics of effective TPD established by Desimone (2009) and Darling-Hammond et al. (2017) are (a) content focus, (b) active learning, (c) support of collaboration, and (d) a sustained duration. Additionally, TPD should be coherent, model best practices, offer coaching and expert support, and allow time for feedback and reflection.

Measuring the Effectiveness of a Teacher Training Program

In this study, the measurement of a teacher training program's effectiveness relies on Guskey's (2002) five criteria, Bandura's (1997) self-efficacy, Clarke and Hollingsworth's (2002) teacher change environment model, and multiple scholars' training design elements (Darling-Hammond et al., 2017; Desimone, 2009; Goldstein & Ford, 2002). Guskey, Bandura, Clarke, and Hollingsworth focused on teachers' knowledge, attitudes, and belief and their work environment. Other scholars focused on the training design elements. Each scholar's training measurement is described below.

Guskey (2002) claimed that the effectiveness of a TPD should examine teacher attitude, knowledge, belief, and other aspects. Specifically, he believes that teacher training program can be evaluated by five critical aspects: Teacher participants should (1) feel satisfied with the process and results of the TPD; (2) acquire knowledge and skills; (3) demonstrate a change in their teaching practice, meaning they should be able to apply new knowledge and skills in their practice; (4) the organization should support teacher participants; (5) TPD should lead to positive student learning outcomes. Using these five levels as guidelines is one framework for measuring the effectiveness of TPD. Guskey

(2002) considered teacher satisfaction with the process and results of TPD as the first criterion of effective TPD. Teacher satisfaction is a teacher attitude towards the training program. Eagly and Chaiken (1993) defined that teacher attitude is a psychological tendency expressed by evaluating the training program with some degree of favor or disfavor. Guskey (2002) also regarded increased teacher knowledge is the second criterion of effective TPD. In this study, teacher knowledge refers to PBL's general pedagogical knowledge (GPK), which means the broad principles and strategies of PBL, classroom management, and student learning in the PBL environment are not linked to the subject (Shulman, 1987). Outside of the five criteria, Guskey (2002) also addressed that one of the TPD's goals should change teachers' beliefs because One of the outcomes of effective training is that teacher's belief in the pedagogy is changed after the training (Desimone, 2009; Voet & Wever, 2018). Teacher belief means teachers' evaluation and judgement about PBL and its implementing environment, aligning it with previous experience (Gill & Hoffman 2009; Pajares 1992).

Besides Guskey's (2002) training measurements, Bandura's (1997) self-efficacy should be evaluated as well to measure a training program's effectiveness. Bandura (1997) pointed out that self-efficacy is also a teacher's belief, which is defined as a belief in their capacity to successfully perform and complete tasks. He identified four sources that affect self-efficacy: (1) performance outcomes, referring to the teachers' positive or negative teaching experience in the study; (2) various experience, referring to the teachers' observing other teachers successfully completing a task; (3) social persuasion, referring to giving the teachers positive verbal encouragement to believe that they have the skills and capabilities to succeed; (4) emotional and physiological states, referring to

the teachers' emotional, physical, and psychological well-being, which affects how they feel about their abilities in a particular situations.

From the perspectives of training design elements, Goldstein and Ford (2002) claim that TPD needs to have quality instructional design featured in (1) clear objectives, (2) instructional plans, and (3) learning principles. Moreover, TPD should provide (4) a supportive work environment in which trainees can practice learning and access resources and strategies. As claimed by Desimone (2009) and Darling-Hammond et al. (2017), TPD should also be featured in (1) content focus, (2) coherent, (3) active learning, (4) support of trainee collaboration, (5) modeling the best practice, (6) coaching and expert support, (7) allowing time for feedback and reflection, and (8) a sustained duration.

Another way of measuring TPD's effectiveness is to see whether the training brings about teacher change. According to Campbell (1971), the definition of training is a planned learning experience whose purpose is to change teachers' knowledge, behaviors, or skills. However, many teachers struggle to change their teaching styles and adapting to reforms (Day & Leitch, 2001; Fullan, 2007; Reigeluth & Karnopp, 2013; Thomas et al., 2005). Clarke and Hollingsworth (2002) pointed out that once teachers understand what factors could cause the change, they may start changing their teaching approaches. These two scholars developed a teacher change environment model and identified the environment that teachers need to change: (a) personal domain in which teachers' knowledge, belief, and attitudes would evolve, (b) external domain in which teachers' work environment would affect the change, (c) domain of practice in which teachers would change their classroom practice, and (d) domain of consequence in which teachers

would see positive student learning outcomes. In this study, the researcher focuses on two areas regarding teachers' change in practice: (1) whether teachers can apply the seven teaching elements to PBL implementation, and (2) whether teachers can apply the seven design elements to their PBL design. Guskey's first two criteria perfectly matched the first domain in Clarke and Hollingsworth's (2002) model, and the last three criteria were accordingly aligned with the last three domains.

Goldstein and Ford (2002), as well as Desimone (2009) and Darling-Hammond et al. (2017), focused on the training program design. Shoobridge (2002) identified multiple factors such as needs analysis that are associated with training effectiveness, and he categorized the factors into three areas: (1) trainees, (2) training program (design), and (3) trainees' work environment. Furthermore, many other related studies reported similar factors as Shoobridge found (Chen et al., 2007, Damschroder et al., 2009, Desimone & Garet, 2015; Gagen & Bowie, 2005; Garet et al., 2001; Prenger et al., 2017).

Guided by these scholars stated above and many other scholars, the researcher assessed the effectiveness of the training program in three components accordingly: (1) trainees; (2) training program design; (3) trainees' work environment. In each area, the researcher synthesized and identified the factors in Chapter III in the instrument development and explored in the data collection process. Therefore, these three major areas with factors categorized, based on which a codebook is developed to measure a TPD's effectiveness, are presented in Table 1.

Table 1

Framework to Assess the Effectiveness of a Teacher Training Program

Training Program Components	Categories and Codes Reflecting the Training Effectiveness
Trainee	1. Knowledge (acquired/increased) 2. Belief including self-efficacy (changed) 3. Job attitude (satisfied/enjoy) 4. Change in practice (able to apply new learning to practice) 5. Knowledge (acquired/increased) 6. Belief including self-efficacy (changed) 7. Job attitude (satisfied/enjoy) 8. Change in practice (able to apply new learning to practice)
Training Program Design	1. Need analysis 2. Objective 3. Instruction plan 4. Learning principles 5. Coherence with job requirement 6. Content focus 7. Active learning 8. Collective participation 9. Model the practice 10. Opportunity for practice 11. Allow time for feedback and reflection 12. Sustained duration
Trainees' Work environment	1. Organizational support 2. Coaching and expert support 3. Peer support

The Perception of a Teacher

Ou (2017) introduced the definition of perception in the field of philosophy, psychology, and cognitive science, as "the process of attaining awareness or understanding of sensory information" (p. 18). In this study, perceptions are expressed

through the angles of (a) understanding of broad principles and strategies of PBL pedagogy and (b) teachers' belief, meaning their evaluation and judgment about PBL teaching and student learning in PBL. Teacher Professional Development (TPD) should examine teacher belief because changes in belief can lead to changes in practice (Pajares, 1992; Spillane et al., 2016), and teacher belief is a strong indicator of how well teachers implement inquiry-based learning (Haney et al., 1996). Spillane et al. (2016) stated teachers' belief about teaching and student learning affects teachers' instructional practice and reform initiatives. In general, beliefs are difficult to change in adulthood. Teacher Professional Development (TPD) should provide teachers opportunities to interact with a mentor to develop their knowledge, belief, and practice (Penuel et al., 2013; Spillane et al., 2016) and make the learning content-focused (Desimone et al., 2002; Hopkins et al., 2013). One of PBL implementation's major barriers is teacher belief in PBL teaching and students learning in PBL (Binns & Popp, 2013). More traditional or procedural beliefs can undermine teachers' adoption of reform-oriented teaching approaches such as PBL (Coburn, 2001).

Chapter Summary

Project-based Learning (PBL) has positive empirical evidence in improving student achievement and increasing student motivation. Due to the complexity of PBL, teachers, including STEM teachers, face multiple challenges not limited to understanding PBL, PBL design, and PBL implementation. Therefore, there is a great need for training teachers in learning PBL. To ensure the training is effective, the training effectiveness factors need to be identified, and the training needs to be carefully designed.

CHAPTER III

RESEARCH METHODS

Overview

This chapter describes the research methods for this study. The study used an exploratory single case study approach to explore (a) two teachers' perceptions towards the effectiveness of a teacher training program regarding PBL, (b) their perception changes, and (c) factors associated with the successes and challenges of the training program. A pilot study's findings supported this study's design conducted one year ago. This study's intervention, a teacher training program, was designed with four phases featured with four different teacher roles: (1) providing foundational knowledge of PBL, *teachers as a learner*; (2) applying PBL principles to co-design lesson plans, *teacher as co-designer*; (3) putting PBL lesson plans into practice, *teacher as an enactor*; and (4) designing PBL lesson plans independently, teacher *as an independent designer*. Throughout the four phases, multiple data collection methods were used to observe and track the teachers' perception changes. The researcher investigated their perceptions and the successes and challenges of the training program mainly via a deductive coding approach for the predefined categories and codes identified by the literature review. An inductive coding approach was subsequently used to explore the perceptions and training effectiveness outside of the scope of predefined categories and codes.

Purpose of the Study

The purpose of this study was to investigate teachers' perceptions towards the successes and challenges of a designed teacher training program in learning PBL at a STEM school. The training program had two goals:

1. Train teachers in PBL teaching (i.e., PBL pedagogy, PBL design, and PBL implementation).
2. Inform teachers and teacher educators about (a) the effective design elements in a teacher training program to understand PBL pedagogy, PBL design, and PBL implementation in STEM classrooms and beyond; (b) how the training affects classroom teachers' perceptions towards PBL; and (c) the factors associated with the successes and challenges of this training program.

Therefore, the following research questions were addressed:

1. How do teachers perceive the effectiveness of a PBL training program?
2. How do teachers' perceptions towards PBL change during the training program?
3. What are the factors associated with the successes and challenges of the training program?

Methodology

This study adopted an exploratory single case study approach. Merriam (1998) depicts a case bounded within real-life phenomena in describing and analyzing people, processes, and programs. Stake (1978) considers a case as a constituent member of a target population. Case studies allow researchers to explore the explanatory laws because case studies' descriptive and naturalistic features add to the existing experience and improve understanding of similar settings. Yin (2017) claims that an exploratory case study answers *what* and *how* questions to develop a conceptual framework for further study, which is used when there is no clear single set of outcomes and the researcher does not have any propositions.

The case in this study explores two middle school teachers' perceptions towards the effectiveness of a training program for PBL. From Merriam's (1998) perspective, this case was bounded within a PBL training program to describe and analyze the trainees' perceptions and activities throughout the training, implementing the training, and evaluating the training effectiveness. From Stake's (1978) perspective, the teachers recruited are the target population of novice teachers who need training for PBL. This case's findings aim to add teachers' experiences to existing experiences in similar studies in learning PBL and improve the understanding of PBL professional development. From Yin's (2017) perspective, I investigated unknown outcomes in an open-minded manner in the exploration of how teachers respond to a PBL training program at a K-12 school, aiming to find out the answers for what and how questions to develop a conceptual framework of an effective PBL training for notice teachers.

Context

This research was conducted in a small K-12 charter school in West Texas, with a student body of 780 specializing in STEM. Among students, at the time of data collection, 49.5% were Caucasian, 45.5% were Hispanic, 1.5% were Asian, 1% were African American, 0.5% were American Indian, and the rest were two or more races. The teacher-to-student ratio was approximately 1 to 25. In each classroom, teachers had a smart board, a laptop with an embedded webcam, desks, and chairs. Each class period was 47 minutes. The passing time between class periods was three minutes. The school had no ringing bell, and teachers dismissed classes. Student enrollment was based on a lottery drawing. Starting in ninth grade, students choose one path of the three for STEM career preparation: (1) medical field; (2) engineering; and (3) computer science.

Due to COVID-19, all of the classes were taught online for the first four weeks of the 2020-2021 school year. All teachers worked in their empty classrooms while all students stayed home. Each student was provided with a Chromebook with an embedded camera, and parents picked up the Chromebook before school started. Most of the classes used an online meeting app, Zoom, for class meetings. The elementary school used Google Classroom, and the secondary school used PowerSchool as the content management system to deliver content. One week before the school started, teachers went through annual training, including school policies, content management systems, and online meeting apps, but only 2.5 hours long training on PBL.

After four weeks into the school year, three learning modes were offered to students during the COVID-19 period: (1) on-campus learning from Monday to Friday; (2) hybrid learning, meaning on-campus learning on Mondays and Wednesdays and remote learning on Tuesdays and Thursdays; and (3) remote learning from Monday to Friday. Parents were asked to make decisions for students' learning mode every six weeks. About 85% of the students were on-campus for sixth graders, 10% were hybrid, and 5% were remote learners. Teachers and students were required to wear a mask on campus every day according to the school policy.

Because it is a STEM school, teachers are encouraged to design PBL lessons as long as they follow the state standards, Texas Essential Knowledge and Skills (TEKS), for their teaching subjects. Three or four teachers of the grade level spend one hour on Monday afternoons designing an integrated PBL for their teaching subjects for a cycle of six weeks, then implement it with five or six groups of designated students in their classrooms on Fridays. This implementation is called *Friday PBL*, and it occurs for the

first two class periods on Fridays for every grade level.

Friday is a half-day for students, so teachers' time in the afternoon is either set for professional development and meetings, lesson planning, or other school duties. Therefore, Friday afternoons were the best feasible time to conduct this study's training, preferably in the classroom. Training online via Zoom was the other option when the classroom meeting was not available.

Research Participants

Because the school's training on PBL was only 2.5 hours, new teachers gave feedback that it was insufficient for them to learn PBL and were not ready to teach PBL. Hence, to help these teachers with little to no experience with PBL (less than three PBL projects previous to this study), I wanted to offer additional training. Under the school administrator's permission, I initially invited five teachers to participate in the training program and the study's purpose was verbally described. Only two teachers were interested. Following up on their interests, I wrote them an email with an information sheet to provide a more detailed description of my training and what was expected from them. These two teachers, Greg and Jen (*pseudonyms*), were willing to commit to the training after viewing the information sheets.

Teacher Participants

Greg was a second-year teacher and he did not undergo a traditional teacher education. During the research he was going through an alternative teacher certificate program. His bachelor's degree is in engineering. In the 2019-2020 school-year, he taught Algebra 1 for eighth and ninth graders, Algebra 2 for 10th graders, and engineering for sixth grade for only one semester. This school year of 2020-2021, he

taught financial math and engineering for 12th graders and engineering for sixth graders. He designed three projects before this training. When I recruited Greg, I had only known him for almost three months. He seemed easy to approach, so I proposed the training idea to him. He showed great interest and extended his acceptance because he wanted to learn more about PBL, and his curriculum demanded him to do projects with students.

Jen was a brand-new teacher, teaching English and social studies for sixth graders. Like Greg, she was going through an alternative teacher certificate program during the research. She underwent a two-year teacher education program and another two years' multidisciplinary studies for her undergrad study. She was new to PBL. Before my training, she designed and implemented a *Friday PBL* with three other co-workers for the sixth graders. Jen and I were both new teachers at the school. She expressed her desire to learn PBL when we went through the school's annual training. When I approached her about my training plan, she willingly accepted it after getting to know her for almost three months.

Because both Greg and Jen were teaching sixth grade, I decided to focus on this grade level's PBL design and implementation. This way, both teachers had the common ground to discuss their learning experience with the same groups of students, and they could better collaborate. Table 2 presents the demographic information of these two teachers.

Table 2

Demographic Information of Two Teachers

Name	Age	Gender	Years of teaching experience	Numbers of PBL taught
George	49	Male	1	3
Jen	33	Female	0	1

Roles of the Researcher

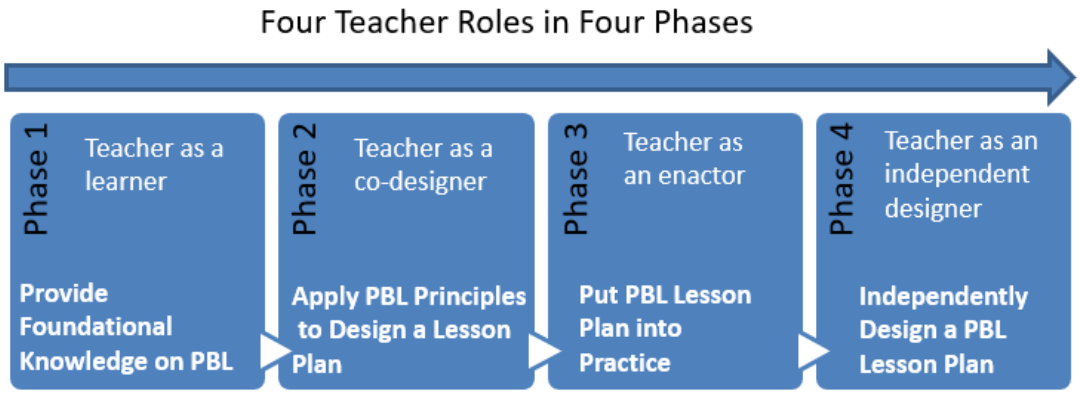
I have practiced instructional design for over 10 years as a K-12 classroom teacher and have undergone doctoral-level instructional design training. At present, I am a full-time teacher, teaching technology applications for seventh and eighth graders at the research site. This is my first year working at this school. My classroom and the teacher participants' classrooms are in the same hallway, making it easy for me to access their classrooms for data collection. I had three roles in this training program: (1) the designer of the PBL training program; (2) the trainer/mentor of two teachers to improve their PBL teaching skills (i.e., increase the knowledge on PBL pedagogy, the skills of PBL design, and PBL implementation); and (3) the researcher/participant observer in their classrooms when the teachers were implementing PBL. Because the two teachers had little experience in PBL, I presumed that modeling and more frequent engagement would help novice teachers (Desimone, 2009; Hong & Matsko, 2019). This required the researcher's deeper involvement with teachers in their classroom. Therefore, participant observation was necessary for this study.

PBL Training Design

This PBL training was based on Kali et al.'s (2018) training design which comprised three phases: (1) teacher as a learner, (2) teacher as a designer, and (3) teacher as an enactor. Because scaffolding fosters the learning transfer (Van de Pol et al., 2010), I altered the three phases to four phases: (1) teacher as a learner, (2) teacher as a co-designer, (3) teacher as an enactor, and (4) teacher as an independent designer. In Phase 1, as a learner, teachers learned the foundational knowledge of PBL. In Phase 2, as a co-designer, each teacher planned six-week-long PBL lessons with me. In Phase 3, as an enactor, teachers implemented the co-designed lesson plans in their classrooms, and I gave feedback as needed after class. In Phase 4, as an independent designer, teachers created a new lesson plan independently within two weeks after the PBL implementation. The training design is illustrated in Figure 2. More details about each phase are described below.

Figure 2

The Design of the Training Program



First Phase of the Training (1.5 hours) — Provide Foundational Knowledge on PBL

The first phase of the training was launched in my classroom for 1.5 hours, in the afternoon on the third Friday in October 2020. The teacher's role in this phase was as a learner. This phase's goal was to train teachers on PBL foundational knowledge, in which the key principles were the seven essential PBL design elements adopted from BIE. Havice et al. (2018) reported that using a set of PBL principles led to a successful implementation of PBL in STEM classrooms. In addition to the key principles, three video case analyses were used so that teachers could learn from the good practices (Blomberg et al., 2013). For the first day of training, I implemented three different sessions:

1. Session 1 (35 minutes): PBL foundational knowledge
    a. Teachers and I met in my classroom.
    b. The training began by showing a short YouTube video about PBL.
    c. I provided a handout about PBL foundational knowledge (see Appendix A).
    d. I provided information about PBL's history, characteristics, misconceptions, benefits, and challenges. For PBL misconceptions, the two teachers and I took turns reading one article out loud.
2. Session 2 (10 minutes): Seven essential design elements of PBL
    a. I provided a handout about the seven essential design elements of PBL (see Appendix B).
    b. I explained each element.
3. Session 3 (45 minutes): Video case analysis.

a. I showed the Case 1 video on an environment project for Kindergarten.
b. Two teachers filled out a worksheet (see Appendix C) in the column of Case 1, identifying the seven design elements for the case while they were watching.
c. We compared our answers for the identified elements.
d. I showed the Case 2 video on the virtual library project for a seventh-grade social studies class.
e. Two teachers filled out the same worksheet in the column of Case 2.
f. Then, we compared our answers for the identified elements.
g. I showed the Case 3 video on the financial path project for high school students.
h. Two teachers filled out the same worksheet in the column of Case 3.
i. We compared our answers for the identified elements.

Second Phase of the Training (35.5 hours) — Apply PBL Principles to Design a Lesson Plan

The second phase of the training was implemented either in my classroom or via Zoom. The teacher's role in this phase was a co-designer. The goal of this phase was to train teachers on PBL design in which I took the lead. In the following two weeks after Phase 1, I spent six hours with Jen co-designing a project that integrated English and social stud that she was teaching. In addition, I spent 12 hours keeping designing on my own to take the workload off Jen because she was already fully occupied with teaching and grading as a brand-new teacher. For the same reason, besides nine hours co-designing with Greg, I spent an additional eight hours on my own finishing the PBL

design because Greg was exhausted from teaching three subjects for two grade levels. In total, the planning time for Jen's project was 18 hours and 17 hours for Greg, while the three of us were all teaching full-time.

The original plan was to design a six-week PBL. Because both teachers needed a week to finish their current content, we had to cut the PBL from six weeks to five weeks. As we proceeded with our design, the school informed teachers to save the last week of the semester for the final review. Thus, we had to cut the PBL from five weeks to four weeks. After two weeks into planning, we were ready to launch the PBL; the entire sixth grade was sent home because several students were tested positive for COVID-19 and came back to the campus in the middle of the following week. Unanticipated, the time length shortened from four weeks to 3.5 weeks, and we had to adjust the learning pace faster than what we planned.

Phase 2 included two sessions. The first session of this phase, the fourth session of the full training, was to model PBL design for one of the three video cases used in the first phase. This session was completed at the end of the first training day with Phase 1 training to better use training time.

1. Session 4 (30 minutes): Modeling PBL design procedures
    a. I provided the first method of planning: Using aligned sticky notes for milestones (i.e., the key components of the project), key activities, and accordingly assessments on a large poster, which would benefit teacher team planning with the flexibility to revise the plan by moving the sticky notes and it could serve students as a visual aid in the classroom.
    b. I provided the second method of planning: Using the graphic organizer on

the PowerPoint (see Appendix D) to display the planning components stated above, which could be saved digitally.

2. Session 5 (35 hours within two weeks): Co-designing PBL with two teachers together or separately.
    a. The first co-designing meetings (4 hours on Zoom): I met each teacher separately for two hours on the weekend via Zoom. The goals of the meeting were (a) to identify the teaching content scope from their curriculum and accordingly TEKS, (b) to brainstorm the authenticity of the project, (c) to start the planning using the PowerPoint method, and (d) to add me as a co-teacher to their PowerSchool so I could have access.
        (i) Jen's meeting (2 hours): I recommended that we design an integrated PBL for the two subjects that Jen was teaching. This way, the same groups of students had sustained two class periods working on their project, one morning class set for English and one afternoon class set for social studies. Also, this would reduce Jen's planning and grading workload. Jen accepted the recommendation with joy. We brainstormed ideas of a project that could include informative text required by English TEKS and three geographic (the U.S. and Canada, Europe, and Latin America) regions required by social studies TEKS. We decided to ask students to design a virtual museum that displays these regions' information. I asked Jen to contact the local museum to see if they would allow our students to display their work in the museum.

(ii) Greg's meeting (2 hours): We accomplished the preliminary planning using the PowerPoint method, and we identified an entry event. The entry event was to introduce six cases of different children with different cerebral palsy needs. We also decided to ask each student group to design a therapeutic toy for the child if they selected it as their final product.

(b) Setting up management documents for both teachers (1 hour for each teacher): I set up the drafts of the management documents, including a Google Doc named group organizer (see Appendix E) for teachers to group students and another Google Doc named personal workspace (see Appendix F) for each student to demonstrate their work.

(c) Second meetings - Individual teacher meetings for management documents demonstration (1 hour for Greg and 1.5 hours for Jen): After school in my classroom, I demonstrated to each teacher how to use the management documents, instructing them how to group students based on their interests as well as how students establish their group norms and group meeting methods. For each example, students who wanted to study the region of Europe could write their names in the box of the European area and next to the group role name (i.e., leader, technician, organizer, editor). Students who would like to help Child A could write their names in the box of the Case. Both teachers were amazed when they saw these documents and favored the grouping strategy that allowed student choice.

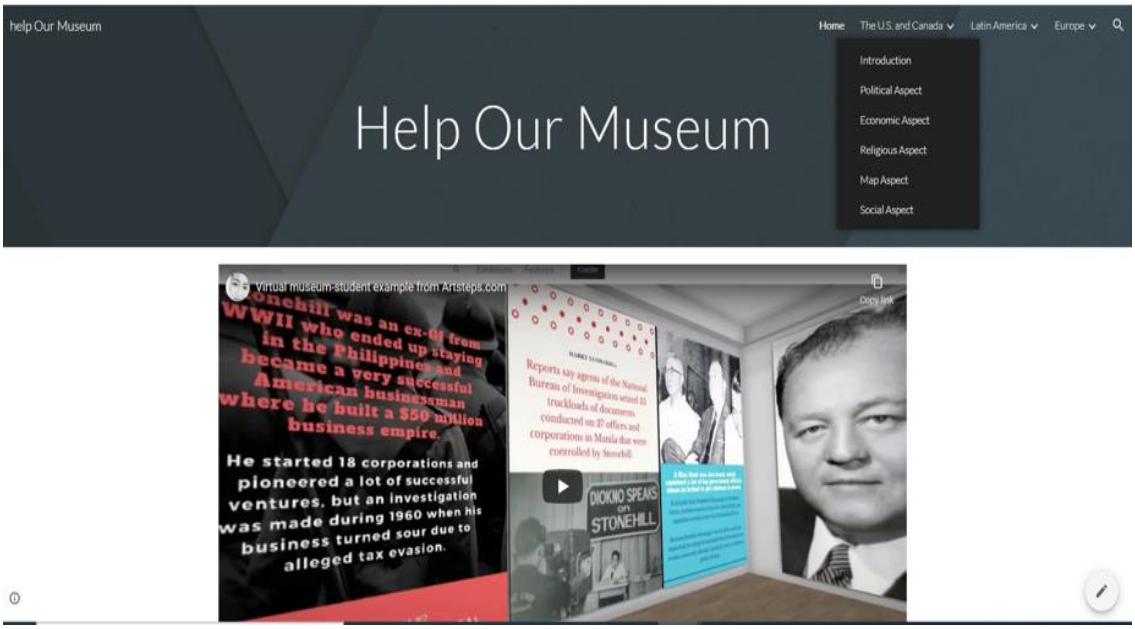
(d) *Backward design* and refining management documents for Jen (12 hours):

i. Backward design: After the second meeting with each teacher, I started focusing on Jen's design because her PBL was more complex than Greg's. I turned the TEKS of English and social studies into key questions for students to understand and self-evaluate easily. Based on these questions, I searched the information from the curriculum and categorized them into *must-know knowledge*, *research highlights*, and *self-evaluation questions*. This process was called backward design, which means mapping backwards from TEKS to the design of knowledge points.

ii. Refining management documents: Because the information presented by the curriculum for the region study was too much for 3.5 weeks, I decided to build a Google Site (see Figure 3), using a framework developed by a master teacher at the school for each region. The framework was P.E.R.M.S., meaning political, economic, religious, maps, and social aspects of the region. I also created a timeline with milestones laid out horizontally on the timeline. Under each milestone, student tasks and assessments were aligned vertically. I also designed templates for student personal workspace, created rubrics, and built PowerSchool pages for Jen.

Figure 3

Google Site That Narrowed Down the Broad Learning Scope



Note. https://sites.google.com/view/help-our-museum/home

(e) Third meeting with both teachers for PBL design debrief (2 hours):

i. Teachers and I met in my classroom after school.

ii. I demonstrated how I designed all the management documents for Jen not to miss the co-design process that was supposed to happen but constrained by the teachers' time.

iii. I provided a handout about PBL design that BIE developed.

iv. I engaged teachers to analyze whether their driving questions fit the criteria (i.e., engaging, challenging, open-ended, and linked to learning goals).

v. I explained my steps of PBL design.

They were extremely fascinated by the Google Site, scaffolded personal workspace template, and the timeline. Most of all, they gave me the highest compliments for my backward design.

(f) Co-design with Greg and refining management documents for Greg (11.5 hours).

i. Greg worked with me for 3.5 hours to co-design a management document, student personal workspace in my classroom. We identified that six milestones were the six engineering process components: define the problem, generate concepts, design solutions, build and test, evaluate a solution, and present a solution. Greg helped me understand some engineering terms and provided me with some assessment questions when I demonstrated the process of content scaffolding. He was captivated by my technics of organizing the Google Doc, such as bullet pointing and adding tables. He was also very excited to learn the process of scaffolding.

ii. I spent an additional eight hours refining all the management documents on my own: personal workspace, timeline, presentation slides, rubrics, PowerSchool pages.

(g) Fifth meeting - Individual teacher meeting for PBL launch (30 minutes for each teacher): I debriefed the launch process for the next day with Greg in my classroom. I did the same process with Jen via Zoom because she was quarantined at home.

Third Phase of the Training (15 days) — Put PBL Lesson Plan into Practice

The third phase of the training was implemented in each teacher's classroom for 15 days over 3.5 weeks. The teacher's role in this phase was as an enactor. The goal of this phase was to train teachers on PBL implementation. This phase had four sessions:

1. Session 6 (10 minutes): Seven teaching elements.
   (a) In the third meeting during Phase 2, in my classroom, I provided a handout (see Appendix G).
   (b) I explained the seven teaching elements.
2. Session 7 (15 minutes): Case analysis. The original plan was to analyze three case videos, but both teachers were exhausted after teaching an entire day. We agreed only to select one video case that was for the middle school level.
   (a) I provided a worksheet (see Appendix H).
   (b) The teacher filled out the worksheet while they were watching the video to identify the seven teaching elements.
   (c) We compared our answers.
3. Session 8 (5 minutes): Teacher change environment.
   (a) I provided a handout of the teacher change environment (see Appendix I).
   (b) To save time, I briefly explained how I would use the handout because once teachers understand what factors could cause the change, they may start changing their teaching approaches (Clarke & Hollingsworth, 2002). I informed them that I would ask them to reflect on the four domains (i.e., personal domain, external domain, the domain of practice, and domain of consequence) in the middle and after the implementation phase.

4. Session 9: PBL Implementation. As my time permitted, I joined the teacher' Zoom meetings or went into their classrooms when they were teaching.
   (a) At the end of each implementation day, I asked each teacher to verbally reflect on two questions: (i) which part of the lesson went well? (ii) Which part of the lesson did not go well?
   (b) I gave feedback to address the areas that teachers could improve on or help them solve problems as they occurred.

Fourth Phase of the Training — Independently Design a PBL Lesson Plan

The fourth phase of the training was implemented within two weeks after the PBL implementation. The teacher role in this phase was an independent designer. The goal of this phase was to provide the opportunity for teachers to design PBL on their own. This phase's rationale was based on the theory of learning transferring (see Chapter II). This was the last session of the entire training program, Session 10.

Session 10: Independent PBL design. Two teachers had two weeks to turn in their new PBL lesson plan. During the two weeks, Jen reached out to me for idea brainstorming and feedback for her lesson plan draft. Greg did not reach out.

(a) Two weeks after the PBL implementation, I used a BIE rubric (see Appendix J) to evaluate whether each teacher had used the seven essential PBL design elements and determine how well the teacher had transferred PBL design knowledge.
(b) I provided feedback to them in person about their design.

The entire training procedures are presented in Table 3.

Table 3

Procedures of the Training

Procedures	Phase of Training	Researcher's Role	Teacher's Role	Training Length
Provide foundational knowledge on PBL	**Phase 1** (1) Session 1: Provide foundational knowledge on PBL (2) Session 2: Explain essential elements of PBL design (3) Session 3: Analyze three case studies regarding design elements	Training provider	Trainee	1.5 hours (Friday afternoon)
Apply PBL principles to co-design a lesson plan	**Phase 2** (1) Session 4: Modeling PBL planning procedures	Training provider	Trainee	0.5 hour, the first day (Friday afternoon)
	(2) Session 5: Co-design a PBL lesson plan	Co-designer	Co-designer	Six co-designing hours with Jen plus my own 12 hours for Jen; Nine co-designing hours with Greg plus my eight hours for Greg.

(*table continues*)

Table 3 (*continued*)

Procedures	Phase of Training	Researcher's Role	Teacher's Role	Training Length
Put a PBL lesson plan into practice	**Phase 3** (1) Session 6: Provide knowledge on essential elements of PBL teaching (2) Session 7: Analyze three case studies (3) Session 8: Explain the teacher change environment	Training provider	Trainee	0.5 hour
	(4) Session 9: Implement in classroom	Observer/ Mentor	Classroom teacher	3.5 weeks
Design a PBL lesson plan independently	**Phase 4** Session 10: Teachers independently design a new PBL lesson plan	Evaluator	Classroom teacher	Within two weeks after the PBL implementation

Data Collection

Data Sources

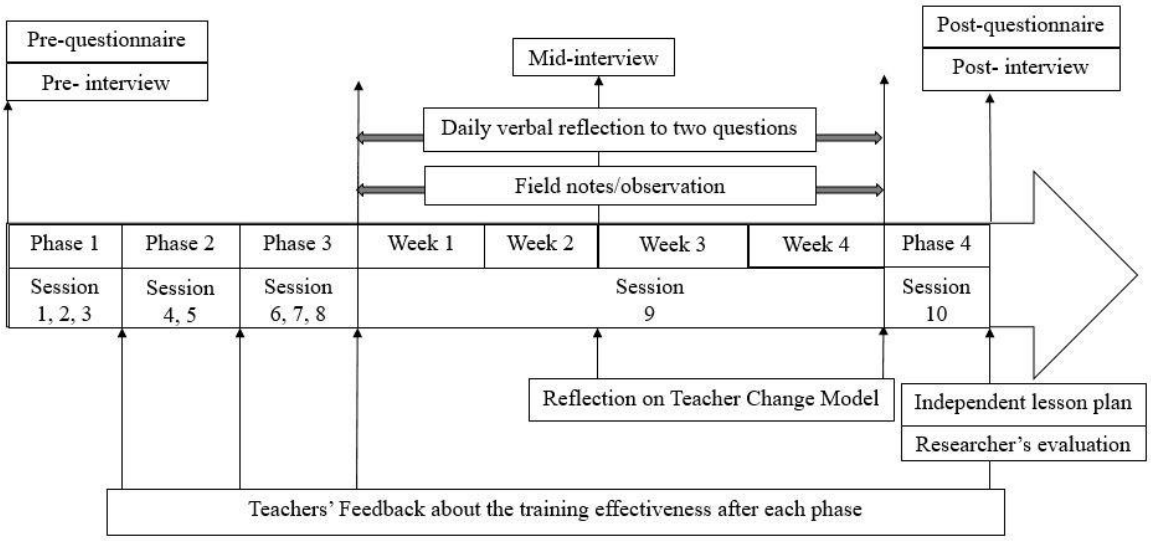
To answer the three research questions, multiple sources of data were collected. Six categories of data that contain 13 data sources were collected: (1) questionnaires including pre- and post-questionnaires; (2) interviews including pre-, mid-, and post-interviews; (3) observation documents including field notes and the summative observation rubric; (4) verbal reflections including daily reflection during the implementation phase, reflection after each training phase, reflection on the four domains of teacher change environment; (5) documents including a lesson plan and evaluation form from the researcher; and (6) researcher's reflective journal. Of the six types of data sources, questionnaires, interviews, observation, reflection data were the four primary data sources. Documents and the researcher's journal were secondary sources.

Questionnaires were used because participants could retrieve information from their knowledge reservoir, not pressured as in an interview giving answers immediately. Also, it is more efficient to use questionnaires when quantitative data such as a Likert-scale rating were collected. Interviews can explore specific information from participants (Merriam, 2009). Interviews were used to explain and elaborate the questionnaire's responses, especially making the quantitative data clarified with contextual evidence (Greene et al., 1989). Observation is the best technique when an activity can be observed firsthand (Merriam, 2009). To examine how teachers perform in class, it is necessary to observe teachers and give them feedback. Teacher reflection was part of training because reflection helps construct professional knowledge (Cochran-Smith & Zeichner, 2005).

Also, participants' reflection on their successes and challenges helps answer the third research question. The evaluation of documents (i.e., teachers' lesson plan) was to check whether the knowledge was transferred. The researchers' journal can provide more contextual information. The overall data collection procedure took over 10 weeks, approximately 35 hours. Each instrument was implemented in the timeline illustrated in Figure 4. More details about each data source, instrument, and procedure are described below.

Figure 4

Timeline for the Data Collection Procedures



Questionnaire

An open-ended pre- and post-questionnaire were provided respectively before and after the training in each teacher's classroom for about 10 minutes. The pre-questionnaire (see Appendix K) had eight items. The first two questions asked teachers' knowledge of the characteristics and procedures of PBL. The next three questions asked teachers to lists

their previous projects that they had taught and their successes and challenges. The last four items asked teachers to rate their confidence level to teach PBL, the support level of the school, their mentor, and peers. The post-questionnaire (see Appendix L) removed the questions about previous PBL teaching experience instead of asking teachers to list the successes and challenges of our co-designed PBL. Teachers were asked to rate their agreements on 20 items from a range of strongly disagree, disagree, uncertain, agree, and strongly agree with a Likert-scale from 1 to 5. The first eight items were developed from Guskey (2002), and the following 12 items were mainly developed from Desimone (2009), Darling-Hamoond et al. (2017), Goldstein and Ford (2002), and Shoobridge (2002) presented in Chapter II.

Interview

Three semi-structured interviews were conducted in the teacher's classroom: (1) a pre-interview (Appendix M) following the pre-questionnaire before the training, (2) a mid-interview (see Appendix N) conducted in the mid-term of the training, and (3) a post-interview (see Appendix O) and following with a post-questionnaire after the training. Each interview was audio-recorded, and it took approximately 30 to 40 minutes. The pre-and post-interview questions were designed to clarify or elaborate the answers to the pre- and post-questionnaires. The seven-question pre-interview also asked teachers' beliefs about student learning in PBL and their current teaching style. The five-question mid-interview focused on asking participants to reflect on any changes in learning PBL, PBL design, and PBL implementation. Also, they were asked what other support they still needed. The 16-question post-interview mainly asked participants' perceptions of the training program, their knowledge gain throughout the phases, their successes and

challenges during the training, their perceptions of the mentor support, and other sources' support.

Field Notes of Observation and Summative Observation Report

As a full-time teacher at the research site, I had limited time to observe these two teachers. The solution was to obtain the video data that teachers archived for their daily lesson prepared for the online students during COVID-19. However, the administrator's permission was not obtained. I only had conference time in my seventh period, which was the last class period of the school day, to observe a teacher fully. To compensate for the time constraint, lessons were designed in a self-directed learning approach, which freed me to observe in other periods for about 30 minutes as soon as I finished giving my students a short instruction. The observation took place either on the Zoom app or in the classroom. Since PBL was launched, Jen was quarantined at home because of a close COVID-19 exposure, and had to teach online for six days. I joined her Zoom to observe her class and provide assistance when needed.

After PBL implementation phase, a summative observation rubric (see Appendix P) was used to rate teachers' performance of PBL implementation from one to five and provide justification for the seven items which were developed based on the work of Stearns et al. (2012) and Boss and Larmer (2018). Rationale for the rating was based on my field notes over 15 days. These items examined whether the teacher (a) clearly stated goals and tasks; (b) asked effective open-ended questions within small groups; (c) established a collaborative learning environment; (d) provided students with management tools or strategies; (e) provided students with scaffolding lessons, activities, or materials; (f) communicated clearly about the formative assessment; and (g) identified and engaged

the students around their interest and cultural contexts.

Teacher's Verbal Reflections

Three types of reflections were collected at different times of the study. These reflections include daily reflection on the lesson, reflection after each training phase, and reflection on the model of teacher change environment (i.e., personal domain, external domain, domain of practice, and domain of consequence). More details are described below:

1. Daily reflection on the lesson (5 minutes). During the PBL implementation phase at the end of the school day, I asked each teacher to verbally reflect on two questions: (i) Which part of the lesson went well? And (ii) Which part of the lesson did not go well? I audio recorded their verbal reflection. Then, I gave feedback to the teacher for any occurring challenges or needs.
2. Reflection after each training phase (5 to 10 minutes). At the end of each training phase, I asked teachers two questions and audio-record them: (i) Which part of the training benefits you so far? (ii) Which part did you not know about PBL before? Their short reflections were audio-recorded and gave me other perspectives about their knowledge gain as the training proceeded.
3. Reflection on the teacher change environment (10 to 20 minutes). In the middle of and after the training, I asked each teacher to reflect on their teaching experience prompted by the worksheet that I designed based on the teacher change environment (see Appendix I). I asked them to reflect whether their knowledge, belief, and attitudes towards PBL had changed in the personal domain. I asked them whether they had received any supports from

me and other external sources in the external domain. In the domain of practice, they reflected on the successes and challenges that they had encountered. Their reflections were audio recorded.

Documents

Within two weeks after the PBL implementation, which was during the winter break, both teachers were asked to design a PBL for the next grade cycle independently. I asked both teachers to submit four documents: (1) the initial planning using PowerPoint; (2) timeline after refining the lessons; (3) a Google Doc for personal workspace template for students use; and (4) PowerSchool pages to display the daily lessons. Based on the BIE rubric, I filled out an evaluation form after evaluating their PBL design skills for the documents they submitted.

Researchers' Reflective Journal

During the 10-week data collection, I wrote a journal for over 20 days on a personal blogger to reflect on the training implementation and my learning. Sometimes, it was short notes about the training activities, and sometimes it was about my achievements and hurdles implementing the training. This data was supplemental to other data sources, providing more context information and further justification to other data. These reflections included my perceptions towards the training and the participants, my feelings after interacting with the participants, my learning at the present time.

Data Analysis

Overview

An exploratory case study methodology was used to guide the overall analysis of the data collected. The leading analysis approach for the qualitative data was deductive

coding using provisional codes, supplemented by an inductive coding approach using open codes. Only partial data on questionnaires were quantitative data, analyzed by simply comparing and displaying them. The analysis started with highlighting the meaningful groups of data as units of analysis. Within the units of analysis, key phrases were underlined and later extracted into codes after similar expressions appeared repeatedly and formed a pattern.

First and foremost, I investigated the teachers' perceptions from a deductive coding approach based on a literature review to assign the predefined codes as provisional codes. Provisional codes were developed based on the literature review related to the study, the study's conceptual framework, and previous research findings, and they can be revised, modified, deleted, or expanded (Saldaña, 2013). For example, one of the training criteria noted by Guskey (2002) is that teachers should demonstrate a change in their teaching practice. Thus, the provisional code was developed into *change in practice*. Another criterion by Guskey (2002) is that the organization should support teacher participants. Hence, the provision code was identified as *organizational support*.

While scrutinizing the data with the deductive coding approach, I also explored the data with an inductive coding approach to label the data that were not salient in the literature and outside of the scope of predefined categories and codes with open codes, which were freely and substantively generated (Glaser, 1998). For example, one participant consistently mentioned his struggles in managing student disruptive behavior and disciplining students throughout the entire training. This finding was not included in the literature review that focused on PBL. The code was labeled *classroom management skills* as an open code. The process of deriving provisional and open codes occurred at the

same time.

General Data Analysis Procedure

The data analysis started from a constructed framework (see Table 1) to assess the effectiveness of the training program described in Chapter II based on multitudes of recent studies in the past 20 years. The framework comprised three components: (a) trainees, (b) training program design, and (c) trainees' work environment. In each component, categories and codes were identified to examine the training effectiveness based on the literature review. The identified categories and codes were used as the provisional codes, serving the "start list" before fieldwork (Miles & Huberman, 1994, p. 58). Within the framework, I selected the unit of analysis, the portion of content that helped make my coding decisions at levels of words, phrases, sentences, and paragraphs (Milne & Adler, 1999).

The data analysis table (see Appendix Q) presents data in alignment with each research question examined through the three components lens. For the first and third research questions, the three components are (a) trainee, (b) training program design, and (c) trainee's work environment. For each component, categories and codes that reflected the training effectiveness were labeled with provisional codes and open codes. For the second research question, I investigated trainees' perception change in terms of understanding PBL pedagogy and their belief in PBL that were further examined, specifically dealing with change. The difference was that while the first research question focused on the ultimate results of the training comparing before and after, the second research question's findings articulated more about the transformation of trainees' perceptions during the training phases.

Two Sets of Documents for Each Data Source

Each data source was recorded on Google Docs with two documents: one for Greg and the other for Jen. For each participant's data, one color was used to highlight units of analysis. Within the unit analysis, different colors were used to highlight the key phrases and sentences, then were labeled with provisional or open codes using comments. For example, a unit of analysis was "my biggest gain for the PBL is the organization part. I've gained a lot of knowledge about that. Setting up a timeline, sticking to the timeline, and understanding that I may have to be flexible if I need to be flexible." The key sentence is "my biggest gain for the PBL is the organization part," and the key phrase is "timeline." The open code was developed into "management documents" after a pattern was formed.

Three Cycles of Analysis

Each data source was analyzed for three cycles. The units of analysis were identified in the first cycle of coding. Within the unit, the provisional codes and open codes were identified. In the second cycle of coding (over 10 days), I checked my preliminary codes to see whether they aligned with the meaning and then revised, added, deleted, or merged these codes. In the third cycle of coding (over another 10 days), the second cycle was repeated for better coding accuracy.

Organizing Data

After the three cycles a Google Spreadsheet was used to organize the 13 data on 13 tabs to provide a systemic view of the large data sets. The four primary data sources were organized by the columns titled Greg and Jen within the predefined assessment

framework plus open rows for open codes. Next to each participant column, an open column was added on the right for interpretation or notes.

Coding with an Independent Researcher

I invited an independent researcher to check the dependability of my coding and interpretation. Because the researcher's time was limited, only the data from the three interviews and teacher reflections were checked. For the sake of the researcher's convenience, I created another Google Spreadsheet that organized the data into seven key categories presented in seven different Spreadsheets: (a) belief, (b) knowledge, (c) attitudes, (d) changes in practice, (e) training successes, (f) training challenges, and (g) work environment. On each spreadsheet, under each participant, one column was for the units of analysis, the other was for the codes. I presented the spreadsheets to the researcher in two 2-hour Zoom meetings. In each meeting, I read the unit of analysis out loud, and then we discussed if our interpretations and codes were in agreement or disagreement. When she agreed, I kept the codes that I generated. When she disagreed, I added her codes below my codes for possible revision later. She agreed with 99% of the codes. Only a couple of codes were added from her perspective. For example, I coded "It was challenging because they are sixth graders" as "belief about a student," but she coded "student maturity affects PBL." My code was for a major category, and hers was for a subcategory.

Analysis Specific to Each Research Question

Research Question 1

To measure the training program effectiveness, a codebook framework was developed based on the literature review presented in Chapter II. The three major

components are trainee, training program design, and trainees' work environment. Under the component of trainee, four categories were examined based on Guskey's (2002) criteria and the personal domain developed by Clarke and Hollingsworth (2002): (a) whether trainees' knowledge is acquired or increased, (b) whether trainees' beliefs are changed, (c) whether trainees are satisfied with the training, and (d) whether trainees applied new learning to their teaching practice. Under each category, subcategories/codes were developed by open coding. For example, Table 4 shows the categories and codes developed within the component of trainee that reflected the effectiveness of the training program.

Table 4

Categories and Codes for Trainee Component for Research Question 1

Component	Categories	Subcategories/Codes
Trainee	Knowledge (acquired/ increased)	Knowledge of PBL pedagogy
	Belief (changed)	Beliefs about PBL teaching Beliefs about student learning in PBL Self-efficacy in teaching PBL
	Attitudes (satisfied/ enjoy)	Attitudes towards PBL teaching
	Change in practice (able to apply new learning to practice)	Applied teaching elements to PBL implementation
		Applied design elements to own PBL design
		Applied lesson design thinking

Under the training program design component, the training design satisfaction was labeled as a category based on Guskey's (2002) criterion. Based on multitudes of

studies about the training effectiveness presented in Chapter II, 12 items were predefined as a collective provisional code whether the training program (a) performed a need analysis; (b) had clear objectives; (c) had a well-designed instruction plan; (d) used learning principles; (e) was coherence with job requirement; (f) focused on using the teaching content; (g) involved participants to learn actively; (h) involved participants for collective participation; (i) used the modeling of the practice; (j) provided opportunities for participants to practice; (k) allowed time for participants to reflect their learning and be given feedback; and (l) had sustained duration. Besides the 12-item provision code, another is *student outcome* identified based on Guskey's (2002) other criteria. Subsequently, two open codes were identified: *management documents* and *four phases*.

Under the trainees' work environment, organizational support, coaching and expert support, and peer support were identified based on the literature review. For Research Question 1, this study focused on the coaching and expert support, which was my support as their mentor. The other two supports were examined for Research Question 3. The analysis approach on the category of mentor support relied on open coding. Three open codes were identified as *modeling*, *feedback*, and *availability to support*.

Research Question 2

To measure the two teachers' perception change, I looked at keywords such as *understand*, *realize*, *aware*, *think*, *believe*, and phrases such as *I was… before. Now I..*, *I did not know … before*. The perceptions included the understanding of PBL and belief in PBL. The related provisional codes were predefined such as *understanding of PBL pedagogy*, *beliefs about PBL teaching*, *beliefs about student learning in PBL*. One open

code was added later, *belief about student maturity in PBL*. Table 5 shows the categories and codes that reflected the teachers' perception changes.

Table 5

Categories and Codes for Perception Change for Research Question 2

Component	Categories	Subcategories/Codes
Perception change	Understanding	Understanding of PBL pedagogy
	Belief	Beliefs about PBL teaching
		Beliefs about student learning in PBL
		Belief about student maturity in PBL

Research Question 3

Successes and challenges for the third research question are defined in the scope of the teacher training program. In this study, this training program's success criteria lie in: (a) trainees' acquisition or increase in knowledge on PBL pedagogy, (b) trainees' use of seven PBL design elements, (c) trainees' enactment of seven PBL teaching elements, and (d) trainees' willingness to continue using PBL. If these criteria are met, then the program is considered as successful. Any barriers, problems, and/or difficulties that interfere with these successes are viewed as challenges. Therefore, the same framework of measuring the training effectiveness was used to measure the training program successes and challenges.

Under the trainee component, *belief* was a provisional code because many studies report that teacher belief affects teacher practice (Haney et al., 1996; Pajares, 1992; Spillane et al., 2016). Two open codes that affected teacher performance in this training

were identified: *classroom management skills* and *time to participate in training*. Under the component of training program design, three open codes were identified: *the design of progressive phases*, the *design of management documents*, and *time constraint*. Under the work environment component, three provisional codes of different support sources were predefined from the literature: organizational support, mentor support, and peer support. Later, two open codes were identified, test pressure and COVID-19. Under the category of COVID-19, three subcategories/open codes were identified: *Student absence and tardy*, *difficulty to engage online students*, and *difficult to teach online at home*. Table 6 shows the codes and categories developed within the three components that measure the training program's effectiveness in the third research question.

Table 6

Categories and Codes for Perception Change for Research Question 3

Components	Codes/Categories	Subcategories/Codes
Training program design	The design of progressive phases	
	The design of management documents	
	Time constraint	
Work Environment	Organizational support	
	Mentor support	
	Peer support	
	COVID-19	Student absence and tardy
		Difficulty to engage online students
	Test pressure	Difficult to teach online at home
	Test Pressure	

Trustworthiness of the Study

To build trustworthiness of the current study, five areas were examined: (1) credibility, (2) transferability, (3) dependability, (4) confirmability, and (5) reflexivity.

Credibility

Credibility refers to the researcher's confidence in the findings based on the research design, participants, and context (Krefting, 1991). It concerns how well the researcher manages the threat to the study's internal validity and the instruments' validity to measure the phenomenon under study (Sandelowski, 1986). This study attempted to establish credibility through the six aspects below.

Prolonged Research Engagement

Before this study, I spent half a year on a pilot study regarding PBL mentoring with one mentor teacher and two mentee teachers for a STEM program. This experience increased my understanding of the research context in which the reality occurred, and provided an understanding of how a STEM program utilized PBL and how PBL was managed and implemented by teachers and the school. From the pilot study, I observed and found a need for professional development for novice teachers to learn PBL. Therefore, questionnaire and interview items based on the pilot study for this current study were developed. Built on the pilot study, the validity of the instruments of this study should be increased.

Instruments Developed Based on Previous Studies and Checked with Experts

Most instruments utilized to measure the training effectiveness were all developed through a thorough literature review on previous studies over the past 20 years. The collected data measured by these instruments were analyzed through a deductive coding

approach. To compensate for the limitation of using a deductive coding approach, an inductive coding approach was used to explore the training effectiveness under this study. To ensure the instrument development's accuracy, the instruments were presented to other experts who assisted me in forming interview questions and the alignment with the research questions.

Training Design

The training design adopted Kali et al.'s (2018) teacher training design, involving teachers as a learner, teacher as a designer, and teacher as an enactor. To provide scaffolding learning, the role of teachers in Phase 2 was altered to be co-designers, designing PBL lessons with me under my guidance and facilitation. After enacting the co-designed PBL lessons in their classrooms, the teacher role transitioned to be independent designers, where they can continue implementing for a second PBL independently in the near future. This design supported teacher learning in a scaffolding manner and pushed their PBL practice into an ongoing cycle.

Training Pilot

Before implementing the training, two fellow doctoral students were recruited to play the trainees' roles to test the training's duration and flow and collect feedback to improve the training. Due to doctoral students' time constraints, only Phase 1 and the first session in Phase 2 were conducted with these two students over two days. Each time, I went through the same procedures to engage the participants and recorded each activity's time length. At the end of each training session, both students were asked for feedback on improving the training. They both suggested saving the online videos as media files on my computer, just in case the Internet is down when providing training. They perceived

the training was easy to follow, and the training materials were sufficient and informative.

Triangulation

Triangulation means the use of multiple methods, sources, analysts, theories to review and corroborate the findings for reaching a general consensus in social inquiry (Denzin, 1978). I used three triangulation methods for this study to ensure credibility: (1) method triangulation, (2) triangulation of sources, and (3) analyst triangulation.

1. Methods triangulation: Five different data collection methods were used (i.e., questionnaire, interview, observation, teacher reflection, and document) to check the findings' consistency.
2. Triangulation of sources: Pre- and post-questionnaires within the method of the questionnaire, and Pre-, mid-, and post-interviews were collected within the method of interview. Field notes and summative observation reports were collected within the method of observation. Daily reflection about the lesson, reflection after each training phase, and reflection on the teacher change environment within the teacher reflection methods were collected along with teachers' lesson plan and the researcher's evaluation form within the method of documents. Within each data source, two different perspectives were compared as well.
3. Analyst triangulation: During the instrument development phase, an expert was invited to check the alignment between the research questions and the items, data interpretation, and analysis. Additionally, advice from another expert was sought about forming interview questions. During the data analysis

phase, a fellow researcher was invited to check my interpretation and coding.

Member Check

After each data collection, when some statements appeared unclear, I followed up with the teacher and clarified what they meant. For example, Greg rated his confidence level as three out of five in the pre-questionnaire but stated later that his confidence level was 10% in the beginning. I verified with Greg that his initial rating in the pre-questionnaire was overconfident, and 10% of confidence was accurate. For another example, Jen stated that she needed more time observing so I followed up with her and asked whether she needed to observe other teachers or be observed by a mentor. She confirmed that she needed time to observe other teachers to learn. The member check ensured the clarity and accuracy of the data.

Transferability

Transferability refers to "the degree in which the findings can be applied to other contexts and settings or with other groups" (Krefting, 1991, p. 216). When the researcher provided sufficient descriptive data to allow readers to compare the findings to their settings, then the researcher enables transferability (Korstjens & Moser, 2018). To add details beyond the observation and help the interpretation of the teacher participants' perceptions and actions, thick description was used to provide background information to capture their thoughts and emotions and resonate with readers making the findings meaningful to readers in the case (Ponterotto, 2006). Thus, the study's transferability is established to a certain extent to allow readers to transfer this case findings to their context.

Dependability

Dependability refers to the consistency of the data, meaning "whether the findings would be consistent if the inquiry were replicated with the same subjects or in a similar context" (Krefting, 1991, p. 216). To establish dependability, an expert was used to examine the instrument's alignment with the research questions; she also helped me interpret some data when I had difficulty understanding the teacher's ambiguous statements. Moreover, the data sets in three cycles were analyzed over three different time periods. In between cycles, the analysis was prolonged over 10 days to ensure interpretations and coding were consistent each time. Another researcher was invited to check the data's interpretations and coding from the primary data sources. She enriched and clarified my interpretations and provided a couple of different codes.

Confirmability

Confirmability refers to the audit strategies to confirm the process, product, data, interpretation, findings, and recommendation of the research (Lincoln & Guba, 1985). When credibility and dependability are established, confirmability is achieved (Lincoln & Guba, 1985). A pilot study was conducted before this study and part of the training was tested with my research fellows and an expert to validate the data alignment, interpretation, analysis, findings, and recommendation throughout the study. Additionally, a researcher was invited to check the coding and interpretation. For example, Greg had some doubts about PBL in the beginning. He was in the process of opening himself up as the training proceeded; some of his statements were ambiguous to understand, such as,

If I start my own biases, saying okay, I need to provide that information to the

> students without them researching on their own, for example, I am always likely to give you that information, but in PBL, let us see if I can guide you to that information for you to find it by yourself.

Therefore, advice from an expert was sought, and later an independent researcher to clarify and validate my interpretation; consequently, it is assumed that this study's confirmability is established.

Reflexivity

Reflexivity refers to the researchers' self-awareness and reflection about their roles in the study (Korstjens & Moser, 2018). While collecting the data, reflections were recorded on a personal blog throughout the training process. These reflections included my perceptions towards the training and the participants, my feelings after interacting with the participants, and my learning at the time being. I consider myself an experienced teacher with 10 years of teaching experience. I always have higher expectations of my students. During this training, I had higher expectations towards my mentee teachers. When I gave feedback to the teacher, I expected them to act upon it and improve. When they did not, I found it difficult to keep encouraging them. For example, I struggled during the implementation phase when I had to abandon my researcher role and act as a teacher to ensure student learning. Indeed, students in Greg's classroom were often off-task and distracted by each other, so I had to step in and address their behavior issues several times. My interference might have affected Greg to teach unnaturally, which might have affected the authenticity of the field notes to some degree.

I also had to give students feedback because Greg had not addressed student progress as a whole class when the project was already halfway through. This was

necessary modeling on how to provide student feedback addressing the entire class's progress because I observed Greg using the same strategy for his next PBL that he designed. However, conveying problems like these several times with Greg created some friction between him and I when Greg was already exhausted. Indeed, Greg expressed his frustration that some unruly students took a lot of his energy, and three teaching preparations took a lot of his time. I reflected on my experience with Greg at that time and decided not to ask Greg to reflect on his daily lessons for a couple of days because it only added to his tension.

I also reflected on whether I had biases towards the teacher participants, and at one point, discovered I might have a bias towards Greg during the implementation phase. I offered feedback to Greg for his improvement, and he said he would act on it. However, 90% of the time, he did not take action, which made me frustrated. After consulting with an expert, I was reminded of two aspects to reflect: (1) the rapport between the mentor and mentees might not have fully developed, thus, Greg might not entirely trust my mentoring; and (2) Greg did not have the time and energy to act on the improvement. I assume the latter was the real reason because Greg mentioned that three teaching preparations fully occupied him, and he did not have time to give grades to the students. I reminded myself to step back from my frustration and understand Greg's work tasks and the fact that Greg was a novice teacher who was still developing his expertise. These reflective notes in my journal are supplemental data to provide more contextual information to interpret the data.

CHAPTER IV

FINDINGS

This chapter presents the findings of this study that correspond to each research question. Overall, the two teachers perceived the training program to be effective in training them for PBL and they transformed their perceptions towards PBL to different extents after the training. The study's findings suggest that factors such as teacher belief, classroom management, and time to participate in training were associated with the successes and challenges of the training program

RQ1: How Do Teachers Perceive the Effectiveness of a PBL Training Program

Overall, the two teachers perceived the training program was effective because they (1) gained knowledge on PBL pedagogy, PBL design, and PBL implementation, (2) positively changed their belief in PBL teaching, (3) increased self-efficacy to use PBL, and (4) demonstrated the application of the design and teaching elements. Both teachers rated the program with high ratings, perceived the training design was beneficial, and their expectations were met entirely. Also, they valued the mentor's vast array of support during the training.

To provide a clear picture before elaborating on each component, the comprehensive findings regarding these three components of the training effectiveness based on the teachers' perceptions are summarized in Table 7.

Table 7

Teachers' Perceptions Regarding the Three Components of the Training Program Effectiveness

	Trainee	Training Program Design	Work Environment Mentor Support
Effectiveness of the training program	1. Increased the knowledge on PBL pedagogy 2. Transformed belief toward PBL teaching 3. Increased self-efficacy in PBL teaching 4. Changed attitude towards PBL teaching 5. Applied PBL teaching elements 6. Applied PBL design elements	1. Rated almost five on every item out of five 2. Phase 1: Learned seven design elements and preliminary planning 3. Phase 2: Learned management documents and the timeline 4. Phase 3: Learned scaffolding and benefited from mentor's daily feedback 5. Phase 4: Understood backward design and the importance of a public product 6. Trainees' expectations were all met	1. Modeled the practice 2. Provided daily feedback 3. Provided logistical and emotional support 4. Availability to support

Effectiveness of Trainee Component

Knowledge on PBL

In this study, knowledge on PBL contains knowledge on PBL pedagogy, PBL design, and on PBL implementation.

Knowledge on PBL Pedagogy. Both teachers gained knowledge on PBL (i.e., characteristics, more about the process instead of just product), PBL design (i.e., the design of management documents, scaffolding), and PBL implementation (i.e., the procedures of PBL, student assessment). In this study, knowledge on PBL pedagogy refers to the understanding of broad principles and strategies of PBL, specifically on PBL characteristics, PBL design, and PBL implementation.

Both teachers gained knowledge on PBL characteristics (e.g., driving question, collaboration, a product to address the driving question). Comparing the pre- and post-questionnaires, Greg listed six PBL characteristics in the post-questionnaire compared to three in the pre-questionnaire. Jen listed 11 characteristics in the post-questionnaire compared to four in the pre-questionnaire. See Table 8 for the knowledge on PBL on specific characteristics gained by the two teachers.

Table 8

Gained Knowledge on PBL Pedagogy

		Greg		Jen	
		Pre-questionnaire	Post-questionnaire	Pre-questionnaire	Post-questionnaire
Knowledge of pedagogy	Characteristics of PBL	1. Process 2. Emphasis on students 3. Teacher as a facilitator	1. Student-centered 2. Focus on a challenge or problem to research and solve the problem 3. Open-ended questions 4. Inquiry-based 5. Provides the opportunity for feedback 6. Requires students to present to an audience	1. Collaboration 2. Research 3. Hands-on 4. Presentation	1. Culture 2. Research 3. Critical thinking 4. Teamwork 5. Ownership 6. Process 7. Student choice 8. Flexibility 9. Inquiry 10. Authentic 11. Relevant
	Procedures of teaching PBL	1. Identify a problem 2. Investigate the problem 3. Explore solutions 4. Come up with a conclusion	1. Entry event 2. Driving question 3. Research 4. Proper development 5. Presentation 6. Assessment	1. Entry event 2. Know and need to know 3. Content activities 4. Critical friends (peer critique) 5. Culminating event	The whole process involves: 1. Essential/driving question 2. Brainstorm a plan 3. Create a timeline 4. Create an initial plan on PowerPoint 5. Product Engagement involves: 1. Excite students 2. Present problem 3. Entry event 4. Monitor students 5. Assess students

Also, Jen emphasized her knowledge gain on PBL: PBL was more a process than just a product at the end of a unit. She mentioned this gain in the reflection after Phase 1, and in the mid- and post-interviews. She said, “I have learned that it is not just about the product; that is not the goal, is just a part of the process, and the process of learning throughout the time that you are given.”

Knowledge on PBL Implementation. Both teachers also gained the knowledge on PBL implementation in terms of the procedures of PBL teaching. In the pre-questionnaire, Greg highlighted four procedures of implementing an engineering project that came from his curriculum. In the post-questionnaire, Greg listed similar procedures but used the terms in PBL and added “presentation” and “assessment.” In the pre-questionnaire, Jen listed five procedures of implementing PBL that she learned from her previous training and Friday PBL. In the post-questionnaire, Jen provided five steps of PBL design and five steps of PBL implementation that focused on student engagement. See Table 8 for the knowledge of PBL implementation on specific procedures gained by the two teachers.

Greg also highlighted his knowledge gain on student assessment. In the teacher reflection during the mid-term of the training, Greg reported that he gave the same grade to the students within the same group. By then, he learned how to give students individual grades within a group because he thought that the management document of personal workspace (i.e., a Google Doc) allowed students to demonstrate their learning individually by answering the questions on their own.

Knowledge on PBL Design. Both teachers also gained knowledge on PBL design. Among the knowledge gain on PBL characteristics, PBL design, and PBL implementation, Greg's most salient gain was in PBL design. He mentioned four times in the reflection after Phases 2 and 3 and in mid- and post-interviews. He was very excited and underlined this knowledge gain in the mid-interview: "my biggest gain on PBL is the organization part." The following statement from the post-interview best captured his knowledge gain on PBL design during this training:

> In the beginning, the concept was foreign because it was kind of like learning a foreign language ... I didn't know all of these. All of these were new to me; the steps of planning and design elements [were new to me]. Now I have a better understanding. I can think about the timeline … I can think about flow charts …

Greg's other noticeable knowledge gain on PBL design was on scaffolding, and he mentioned this gain in the mid- and post-interviews, and in the reflection session after Phase 3. He thought the most beneficial training phase was Phase 2, the co-design phase. Particularly in this phase, he learned "how to break things down to student level." He underlined his knowledge gain on scaffolding in the post-interview: "I can present the project and break it down for the kids. It's easier to manage now, and I can do it on my own." These statements were confirmed and demonstrated through his design documents for the independent PBL design in Phase 4. The teaching content was well scaffolded and well organized by using the templates that I provided.

Among the knowledge gain on PBL characteristics, PBL design, and PBL implementation, Jen's most salient knowledge gain was also in PBL design and her independent PBL design was evaluated with a high score based on BIE's rubric. Also,

she perceived that her lesson design mindset changed from "linear" to "systemic" in the mid-interview and mentioned again in the post-interview:

> I can see the broader picture now, instead of seeing it being a narrow picture: this is the TEKS that we have to learn, this is what I have to show them … Now I look at the bigger picture, the broader picture. I can say, alright, here's some TEKS, they kind of relate to [the TEKS]; I can add them together. I can add the content. It's not something that bogs students or me down by the very straight narrow [thinking]. I kind of have this very open mindset now.

Jen explained that linear thinking means thinking about day-to-day lesson plans and systemic thinking means thinking from a broad picture to design a project by embedding daily lessons. Jen demonstrated this transformed mindset when she reflected in the post-interview on how she viewed the reading standard test from design thinking perspectives in PBL. She related some elements of PBL to the test preparation process and believed that both had essential questions and final goals. She planned to build a culture for the reading activities and "squeeze some fun in." She also wanted to make the test drill content-focused. These reflections demonstrated that she was able to apply the learning from PBL to her new teaching context and became less stressed by the test pressure. She said, "It may not be much fun… I will not be as excited as doing a PBL, but it is better."

In summary, Greg and Jen gained knowledge on PBL characteristics, PBL design, and PBL implementation. Greg emphasized his learning on scaffolding and how to give students individual grades for group work. Jen highlighted her learning on the application from PBL design and implementation of test preparation.

Teacher Beliefs in PBL

One teacher was pessimistic about student maturity to handle PBL but transformed the belief in using PBL for content-teaching. One teacher strengthened the belief in student learning in the PBL environment and transformed the belief in using PBL to teach to the state standards. In this study, two types of teacher beliefs were examined: belief about PBL's influence on student learning and PBL teaching belief.

Belief in PBL's Influence on Student Learning. Greg perceived that PBL was too rigorous for younger students and doubted student maturity to handle PBL. In the pre-interview, Greg stated that he believed that students could benefit from PBL in the right environment, not limited by materials and technology. However, throughout the training program, Greg consistently expressed his doubts that sixth graders were not mature enough to handle PBL and his struggle managing student misbehaviors. During a reflection session after the implementation phase, he seemed frustrated when I asked him to reflect on student learning:

> This is a lot more; a lot more than what they would do in actual sixth-grade class. This is a lot more than what they were expected to do, and they haven't done this kind of project in this class or any other classes.

Based on the field notes, I found that Greg struggled during the implementation phase as he repeatedly mentioned in managing student disruptive behaviors. Greg said that certain students took a lot of his energy. He often looked exhausted when I observed his class at the end of the school day.

Jen's belief in PBL's influence on student learning was strengthened. In the pre-interview, she reported that she believed that PBL has a significant influence on student

learning because of her daughters' positive PBL experiences. In the post-interview, Jen strengthened the same belief because she understood better after implementing PBL in her classroom and saw some successful student learning evidence.

Belief in PBL Teaching. Greg's belief in PBL teaching transformed from content-teaching focused to using PBL for content-teaching for some subjects. At the beginning of the training, he described himself as "a little bit old school" and "still had some doubts about PBL," and he believed that teachers should teach foundational concepts first and use PBL later. In the post-interview, his belief, focusing on content-teaching, held the same on subjects like mathematics, reading, and writing "unless someone shows him how." However, Greg evolved his belief on PBL use on some subjects like physics and history, that teachers need to teach PBL and "they can do it." This is a noteworthy belief transformation compared to his previous statements regarding PBL teaching.

Jen's belief in PBL teaching transformed from doubting the use of PBL for the state standards to using PBL to teach to the standards. At the beginning of the training, Jen was not convinced whether PBL could cover all the TEKS that students needed to learn. In the post-interview, she desired to continue using PBL because she believed that PBL could include the necessary TEKS by backward design (i.e., start planning from mapping TEKS to PBL design).

Self-Efficacy Increased

The two teachers reported that their self-efficacy on their ability to use PBL increased. Both of them rated their self-efficacy three out of five in the pre-questionnaire and both increased their rating to four out of five in the post-questionnaire. In the post-

interview, Greg reported that he was overconfident in the beginning of the training and his actual confidence level was 10%. He described his confidence in using PBL increased to "80% to 85% by then." Jen mentioned in the mid-interview that her confidence level did not change because she had been teaching online quarantined at home for almost two weeks. She reported her confidence level increased after coming back to the classroom.

Greg's Change in Self-Efficacy. Greg's attitude towards PBL teaching started from being apprehensive and evolved to feeling better later, then transformed to confident enough to share with his co-worker after the training. In the pre-interview, Greg was apprehensive, and he described PBL as "daunting" and "big." In the mid-interview, Greg felt much better with the tools of management documents. He reported:

> The biggest appreciation is me not being apprehensive about implementing PBL because it was so daunting, so big. The project was daunting, and the idea was daunting. Now I feel much better, and I have the tools to do it ... It's easier to manage now.

In the post-interview, Greg described his increased confidence but with some concern: "I'm very confident. Again, my only concern is getting better at classroom management and understanding better how to group students. My confidence level is 80% to 85%; I just need more practice." He also said that he shared his design with his co-worker and encouraged the teacher to use it. Before the training, Greg did not know how to design or implement PBL. During the training, I modeled twice in his classroom. The first time was modeling how to introduce the project to students on the PBL launch day. The second time was to model how to give student feedback and address their progress as a whole class. Greg reported my modeling was beneficial.

Jen's Change in Self-Efficacy. Jen's attitudes towards PBL teaching started from being apprehensive and later evolved to her appreciation towards PBL, and eventually transformed to her desire in the continuum of PBL teaching. In the pre-interview, she said she was a little apprehensive and afraid of PBL teaching because she was still in survival mode as a first-year teacher. She noted that "It was overwhelming for a first-year teacher to implement PBL." In the middle of the training, Jen reported in the mid-interview that she started enjoying the learning process with students because the PBL design for weeks of lessons freed up the daily planning time. She said:

> It [PBL design] is beneficial for the teacher because you put a lot of work into PBL initially; later on, when you implement it, you get to enjoy their learning process, not as much work during the PBL. I started enjoying this PBL. I started thinking about what I'm going to do for next semester.

Jen appreciated the PBL strategy very much and thought that this training program was a turning point. She confessed that she felt burned out and doubted whether she should have continued teaching because of the demanding workload on a first-year teacher. She expressed her appreciation towards PBL in the mid-interview:

> Now I have a better idea how to create [for future lessons]. I will not burn out every day, and I think this has given me a kind of drive and passion back. This is giving me a break, and a different perspective on teaching.

Jen expressed her enjoyment in PBL teaching in the post-interview because she thought that PBL design enabled her to have flexibility in setting time aside with grading and other school duties, not lecturing and standing in front of students as before. Jen said that she had the desire to continue using PBL, and her attitude change towards PBL

teaching was due to her growth in understanding PBL and growth in designing and implementing PBL. She addressed her lesson design mindset changed from "linear" to "systemic," going through the co-design and independent design processes separately in mid- and post-interview. She also described her understanding of the design elements by implementing them in the reflection session after Phase 3.

Change in Practice

Both teachers demonstrated their practice changes to different extents in two areas of application: (1) the seven teaching elements to the PBL implementation, and (2) the seven design elements to the independent PBL design. In applying the teaching elements for PBL implementation, Greg had more room to develop his implementation skills, mainly in activity management and student assessment. At the same time, Jen performed reasonably well as if she were a natural-born teacher. In applying the design elements for PBL independent design, Jen demonstrated her mastery of utilizing all seven elements, which was a big success of the training program. However, Greg applied four elements out of seven because his project was not long enough to incorporate them. As he explained, he wanted to design two small projects first, then a longer one at the end of the semester.

Applying the Seven Teaching Elements to the PBL Implementation

Greg's average score on PBL implementation was 3.1 out of 5, while Jen's was 4.9, based on the summative observation rubric (see Appendix P) that I used after completing PBL implementation. Greg's noticeable low scores (two out of five) were in classroom management and communication on the assessments. Also, Greg was scored two out of five in the area of clearly stating goals because based on my field notes, he

seldom started class with communicating goals; instead, most of the time, he started class by putting students in the breakout rooms (i.e., separate sessions to split students for different groups) on Zoom. His engaging and coaching scores were also rated two out of five because he could monitor students more actively and he did not have a consistent discipline system to manage student misbehavior. Based on my observation, he addressed certain students' behavior issues every day, but soon students repeated the same misbehavior, and no consequences followed. I also scored him with two in communicating about formative assessments because Greg irregularly reminded students of the coming assessments and did not address student progress as a whole, based on my field notes. Greg expressed his frustration towards PBL implementation in the mid-interview: "My success hasn't come yet; can I learn this? Can I implement it correctly? …That's my goal." In the post-interview, Greg reflected on his lack in classroom management: "I do lack classroom management skills for sixth and seventh grade but beyond these grades, I do not have difficulties. By teaching PBL, I have difficulties in group management and understanding group dynamics." Greg explained that he had not engaged students in group work before this training, which indicates that his teaching style could have been more teacher-centered. However, as the training progressed, Greg showed his efforts in building a collaborative learning environment, encouraging students to help each other within a group. He also directed students to the sources and empowered them to research.

Jen also had some struggles with the same group of disruptive students that Greg had, but she redirected them consistently with consequences. For Jen, I rated her with a score of five for almost every item except the item on checking whether the teacher asked

open-ended questions. For this item, she was rated as a score of four because most of the time, she directed students to the sources and guided them to research independently, but sometimes, she gave them answers. Based on my field notes, Jen was a proactive and reflective teacher. Beyond acting upon my feedback for her improvements, she came up with her own strategies to guide and manage student learning. For example, she wrote the day's key activities in columns on the whiteboard in the classroom's back wall. She also listed student names for specific missing assignments but crossed off their names once they completed them. Furthermore, she provided hard copies for some students who preferred paper over using a computer. As Jen described her ability to implement PBL in the post-interview, she was satisfied with her performance: "I did well on engaging and assessing students."

Applying the Seven Design Elements to the Independent PBL Design

Greg's average score on PBL design was 3.9 out of five for his two-week-long PBL, while Jen's was five for her six-week-long PBL, based on the BIE rubric (see Appendix J) used after the completion of the independent PBL design. In Phase 4, I assigned an independent six-week-long PBL design to both teachers. Once they submitted the lesson plans in two weeks, Greg and Jen were evaluated how well they applied the seven design elements based on the evaluation rubric. On the evaluation form, there were seven rows for the seven design elements and three columns for skill levels to rate teachers: (1) lack features of effective PBL, (2) need further development, and (3) include features of effective PBL. I assigned a score of one to two for the lowest level, three to four for the middle level, and five for the highest level.

Greg was rated two for using the driving question element, which was "what is an engineering project?" "What" question normally asked students to identify and understand entities, which is at the bottom of Bloom's taxonomy (1956). His level of challenge could be higher. Jen's driving question was rated five, which was, "As future leaders, how can you learn from past and present worldly issues to help create your social movement and help change the world?" This question asked students to apply, evaluate, analyze, and create, which are at the higher levels of Bloom's taxonomy (1956). Her question was engaging and meaningful for students to apply to the real-world. Greg's element use of critique and revision was rated three because he did not include peer critique. For the element of presenting the public product, Greg limited students' audience to their classmates. However, the final product should be offered to the audience beyond the classroom based on BIE's standards. Therefore, for the element use of the public product Greg was rated two. Jen, was rated five because she asked her students to publish their social movements on social media to advocate.

Effectiveness of Training Program Design

Three data sources measured the effectiveness of the training program design: (1) trainees' rating for the training program in the post-questionnaire, (2) trainees' feedback about training phases given after each phase, and (3) trainees' feedback about the training program in the post-interview.

Trainees' Rating for the Training Program

Both teachers were satisfied with the training program design, and they gave high ratings in the post-questionnaire. A collective of 12 items constructed based on multitudes of studies presented in Chapter II was used to measure the training program

design's effectiveness in the post-questionnaire. Both teachers were asked to rate their agreement levels from *strongly disagree* to *strongly agree* on the training design statements using a Likert-scale from 1 to 5. They rated five for all the items except Jen, who rated four for one item, of which the statement was "This training program had a sustained duration." Jen explained in the post-interview that she needed more time in every way, meaning more time to learn PBL, more time for co-designing, more time for practicing independent design, more time to implement PBL, and more time to work with me (the mentor). She also expressed her need for more time to practice PBL in the mid-interview: "I think it needs to be a full semester-long, but even then it probably wouldn't be long enough."

Trainees' Feedback about Training Phases

Both teachers thought the training phases were necessary steps to prepare for learning PBL, and the training content in each phase was beneficial. After Phase 1, providing trainees with PBL foundational knowledge, both teachers reported that they the three vide cases helped them understand the seven design elements and how to use them for different subjects at different grade levels. When asked "what part of the training benefits you the most," Greg answered "everything," and Jen highlighted "the milestone planner," a flow chart to present the preliminary planning aligned with student activities and assessment provided on the PowerPoint.

After Phase 2, the co-designing phase, both teachers thought the management documents and timeline were the most beneficial tools. Greg was excited about how well the PBL was organized and presented. He remarked, "This way helps me think from the student side, not from my side. I love the way you structure everything, and developed a

system. It is a good system, very intuitive, very efficient, and very helpful." Jen thought the timeline was very helpful for both students and the teacher to manage activities and to be reminded where and when the assessments were. Although both teachers realized how time-consuming and complex the planning could be during the design phase, they thought the planning was very beneficial. Greg said he would keep using the management documents, tweaking them to fit his future projects' teaching content. Jen acknowledged the importance of PBL design and commented:

> To get the big idea, [you] need to develop it before you start it. I think it will be the most beneficial because it is more a rock-solid plan; that way, you only do a little tweaking throughout and can enjoy PBL more later on.

After Phase 3, the implementation phase, when asked the most beneficial part of the phase, Greg answered "scaffolding," and Jen answered "daily feedback" from me. Greg said he learned how to break instruction down to the student's level, and in the meantime, he admitted that he lacked scaffolding for this project because he was still processing the learning. Jen thought that my daily feedback was constructive, and she needed a mentor to "bounce ideas off" to make them clearer. Both teachers pointed out the necessity of the implementation phase. Greg said, "By experiencing the process, I can say this is working for me; this is where I can improve." Jen said, "Experiencing the knowledge is different from knowing the knowledge... I know these elements now, and understand what they mean by implementing them. To implement what it means."

After Phase 4, going through the independent PBL design, both teachers recognized the importance of designing PBL on their own. Both teachers thought it provided an opportunity to think independently and explain the instructions clearer.

When asked which part they did not know before this phase, Greg reported that he did not understand the process of backward design well, and after this phase, he obtained a better understanding. Jen reported that she did not give much credit to the design element of the public product until I pointed it out to her, which made her realize the importance of presenting it to someone else beyond the classroom.

Trainees' Feedback about the Training Program

Both teachers expressed their satisfaction with the training program and confirmed that their expectations before the training were met entirely in the post-interview. In the pre-questionnaire, Greg wrote two expectations: (1) better understand the driving force behind the PBL concept, and (2) better implement the idea/concept in his classroom. Jen listed three expectations: (1) how to create a PBL for her content that was relevant and fun, (2) the proper steps to implement a PBL successfully, and (3) how to use PBL with both content areas that she was teaching (English and social studies). Both teachers had a common expectation of how to implement PBL.

Greg commented in the post-interview, "I learned a lot; this training provided more than I expected, and I really appreciate it." He also informed me that he shared his independent PBL design with another engineering teacher on campus and taught this teacher how he was taught in this training program. This is noteworthy evidence of the program's success.

In the post-interview, Jen reflected on her learning growth when she answered a question. What was the training result to her? She said:

> At the very beginning, I was a little leery, and not convinced about the PBL.
>
> I think I scored two or three initially [about my expertise], and now I feel like this is something that I can continue doing on my own and enjoy.

In summary, both teachers perceived this training design as effective based on (a) the high rating on the 12-items to measure the training design effectiveness, (b) their positive feedback about the training phases, and (c) their statements to express their satisfaction towards the program's positive results.

Effectiveness of Work Environment

Research Question 1 focused on mentor support because many studies found that novice teachers need mentors to facilitate them with vast arrays of development to support difficult teaching (Hong & Matsko, 2019; Hopkins et al., 2013; Teemant et al., 2011; Vogt & Rogalla, 2009). Other factors that affected the effectiveness of the work environment were presented in Research Question 3.

Modeling

I modeled the teaching for Greg twice based on my journal records, but I did not model for Jen because I did see the needs. Greg reported that my modeling was very beneficial in the post-interview. On the first day, I stepped in and modeled how to launch the PBL by introducing the six child cases in detail to students when Greg only briefly mentioned the cases. Later, when Greg was quarantined teaching online at home, I modeled how to give students feedback and address the work progress to the whole class by showing the class exemplary student work and works that were lacking.

Feedback

Both teachers thought my frequent feedback of their improvements was very helpful in the post-interview. Greg attributed the success of his PBL implementation to my support, “I’m not alone. I like your feedback.” Jen enjoyed having someone to “bounce ideas off and be able to discuss things throughout the whole process.” Jen gave two examples that she appreciated a lot. One example was when she was about to abandon the virtual museum due to the pressing final week of the semester, I recommended that she use the virtual museum as bonus work for students, which resulted in five out of six groups producing the work. Another example was when she reached out to me when designing her own PBL in Phase 4. She was going to have students present in class for the social movements so I encouraged her to empower students to present their work through social media to advocate.

Availability to Support

I provided a wide array of supports for both teachers. For example, I supplied a facial mask to Jen when I saw she had difficulty breathing while giving instruction due to wearing a cotton mask. When she was stressed by the school’s new task that she had to drill the reading passages from the state standard test, I sought support from the department chair and provided materials and strategies for Jen. Hence, Jen perceived the mentor as very supportive. She commented in post-interview:

> You were always available when I had a question, a concern. Not just for PBL, also for me as a teacher and peer; you were just available. That really, really, [emphasized] helped. It helps me build confidence and want to understand.

Greg attributed the success of his PBL implementation to my support, "I'm not alone …" In addition, when both teachers were quarantined at home at different times, I volunteered to be the substitute teacher in the classroom during my conference period, which the two teachers appreciated very much.

RQ2: How Do Teachers' Perceptions Towards PBL Change During the Training Program?

Research Question 2 focused on each participant's perception change regarding PBL, especially their understanding of PBL pedagogy and belief in PBL teaching and student learning in PBL**.** To capture the perception transformation over the timeline of this training, three time points were selected: before the training, at the mid-term of the training, and after training. Table 9 presents an overview of each participant's perception transformation of the three time points during this training. Each perception change is elaborated following the table.

Table 9

An Overview of Each Participant's Perception Transformation During This Training

		Before the Training	At the Mid-Term of the Training	After the Training
Greg	Understanding of PBL pedagogy	• Understood the concept of PBL	• Understood how content can be presented via PBL	• Understood better about backward design

(*table continues*)

Table 9 (*continued*).

		Before the Training	At the Mid-Term of the Training	After the Training
	Belief in PBL teaching	• Teach foundational knowledge first	• Same belief, but more open to PBL. • PBL should be separated from content-teaching.	• Subjects like physics and history need to be taught via PBL.
	Belief in student learning in PBL	• Doubted younger student's maturity to handle PBL	• Same belief	• Same belief
Jen	Understanding of PBL pedagogy	• Had a misconception that PBL was about having a product at the end of the unit.	• Understood that PBL is more about process • Understood the importance of a careful design	• Understood the importance of careful design.
	Belief in PBL teaching	• Doubted whether PBL can cover all TEKS.		• Believed that PBL can cover all TEKS.
	Belief in student learning in PBL	• PBL encourages deep learning. • Students retain knowledge better.	• Understood how PBL can support student learning for different levels of students.	• Students can make a difference in their community.

Greg's Perception Transformation

Greg's perception transformation was examined in two areas: (1) understanding PBL pedagogy and (2) belief in PBL teaching and student learning in PBL.

Understanding of PBL Pedagogy

Greg demonstrated his change in understanding of PBL pedagogy, particularly in how the content-teaching was presented by PBL design. Before the training, in the pre-

interview, Greg claimed that he did not know PBL. Still, he understood the concept of PBL in terms of engineering procedures because his undergraduate courses in engineering involved him doing a semester-long project. He highlighted his understanding of PBL pedagogy after going through the co-design phase and 3.5 weeks of PBL implementation. In the mid-interview, he said, "My impression previously was that the students need to gain knowledge so they will do the work. Right now, it's more of them gaining knowledge through the work. I see the benefits."

This change occurred because of Greg's involvement in co-design and the facilitation of the management documents. I observed Greg's excitement whenever he talked about how organized and beneficial the management documents were, based on my journal and through mid- and post-interviews and in the reflection session after Phase 3. Greg fully understood the backward design after the practice of PBL design on his own after Phase 4. In the post-interview, he said: "When I started with the timelines and working backwards, I did not understand very well in the beginning, but I think now, presenting the final event first, then working backward is very helpful." Greg attributed this clear understanding of backward design to the opportunity to practice his own PBL design. He said he could think on his own and explain things better.

Belief in PBL Teaching and Student Learning

Greg initially had a conflicting view between content-teaching and PBL teaching, but his belief regarding PBL teaching changed to be more positive and accepting as the training proceeded. While Greg at first believed that content teaching should be done separately from PBL, after the training, he transformed his belief that some subjects' content can be taught using PBL. However, his pessimistic view about student learning in

PBL remained the same throughout the training.

Greg described himself as “a little bit old-school” in the pre-interview and reflection after Phase 1. He did not think that subjects like mathematics can be taught using PBL because he believed students need to understand the foundational concepts before leveled up by PBL. In the mid-interview, Greg still held the content-oriented belief: “My biases are always towards having students know that information before me as an instructor. I need to instruct them first and then provide the opportunity for them to research.” However, he claimed that he was open to PBL, and still had reservations whether PBL was a better way to teach because he doubted whether younger students were mature enough to handle PBL.

When Greg was asked to reflect on his change after the PBL implementation in the reflection session over the teaching change environment, he still did not see his class success. Holding the same belief that teachers should teach foundational knowledge first, as stated before, he thought that PBL should be taught on Fridays and foundational knowledge should be taught from Monday to Thursday. Yet, he claimed that he saw the benefit of PBL because some groups were engaged, and he appreciated PBL more.

After independently designing PBL, Greg’s belief transformed from content-oriented to using PBL for some subjects. In the post-interview conducted after the independent design, he claimed that he still could not see how the subjects which require more practice in mathematics, writing, and reading can use PBL unless someone shows him. He believed that subjects like physics and history have to be taught via PBL, and teachers can be trained to teach these subjects via PBL. Greg’s transformed belief triggered by the practice of independent PBL design which allowed him to link the

previous co-design experience and experience in PBL implementation to his new design context. In the post-interview, Greg emphasized the benefits of this practice stating: "It gives me the time and opportunity to do correctly. Things are a lot clearer once I get to practice it independently and I do all those things on my own. Again, I appreciate it more."

While Greg's belief in PBL teaching was transformed, his belief in student learning through PBL remained the same throughout the training. He consistently expressed his doubts about younger students' capability to do PBL and was frustrated with managing student disruptive behaviors. For example, Greg commented in per-interview: "It was challenging because they are sixth graders. Are they mature enough to be grouped to handle PBL?" In the mid-interview, Greg reflected: "Even though they are still a little bit young to do group work, I definitely see some groups work." In a reflection session after the implementation phase, Greg said: "This is a lot more, a lot more than what they expected to do …If they are older, they will be able to manage it."

Jen's Perception Transformation

Jen's perception transformation was examined in two areas: (1) understanding PBL pedagogy and (2) belief in PBL teaching and student learning in PBL.

Understanding of PBL Pedagogy

Jen demonstrated her change in understanding PBL pedagogy, particularly in her misconception about PBL's end product and the importance of PBL design. After the training in Phase 1, in the reflection session, Jen confessed her misconception that she thought PBL was about having students produce a product at the end of unit learning, but it was more about the process. In the post-interview, Jen emphasized her realization

again: “I have learned that it’s not just about the product. That’s not the goal. It’s just a part of the process. It’s the process of learning throughout the whole time that you're given.” This understanding change was developed through the co-design process' involvement with backward design, which started from a driving question that drove students to research and develop towards the product.

Jen also understood the importance of a careful design for a project. Going through the co-design phase, Jen recognized in the reflection session after Phase 2 that her Friday project co-taught with three other teachers at that time was not a true PBL because they did not plan the entire project ahead of time; instead, they quickly came up with a weekly plan. She understood that an authentic PBL required abundant time to design before the implementation. This understanding change occurred because Jen felt less stressed about the daily or weekly plan. Once the design was accomplished, she could enjoy learning with students, which she mentioned tin mid-interview:

> I think it will be very beneficial for the teacher, because you put a lot of work into PBL in the beginning, later on when you implement it, you get to enjoy their learning process, not as much work during the PBL. I started enjoying this PBL.

She emphasized the importance of PBL design again in the post-interview:

> I enjoy the fact that even though it took a long time to set up. I say long time, it didn't really take a long time. A week, it seems like a long time when you put it in a week. But in a week, I got almost 8 weeks’ worth of work done. That part makes it enjoyable. During those times, I can either be thinking ahead or be tweaking what we are doing. That part excites me and makes me want to continue. I don't have to worry about every day what I have to do tomorrow and

what we need to do tomorrow.

Belief in PBL Teaching and Student Learning

Jen strengthened her belief in PBL's influence on student learning. In the pre-interview, she believed that PBL encouraged deep learning and it could help students retain knowledge because her daughters had a positive learning experience in this STEM school. In the mid-interview, Jen said that she had a stronger belief in PBL's influence on student learning because she understood better by seeing the positive student learning outcomes in the PBL environment in her classroom. She elaborated her understanding of how PBL supported student learning in the post-interview, "The lower-level students can explore on their own and learn from their peers, which is a huge plus; the higher-level students have the opportunity to build more knowledge for a deeper understanding." During the independent PBL design, Jen researched how younger students impacted the world and she realized that younger students can make a difference to their community. Hence, she allowed students to present the final presentation to the public via social media instead of only presenting to the class. In the post-interview, she said that students can get inspiration and make a difference to their community. Throughout the training, Jen's belief of student learning in PBL was strengthened.

Jen's belief in PBL teaching transformed from doubting whether PBL can cover TEKS to believing it after the training. She reported this transformation in the post-interview that she had doubts that PBL could cover all the TEKS that students needed to learn. After the training, she was convinced that PBL could cover the state academic standards. She explained that this belief transformation was attributed to the backward

design, which required the teacher to design lesson plans from mapping academic standards (such as TEKS) to the design of activities and assessments based on the standards.

RQ3: What Are the Factors Associated with the Successes and Challenges of the Training Program?

Research Question 3 examined the factors associated with the successes and challenges of the training program. Four factors were found in the component of trainee: (1) teacher belief, (2) classroom management, (3) time in participating in the training, and (4) teacher workload. Three factors were found in the component of training program design: (1) the design of progressive phases, (2) the design of management documents, and (3) the time to implement the training. Five factors were found in the category of trainee's work environment: (1) the impact of COVID-19, (2) organizational support, (3) mentor support, (4) peer support, and (5) the pressure of the state standardized test. Table 10 presents an overview of the factors within three components associated with the training program successes and challenges. Each factor is elaborated following Table 10.

Table 10

An Overview of the Factors Associated with the Successes and Challenges of the Training Program

	Trainee	Training Program Design	Work Environment
Factors associated with the success of the training program	1. Teacher strong belief towards PBL teaching and student learning in PBL 2. Having classroom management skills	1. The design of progressive phases 2. The design of the management documents	1. School support on allowing teachers to have the time and freedom to use PBL 2. Mentor support 3. Peer support
Factors associated with the challenges of the training program	1. Lack of classroom management skills 2. Teacher weak belief towards PBL teaching and student learning in PBL 3. Time constraint to participate in training 4. Heavy workload	1. Time constraint to implement the training	1. Difficult to engage online students due to COVID-19 2. Difficult to teach online at home due to COVID-19 3. Student absence and tardy due to COVID-19 4. The absence of substitute teachers in the classroom 5. School's lack of providing sufficient training 6. The pressure of a standard test

Factors Associated with the Successes and Challenges in the Component of Trainee

Four factors were found that were associated with the successes and challenges of the training program: (1) teacher belief, (2) classroom management, (3) time in participating in the training, and (4) workload.

Belief

I found that positive belief in PBL teaching and student learning in PBL was associated with the training success. Negative belief in these two areas was associated with the training's challenges. Teacher belief is a strong indicator of how well teachers implement inquiry-based learning (Haney et al., 1996), including PBL. Greg consistently expressed his doubts about younger students' capability to handle PBL. His belief about students' ability might have been the reason that the driving question in his independent PBL design was at a lower level, and the final student presentation was limited within the classroom. This belief seemed affected by his lack of skill in classroom management as well. Greg also believed that teachers should teach foundational knowledge first before using PBL; this belief was in line with his practice when he designed his own PBL independently, and designed a two-week project that focused on the foundation knowledge, named "what is an engineering project?" Because it was a short project, Greg was not able to use all design elements. Although Greg became gradually open to PBL, as he claimed, he showed some resistance to my feedback during the implementation phase.

Compared to Greg, Jen had a strong, positive belief towards PBL teaching and student learning in PBL because she had seen positive learning outcomes in PBL from her daughters before the training and her students during PBL implementation. Spillane et al. (2016) stated teachers' belief about teaching and student learning affects teachers' instructional practice and reform initiatives. Jen was very proactive, beyond my expectations, using her own strategies to monitor and management student activities. For example, she bullet-pointed each day's key activities on the whiteboard and also recorded

student names on is to remind them of missing assignments. She always immediately took my advice and acted upon them promptly.

Classroom Management

Having the skill of classroom management was a factor associated with the training success. In reserve, lacking the skill of classroom management was a factor associated with the training challenge. Greg expressed his struggles in the classroom management many times. He confessed during interviews and reflection sessions that he did not know how to discipline younger students, nor did he understand the behaviors of sixth graders. Based on the observation, he had consistent difficulty managing and engaging students and lacking this skill made Greg frustrated and exhausted most of the time. For example, based on the field notes, Greg addressed some students' misbehavior issue several times every day. Soon after, the same behavior patterns reoccurred without given a consequence. During a reflection in the phase of PBL implementation he claimed, "I did not see success in my class. I see successes in other classes, just not mine." Jen was better at classroom management. For example, based on the filed notes, Jen started the class by stating the lesson objectives every day and engaged students by actively monitoring and inquiring them. She was also consistent to deal with student behaviors and established a system to reward students. Indeed, the learning environment that Jen established for PBL implementation was better compared to Greg. Consequently, based on my observations, overall student performance in Jen's classroom seemed better than in Greg's, especially considering the PBL implementations as most students in Jen's class showed as staying on task with less misbehaviors, while Greg's class showed half or less than half students off-task with more misbehaviors.

Time Participating in the Training

Time constraint to participate in the training was a factor associated with the training challenge. In Phase 1, Greg and Jen both went through the training on foundational PBL knowledge for 1.5 hours. In Phase 2, I involved Greg to co-design for 9.5 hours and Jen for 6.5 hours. However, they lacked more training hours to complete this phase: I spent additional eight hours for Greg and 12 hours for Jen. In Phase 3, a 15 days' implementation, I monitored each teacher for about 40 minutes' implementation as on-job-training. The total on-job-training time for each participant was 10 hours. Also, the reflection on the daily lesson, the learning in each phase, and the model of teacher change environment was part of the training. The total reflection time for each teacher was three hours. In Phase 4, Greg spent about 16 hours for his independent design and Jen spent about 40 hours. To sum up, Greg' total training time was 40 hours while Jen's was 61 hours. Table 11 presents the training hours for each teacher for each phase.

Table 11

Training Hours of Each Teacher Participant

	Greg	Jen
Phase 1	1.5 hours	1.5 hours
Phase 2	9.5 hours co-design time	6.5 hours co-design time
	8 hours lacking	12 hours lacking
Phase 3	10 hours on-job-training	10 hours on-job-training
	3 hours of reflection time	3 hours of reflection time
Phase 4	16 hours	40 hours
Total Training Time	40 hours	61 hours

A study by Van Veen et al. (2011) claimed that teachers need to change their behavior from 14 to 80 hours in a training. Both teachers overnumbered 40 hours. Still, Phase 2 was designed to fully involve the teachers in co-designing the project but I had to spend additional significant amount of time besides our co-designing time because they were already stressed and fully occupied by teaching, grading, and other school duties. Several times during Phase 2 training, the teachers had to leave the meeting because of their family needs. Greg expressed his lack in understanding the co-design process: “My success hasn't come up yet. Can I learn this? Can I implement it correctly? How can I make it my own? That’s my goal. I'll be successful if I understand and make it my own.” Therefore, insufficient time to participate the training affected the teachers’ understanding of PBL, which was a factor associated with the training challenges.

Workload

Along with the time constraints, the teachers’ heavy workload was a factor associated with the training challenge. Greg mentioned to me several times throughout the data collection that he struggled with three teaching preparations (i.e., financial planning for 12th grade, engineering for 12th grade, and engineering for sixth grade). Greg said in the mid-interview: “

> Because I lack time and lack experience, so I didn’t provide the information and resources to students. We're moving so fast. This is not my only subject. I don't have enough time to put in the amount of effort that I need.

Besides the co-designed PBL, Greg reported that he had to spend extra time after school and on weekends for other teaching work. On the contrary, Jen who had two teaching preparations (i.e., social studies and English) before this training reported in the mid-

interview that PBL eased her workload because it integrated two subjects that she had taught, which gave her passion and drive back. Still, Jen worked late almost every day based on my field notes. To take the workload off them, I took the lead in the co-design phase and spent a significant amount of time designing the PBL for them; both of them appreciated it.

Factors Associated with the Successes and Challenges in the Component of Training Program

I found three factors associated with the successes and challenges of the training program: (1) the design of the progressive phases, (2) the design and use of management documents, and (3) time to implement the training.

The Design of the Progressive Phases

The design of four progressive phases was the factor associated with the s training success. The four-phase-design of the training was adopted from the three-phase design that Kali et al. (2018) developed, and I added the fourth phase based on the principle of learning transfer stated in Chapter II. Greg commented the design was “seamless,” while Jen complimented my design and training, “They are wonderful steps; I think I learned a whole lot, and you did a great job training us through these phases.” With each different teacher role in each phase, teachers developed their expertise on PBL in a progressive manner, which were described in depth in the component of the training program design in Research Question 1.

The Design and Use of the Management Document

The design and use of the management documents were the factor associated with the training success. Both teachers consistently expressed their excitement and

appreciation throughout the training about how the management documents helped them manage PBL. The management documents included a graphic organizer of the timeline, a Google Doc of group organizer, a Google Doc of student personal workspace, the Google Site of narrowed teaching scope, and PowerPoints of preliminary planning. Greg mentioned several times that he was not an organized person, and this organizational system was structured very well. He would adopt the documents for future teaching content. Greg highlighted the use of a timeline that facilitated him to stick to the time. Jen also addressed her appreciation for the timeline because it helped both students and the teacher have better time management. Besides the timeline, Jen also appreciated the Google Site because it helped her narrow down the broad teaching content from the curriculum.

Time to Implement the Training

Time constraint to implement the training was the factor associated with the training challenge. This program was initially planned for a six-week-long PBL. Because of multiple reasons, the length of PBL was shortened to 3.5 weeks. This made it difficult for teachers to see the development in student learning and the planned student activities had to be fastened. Jen gave her feedback to the training program in the post-interview: “I learned a lot but I just feel too fast.” Both teachers thought that one-year mentoring like this would be perfect. Jen also expressed her need during the post-interview to “have more time” for six times in every way: more time in learning PBL, more time in co-designing, and more time practicing PBL.

Factors Associated with the Successes and Challenges in the Component of Work Environment

Five factors associated with the successes and challenges of the training program were found: (1) the impact of COVID-19, (2) organizational support, (3) mentor support, (4) peer support, and (5) the pressure of the state standardized test.

Education Context

COVID-19 was a significant factor associated with the training challenge. First, the teachers found it difficult to engage online when about 15% of the students stayed home due to COVID-19. Greg stated several times that engineering class needs students to come to school and do projects because he thought that students were required to design hands-on products and the teacher could better facilitate. Greg's solution was to allow students to design products online using a 3D-designing tool named Tinkercad. Both teachers reported that it was difficult for students to collaborate, especially when they had students online and on-campus. Jen said the online students tended to be singled out by the on-campus students. Both teachers expressed their struggles engaging online students because some students did not respond to the teacher's questions, some students' voices were lagging, and some had trouble with technology issues.

Second, both teachers found it difficult teaching online when they were quarantined at home and had to teach via Zoom due to a closer COVID-19 exposure. Jen had been quarantined for six school days since the PBL was launched. Greg stayed home for three days one week before the PBL ended and returned to campus once he tested negative. Both teachers felt very frustrated teaching online at home because students still were confused even though the teacher repeated the instruction multiple times. Jen

expressed her frustration in mid-interview, “I can’t see if they are actually doing work...That part is challenging. Showing them on Zoom is so much different from guiding them and showing them in person. If I was there, I could explain better.” She also recognized that the teacher’s presence in the classroom was extremely important, which was the key to implementing PBL and building the classroom culture.

Third, student absences and tardy in the classroom was another problem due to the impact of COVID-19. Both teachers reported that they had several students who did not show up for the Zoom meetings. A handful of students showed up irregularly, which made it very challenging for teaching and group collaboration. There was an inconsistent student number returning to the campus, switching the learning mode. These students did not know much about the project because they missed instruction, so the teacher struggled to help them adjust to the new learning environment and catch up with the work.

Organizational Support

The school’s lack of support in providing substitute teachers in classrooms was found associated with the training challenge. The school did not provide substitute teachers while both teachers were teaching at home due to Covid-19. The absence of substitute teachers in the classrooms made it extremely difficult to manage student behaviors in the classroom, which was associated with the training program’s challenges. When Jen was teaching at home for six days, there was no substitute teacher in the classroom for five days. Most students produced very little work during these days.

The school’s lack of sufficient training was also found associated with the training challenge. There was no basic training such as classroom management, in which Greg

struggled the most. The training on PBL in the summer before the school started was only 2.5 hours, “quick and dirty,” as Jen described. The lack of sufficient training to prepare novice teachers was the factor related to the training challenge.

The school’ support on allowing teachers to have time and freedom to use PBL was found associated with the training success. Both teachers rated the school’s support a five in the pre- and post-questionnaires. Greg said, “It is a PBL school, and we are supported to teach PBL.” Jen acknowledged the school’s support in terms of giving teachers time to plan for Friday’s PBL.

Mentor Support

Mentor support was a factor associated with the successes of the training program. In the section of Research Question 1, mentor support was described in detail. Greg attributed the success of PBL implementation to the mentor support, “I’m not alone … You gave me the tools.” He also appreciated that I spent a significant amount of time leading the co-design phase, which took the burden off him.

Peer Support

Peer support was a factor associated with the successes of the training program. Both teachers liked to have someone else going through the same training with them. They both felt it easier to have someone to talk to and ask what worked and what did not work for them and share ideas.

Standard Test Pressure

The pressure of the state standardized test was a factor associated with the challenges of the training program. In the middle of the implementation phase, the principal required Jen to drill the reading passages and prepare students for the state

standardized test. Under this pressure, Jen had to give up designing a PBL that integrated two subjects for the independent PBL design.

Chapter Summary

Overall, the two teachers perceived the training program to be effective because they (1) gained knowledge on PBL pedagogy, PBL design, and PBL implementation; (2) changed their belief in PBL teaching, (3) increased self-efficacy to use PBL, and (4) demonstrated the application of the design and teaching elements. Both teachers rated the program with high ratings and perceived the training design to be beneficial, and their expectations were met entirely. Also, they valued the mentor's availability to support in modeling and giving feedback during the training.

The two teachers' perceptions of PBL evolved through the training program regarding their understanding and belief. Greg started understanding how content can be presented by PBL in the co-design phase and fully understood the backward design after the independent design phase. He had a conflict between content-teaching and PBL teaching but transformed to using PBL for some subjects while believing that student maturity remained the same. Jen understood that PBL was process-oriented instead of product-oriented at the beginning of the training. Later, she became aware of the importance of PBL design. Jen transformed her belief in whether PBL can cover state standards because of her involvement in PBL design. In the meantime, Jen's belief in student learning in the PBL environment was strengthened that PBL can support student learning after seeing positive evidence.

Twelve factors were found that were associated with the successes and challenges of the training program. Four factors were found in the component of trainee: (1) teacher

belief, (2) classroom management, (3) time in participating in the training, and (4) teacher workload. Three factors were found in the component of training program design: (1) the design of progressive phases, (2) the design and use of management documents, and (3) the time to implement the training. Five factors were found in the category of trainee's work environment: (1) the impact of COVID-19, (2) organizational support, (3) mentor support, (4) peer support, and (5) the pressure of the state standardized test.

CHAPTER V

DISCUSSION

The quantity and quality of K-12 STEM teachers play an important role in preparing U.S. students for academic and career pathways in STEM (Wilson, 2016). STEM education often incorporates PBL in either a single STEM subject or in interdisciplinary STEM subjects (Corlu et al., 2014). However, STEM teachers have difficulty understanding PBL, designing, and implementing PBL (Aldabbus, 2018; Ertmer et al., 2014; Lesseig et al., 2016). It is urgent to provide STEM teachers with a quality training program in PBL.By identifying the effective design elements of a teacher training program in PBL pedagogy, PBL design, and PBL implemenation as well as the factors assosiated with the successes and challenges of the training program, the PD designers and teacher educators will have more successes to prepare quality STEM teachers.

This exploratory case study explored the effectiveness of a designed PBL training program through two middle school STEM teachers' perceptions. In particular, the purposes of this study were to (1) identify the effective design elements in a teacher training program to understand PBL pedagogy, PBL design, and PBL implementation in STEM classrooms and beyond; (2) find out how the training affects classroom teachers' perceptions towards PBL; and (3) identify the factors associated with the successes and challenges of this program. Training was implemented over 10 weeks, throughout which I collected multiple sources of data and analyzed based on a framework developed from the literature by using deductive and inductive coding. The findings of this study demonstrated that (1) the progressive four phases and management documents were the

effective design elements of the PBL training; (2) the use of content-focused practice deepened teachers' PBL knowledge and formed their belief about the training, which contributed to the change of teacher perceptions towards PBL; and (3) twelve factors such as teacher belief, classroom managements, workload, and mentor support were found most strongly associated with the training successes and challenges. This chapter discusses the meaning of this study's findings and their implications and limitations.

The study's findings related to the training's perceived effectiveness suggest that the overall successes of this training program lie in two design elements as noted by the two teacher participants: (1) the progressive design of the four phases, and (2) the design and use of management documents. The first design element comprised four phases that scaffolded teacher growth by assigning them progressive roles. The two teachers' role in Phase 1 was as a learner. They found that the video cases at three different grade levels (i.e., kindergarten, middle school, and high school) helped show how PBL was implemented, and identify the seven design elements. In Phase 2, the two teachers' role was as co-designer. They did not know how to design PBL until they were exposed and involved in the co-design process. Greg noted the necessity of the mentor's leading role in explaining how PBL was structured. However, the two teachers' learning was constrained by their work schedule in Phase 2, which limited their involvement, possibly impeding their complete understanding of the PBL design. To reduce the teachers' workload, Phase 1 and Phase 2 can be moved to summer training and mentors can follow up with Phase 3 and Phase 4. Furthermore, the teachers might have felt a lack of ownership for the project because I was the principal designer. Although teachers' lack of ownership was rectified in the fourth phase of independent design, it is recommended that

novice teachers' involvement in the co-design process be maximized so that they can better understand the PBL design. The two teachers' role in Phase 3 was as enactor. Both teachers recognized the importance of going through this phase because they understood better the PBL pedagogy and PBL design by implementing it. Jen noted that "Experiencing the knowledge is different from knowing the knowledge." The fact that Greg struggled with classroom management during this phase demonstrated the importance of acquiring this skill before undergoing PBL training. If the classroom management training and PBL were performed concurrently, it might overly stress the novice teachers. The two teachers' role in Phase 4 was as independent designers. Both teachers recognized the importance of this phase because they had the opportunity to apply what they learned in the previous phases to the new design context. The independent phase is critical to transition a teacher from co-designer to independent designer, leading to their role as independent enactors in the next phase. Phase 4 allowed the teachers to have a complete ownership for their PBL design. Being able to design PBL on their own increased the teachers' self-efficacy (Bandura, 1997). Noticeably, Greg's belief in PBL teaching was transformed after the Phase 4. Therefore, each phase was found designed effectively to scaffold the novice teachers' growth because novice teachers need scaffolding to learn new pedagogies (Ertmer & Simons, 2005).

The second design element assisting the successes of the training program was the design and use of the management documents (i.e., a graphic organizer of the timeline, Google Doc of group organizer, Google Doc of student personal workspace, Google Site of narrowed teaching scope, and PowerPoints of milestone planner for preliminary planning). The milestone planner was perceived as effective in organizing preliminary

lesson plans for several weeks ahead without overwhelming the teachers. Upon refining the lesson plans, the timeline was utilized as a powerful tool to facilitate time management for the teacher and students. The personal workspace was also perceived as an effective tool to assess individual student work. Both teachers appreciated using the management documents intended to serve them as templates for their future PBL design, and avoiding the struggle of not being expert designers. The training program was perceived effective as it provided the teachers with management documents during the co-design phase. This finding supported by a study by Knight-Bardsley and McNeill (2016) claimed that the design process must encourage teachers' participation by providing a significant amount and variety of resources. Mentors and the designers of TPD are recommended to provide sufficient materials and tools to enable better training results.

The study's findings regarding Greg and Jen's perception changes towards PBL also suggest that practice in PBL design and implementation played the most important role in those changes. It also interacted critically with the two teachers' knowledge and belief in PBL. Greg and Jen understood the backward design further when they actually practiced designing on their own. Jen believed that PBL can cover state standards through backward design, while Greg believed that some subjects can use PBL after the practice of an independent design. Therefore, the practice deepened their knowledge of PBL and promoted changes in beliefs. This finding supports the claim by Spillane et al. (2016) that it is important to provide teachers with learning opportunities to change their knowledge, practice, and belief. The PBL knowledge provided in Phase 1 was implicit to the teachers. In the implementation phase, the PBL knowledge in Phase 1 became explicit by

enacting it through practical application. Likewise, in the independent phase, the implicit knowledge of PBL design in the co-design phase became explicit through the teachers' applying it to a new setting. Thus, the practice was the catalyst to activate teacher's PBL knowledge from implicit to explicit, a relationship supported by other studies (e.g., Black-Hawkins & Florian, 2012; MacDermid & Graham, 2009). Throughout their practice, the two teachers saw positive or negative evidence of student learning, which contributed to their optimistic or pessimistic belief in the pedagogy (Clark & Hollingsworth, 2002; Guskey, 2002; Zambak et al., 2017). For example, Greg's deficiency in the practice of classroom management contributed to negative student outcomes and student outcomes were closely connected with teacher performance. Seeing negative student outcomes may affect his self-efficacy in using PBL based on performance outcomes as one source of Bandura's self-efficacy. Seeing negative student outcomes also might have led to his pessimism about student maturity to handle PBL. Indeed, Jen had less struggles in the practice of classroom management, which allowed better student outcomes. Seeing positive student outcomes reflecting teachers' proficient teaching (performance outcomes) might have boosted Jen's self-efficacy in using PBL and may have led to her optimistic belief that PBL can promote student learning. The reverse was also true: teacher belief contributed to their intention to implement a nontraditional pedagogy like PBL (Anderson, 2002; Lotter et al., 2007). Greg's content-oriented belief was evident throughout the training, while he also became more receptive to PBL because he saw some positive evidence of student learning in his classroom. This belief might have led to the way he designed his own PBL that focused on *foundational knowledge* (the driving question was: *What is the engineering process*?), incorporating

partial design elements. Greg's doubts on student maturity to handle PBL might also have kept him from allowing students to give the final presentation beyond the classroom. By contrast, Jen's strong belief in student learning in PBL allowed her to empower students to present their final products beyond the classroom. To summarize, the two teachers' knowledge of PBL pedagogy deepened by *using* PBL, which then affected their belief in PBL. In return, the teachers' belief related to PBL affected their approach in PBL practice, which further enriched their knowledge of PBL. Figure 5 presents the essential role of PBL practice in this case in interacting with knowledge of PBL and belief in PBL to change teachers' perceptions.

Figure 5

The Essential Role of PBL Practice in Changing Teacher Perceptions during PBL Implementation

I also found four factors closely associated with the training program's successes: (1) teacher belief, (2) classroom management skills, (3) teacher workload, and (4) mentor's support. As stated above, belief affects teacher intentions to implement PBL (Anderson, 2002; Lotter et al., 2007). Among the factors, classroom management was associated most closely with the successful implementation of PBL for novice teachers. Greg lacked classroom management skills to an extent because he neither had any classroom management training before this PBL training nor had mentors help him in

class to build the skill. During the implementation phase, Greg often looked exhausted by the end of the school day after teaching the last three class periods for six graders.

According to Bandura (1997), emotional and physiological state is one source of self-efficacy. The exhaustion and stress in managing students could decrease Greg's self-efficacy in using PBL. Maybe this is the reason that towards the end of the project, he gave up managing students a couple of days and let them freely draw as a break. Unlike Greg, Jen kept using a loud voice all the time to give instructions and bring student attention, which made her voice hoarse for days. Compared to Greg, Jen was better at classroom management even though she was a first-year teacher. Perhaps because Jen underwent a traditional teacher education program, this prepared her with general pedagogy knowledge (GPK) while Greg did not. Teacher education programs have been around since the 1980s seeking to prepare teachers for a significant knowledge base, including GPK (König et al., 2011; Pinchas. 1988; Shulman, 1986; Wang et al., 2011). Jen undertook two years of a teacher education program and two years in multidisciplinary studies without student teaching. Although she did not think that the teacher education program prepared her for PBL teaching, instead only provided her with scenarios of teaching and asked her to create a couple of short lessons, the difference between Jen and Greg managing the classroom demonstrated a possible factor that going through a teacher education program made a difference in the classroom management. Indeed, classroom management is ranked one of the top struggles for novice teachers (Voss et al., 2017), which impedes them to teach effectively and positively assert their authority in the classroom (Hirsch et al., 2019; Westling, 2010). The lack of classroom management skills drains novice teachers' emotional resources (Voss et al., 2017), and

they become exhausted and fall into a negative emotional state. Subsequently, this emotional drain and negative state affect teachers' classroom behaviors, which lead to poorer classroom management (Klusmann et al., 2008b). Schools are recommended to assign mentors to novice teachers in nurturing them towards building classroom management skills. When the mentors are not available, novice teachers are recommended to observe master teachers' classroom teaching to learn how other teachers successfully implement PBL. As Bandura (1997) identified vicarious experiences as one source of self-efficacy, observing other proficient teachers can increase novice teachers' self-efficacy in using PBL. For example, both teachers observed from me how to design PBL in Phase 2, which increased their confidence in using PBL, as they reported in the mid-interview.

Teacher workload is another factor affecting the program's success. Both teachers had a heavy workload. As a second-year teacher, Greg taught three subjects in the first year and another three new ones this year. Jen, as a first-year teacher, taught two subjects. During the training, Greg still had to prepare the other two subjects besides the PBL while Jen enjoyed the interdisciplinary PBL for less workload comparatively. Greg confessed in a reflection session that he had no time to give student assessment feedback due to the heavy workload. Conversely, Jen appreciated that the interdisciplinary PBL, which integrated her two teaching subjects, reduced her time specifically in planning and grading. She said in the post-interview that she worked not as late as before the training because of the reduced workload. Still, both teachers noted that they worked three to four hours after school and 12 hours on the weekends. Due to their heavy workload and time constraints, they were not fully involved in Phase 2, which might have impeded their

understanding of the PBL design. Voss et al. (2017) found that higher teacher workload caused more emotional exhaustion and burnout; these were rated the top two reasons leading to teachers' resignation, followed by the top one reason that teachers are not satisfied with their pay, reported by Phi Delta Kappa (PDK) International Association Poll (2019). To reduce workload, I recommend the schools to train teachers for Phase 1 and Phase 2 in the summer training before the school starts and follow up the teacher with Phase 3 and Phase 4. This way, teachers might not feel as overwhelmed by the school work while they undergo the training once the school starts. The mentor's availability in providing frequent feedback and sufficient support was another crucial element for this training program's success. Both teachers appreciated my frequent feedback and a wide array of support. They desired this mentorship to be longer, at least one year. Hong and Matsko (2019) found that novice teachers need mentors for their vast array of development in classroom management, pedagogy, and school and district policies. Especially, STEM teachers struggle with understanding their content in depth and teaching methods and strategies (Ejiwale, 2013; Hibpshman, 2007; Shernoff et al., 2017). Hence, it is more critical to nurture STEM teachers with mentor supports. Given these factors that are closely associated with the teacher training successes and challenges, STEM and other K-12 teachers can be better prepared with a teacher PD that provides novice teachers with experienced mentors who need to focus on transforming teacher belief, improving their classroom management skills, and reducing their workload.

The teacher participants had their own uniqueness, which made this case study more interesting. The personal differences might have played roles in shaping the

differences in their knowledge, belief, and practice of teaching. Greg was a relatively older teacher, close to 50 years with very limited teaching experience, while Jen was a younger teacher over 30s with very limited teaching experience. Greg may have been exposed to traditional teaching pedagogies for years when he underwent his education while Jen may have been exposed to less traditional teaching approaches as a younger generation. Both of them had alternative teaching certificates, although Jen underwent a teacher education program for four years while Greg did not. Jen might have gained GPK of classroom teaching from her teacher education program, which may have better prepared her in classroom management. Greg's teaching subject was in STEM while Jen's subject was in humanity. Engineering is more procedure-oriented involving more hands-on activities and problem-solving skills but may be more rigid while humanity subjects allow more room for creativity. Greg's personality was more casual, which might be the reason that he was less strict with students and had fewer organization skills. Contrarily, Jen was more structured, which might be the reason that she was stricter with students and had better organization skills.

Limitations

This study has several limitations to be discussed. First, because I did not observe how the teachers taught in their classroom before implementing the training, my needs analysis was limited by the data collected through pre-questionnaire only. I investigated the two teachers' expectations before the training as the needs analysis in the pre-questionnaire, which did not reflect their classroom management needs. If I knew that Greg had struggles with classroom management, I would prepare an action plan to better support Greg. Instead, I only gave him a few tips about managing students during the

training, which was not sufficient and adequate to make a difference. For future studies, a performed needs analysis should be added to understand participants' needs in practice.

Second, the findings and interpretations of this study may be limited to what I observed. I could not fully capture the context complexity during the limited time I interacted and built a rapport with the two participants. The complexity of the context contains (1) the data collection method of video recording was not allowed by the school, (2) my observation time was limited as a full-time teacher at the research site, (3) the PBL implementation time was shortened from six weeks to 3.5 weeks due to multiple reasons, and (4) the state test pressure interfered with the interdisciplinary PBL design for Jen. The relationship between the teachers and I grew more robust because the relationship was strengthened through the mentor providing consistent interaction and feedback (Moir, 2005). However, it was three months before a closer interaction. Martin et al. (2015) claimed that the mentor and the mentee's relationship impacts the mentee's openness to feedback. The relationship was not fully developed before the training, which might affect the teachers' acceptance of my feedback. In return, it might affect teachers' practice during the training. Therefore, building a stronger relationship before the teachers' training is recommended for mentors to maximize the training effectiveness.

Third, this study's findings were also limited to apply to a large teacher population because the sample size is too small, with only two teacher participants. Fourth, the training time might not be sufficient to fully prepare novice teacher's learning in PBL. As desired by the teacher participants, one-year-long mentorship could be ideal.

Implications and Conclusion

There are several implications of this study to be further discussed. First, the findings indicated that the teacher professional development on PBL needs to be carefully designed to facilitate novice teachers regarding classroom management, reducing workload, and practice empowerment. In particular, in terms of classroom management for PBL, novice teachers perhaps need to exercise on Simonsen et al.'s (2008) recommendations to set up routines and strategies in a physical arrangement in the classroom, posting teacher expectations, responding to inappropriate behaviors, and others.

Second, the study's findings also recommend that teacher educators must understand the roles and relationships among teacher knowledge, practice, and belief to design a meaningful teacher professional development. To help strengthen teacher belief in PBL, mentors are recommended to facilitate novice teachers to see positive evidence of student learning. To see the evidence, schools are recommended to support novice teachers by assigning them a long-term mentor for helping them build classroom management skills, providing frequent feedback, and a wide array of sufficient supports.

Finally, the study's findings indicated that similar studies can be conducted with the training design for more teachers teaching different subjects to further transfer the knowledge learned from this study to different contexts. One particular finding was interesting: Greg addressed that it is difficult to see how PBL is implemented in core subjects like mathematics, writing, and reading. Some study supported Greg's statement that some teachers struggled teaching mathematics through PBL strategy and it was a hurdle to jump (Rogers et al., 2011). Future studies should focus on two directions: (1)

design a PBL training for these core subjects like mathematics, and (2) design a PBL training focused on strengthening classroom management for novice teachers.

In conclusion, for STEM school and beyond, the reform-based pedagogies such as PBL aim to shift in teacher instruction beyond content-teaching. To enable the shift, a careful design in teacher professional development needs to scaffold teacher growth by providing the opportunities to practice in their own settings. Overall, the positive improvements in teacher understanding and practices of PBL teaching are heartening given the various barriers to reform-based instruction documented in the literature (e.g., Bauer & Kenton, 2005; Lakshmanan et al., 2011; Sandholtz & Ringstaff, 2014). Teachers specifically attributed opportunities for the active involvement of video case analysis, co-designing, PBL implementation, independent design, and receiving feedback from the mentor embedded within the PD as contributing to their improved understandings and practice. Designers of PD should take into consideration using these components to facilitate novice STEM and other K-12 teachers in overcoming barriers to implement PBL. All in all, novice teachers can jump the hurdle of PBL after going through an effective teacher professional development program.

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APPENDOCES

APPENDIX A

PBL FOUNDATIONAL KNOWLEDGE

Session 1

Introducing PBL

- Project-Based Learning: Explained (3:50). https://www.youtube.com/watch?v=LMCZvGesRz8

The History of PBL

- 16th-18th century, architecture in Italy
- Mechanical area
- Engineering
- 1880-1915, U.S. used PBL for manual training
- 1918, American educator William Heard Kilpatrick formulated the PBL method
- 1940s-1960s, flourished in Europe and Russia, then Israel
- Silent in 1960s-70s.
- Gained popularity since the 1980s to now.

Debunking 5 Myths About Project-Based Learning

(https://www.edutopia.org/blog/debunking-five-pbl-myths-john-larmer)

1. Not just projects, hands-on activity
2. Can teach content knowledge
3. Not just for older students
4. Too much time?
5. Too hard to change the teaching style?

What is PBL?

- Student-centered, inquiry-based approach
- PBL requires students to develop products or artifacts
- learners are engaged in a series of higher-level activities, including planning, searching for information, analyzing the information, and making products
- Sharing ideas and products with others for real-life applications
- More rigorous and extensive way to learn compared to *project* or *hands-on activities*

- Emphasize deeper learning and the development of skills needed for success in college, career, and civic life
- Use scaffolds to guide student learning, including teacher, peers, learning materials, and technology.

What is not PBL?

- Should be central, not peripheral to the curriculum
- Should be the main course, not the dessert
- Should be a process through which learning takes place, not the culmination of learning
- *Should guide the curriculum of an entire course, not just single, time-limited unit (some scholars think)*

Benefit of PBL

- Improving student learning outcomes
- Promote construction of knowledge, deep learning
- Increase student engagement and satisfaction/enjoyment
- Builds success skills for college, career, and life.
- Support collaborative learning
- Cultivate students to be independent researchers, high-order thinkers, and problem-solvers
- Connect students and schools with communities and the real world.
- *Makes teaching more enjoyable and rewarding.*

Challenges of PBL

- Lack of time to collaborate with colleagues
- Lack of access to technology
- Lack of training
- Lack of time to properly implement

Session 2

The seven essential elements of PBL design:

1. Challenging problem or question
2. Sustained inquiry
3. Authenticity
4. Student voice and choice
5. Reflection
6. Critique and revision

7. Public product

Session 3

Examples of PBL

1. Taking care of our environment—*Kindergarten* (10 minutes)
    a. https://my.pblworks.org/resource/video/taking_care_of_our_environment
2. Virtual library, *7th-grade social study* (7.5 minutes)
    a. https://my.pblworks.org/resource/video/march_through_nashville_project
3. Finance consultant: project-*high school math* (7.5 minutes)
    a. https://my.pblworks.org/resource/video/finance_project

APPENDIX B

TABLE OF SEVEN PBL DESIGN ELEMENTS

Seven Essential Project Design Elements	
Key knowledge, understanding & Success skills	**1. Challenging problem or question** (1) Neither too difficult nor too easy (2) The right challenge or problem puts students at the edge of their comfort zone (3) The open-ended question brings the inquiry into focus and leads to learning goals
2. Sustained inquiry (1) Ask questions (2) Conduct research (3) Carry out investigations (4) Weigh evidence (5) Arrive at answers Students can always ask themselves, "what do we need to know to answer the driving question?"	**3. Authenticity** Look for real-world connections, such as: (1) Context (2) Tasks that students undertake (3) Tools they use (4) Standards they refer to (5) Impact of their work Connections to student personal interests, concerns, values, culture, and convenience
4. Student voice & Choice Students make decisions and express and defend opinions throughout the project.	**5. Reflection** Students are prompted to think about their learning experience such as (1) Any obstacles they are facing (2) Challenges they have overcome (3) Quality of work they are producing
6. Critique & Revision Formative assessment to refine their products such as: (1) Teacher evaluation (2) Peer evaluation (1) Outside experts' advice	**7. Public Product** (1) Students are motivated to produce high-quality work when they know their efforts will have a real-world impact. (2) They can share their work in many forms, such as publishing [online or hard copy], public forums, pitch sessions, and demonstrations.

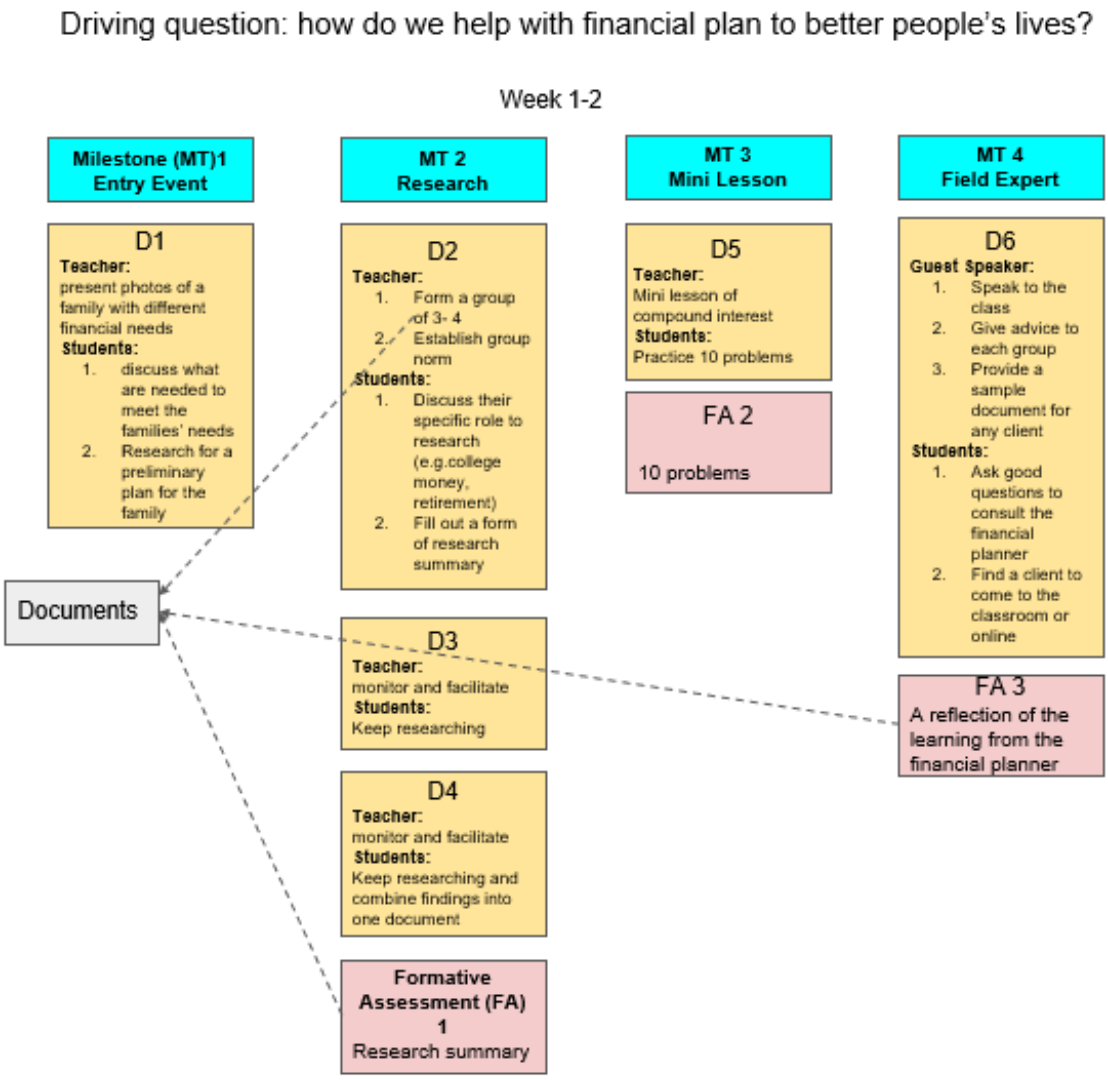
APPENDIX C

CASE ANALYSIS – PBL DESIGN ELEMENTS

	Case 1	Case 2	Case 3
1. Challenging problem or question **(Entry event to start)**			
2. Sustained inquiry			
3. Authenticity			
4. Student voice and choice			
5. Reflection			
6. Critique and revision			
7. Public product			

APPENDIX D

MANAGEMENT DOCUMENT – AN EXAMPLE OF PBL MILESTONE PLANNER ON POWERPOINT



APPENDIX E

MANAEMENT DOCUMENT – AN EXAMPLE OF GROUP ORGANIZER OF GREG'S CLASSES

(CASE 4, 5, 6 ARE THE SAME FORMAT AS CASE 1, 2, 3)

Case 1:Haley

1. Team Leader:
2. Technician:
3. Organizer:
4. Editor:

Personal Workspace:

1.
2.
3.
4.

Group Workspace:N/A

Group Meet Link/method:
Group zoom

Group Norms:
1.Follow the rules
2.Stay on task
3.Meet on Tuesday and Thursday 12:40-1:10 (during PLTW)

Consequences if anyone violates: Three strikes and we will ask for you to be

Case 2:Alex

5. Team Leader:
6. Technician:
7. Organizer:
8. Editor:

Personal Workspace:

1. (Make It accessible)
2.
3.
4.

Group Workspace:

Group Meet Link/method:
TRANDYN-5806497606
Zoom:
tVY05
QeWRQL0E1eURvQT09
Password: ndSh7D
]
Group Norms:
1.
2.
3.

Case 3:Daniel

9. Team Leader:
10. Technician
11. Organizer:
12. Editor:

Personal Workspace:

1.
2.
3.
4.

Group Workspace:

Group Meet Link/method:

Group Norms:
1.
2.
3.

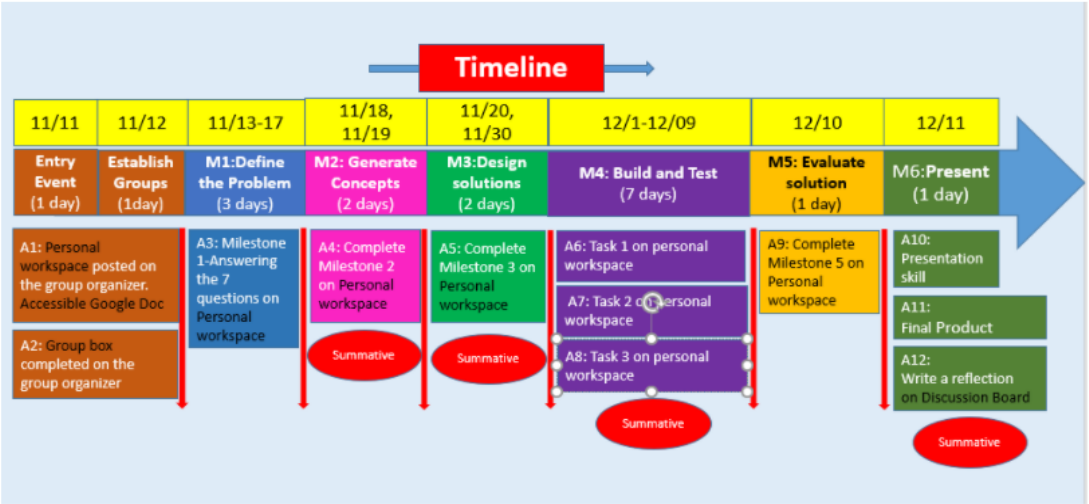
APPENDIX F

MANAGEMENT DOCUMENT – AN EXAMPLE OF PERSONAL WORKSPACE OF GREG'S CLASSES

PBL - Therapeutic Toy Design

Attention: Mr. Greg will give you 12 grades (A1 to A12) shown in the timeline. Grades will be assigned at the Summative check points. Late work will not be accepted. It's IMPERATIVE that you stay on task and commit to the deadlines. Dates for Summative check points are listed below:

Here is our timeline for this project.



Remember! To succeed on the project you need to commit to the deadlines!

Let's start the journey!

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CLICK TO BE TAKEN TO THE SECTION:

Milestone 1: Define the problem Milestone 2: Generate concepts Milestone 3: Design solutions Milestone 4: Build and test Milestone 5: Evaluate Solution Milestone 6: Present solution	

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Milestone 1: Define the problem

Our goal: To understand the challenges children with cerebral palsy face.

What you need to do: research using websites and Youtube videos.

See PowerSchool pages:11.13, 11.16, 11.17.

Watch the video: https://youtu.be/S7C8U24Wjoo

Search websites and YouTube to Answer the 7 questions below (in complete sentences of 3-5). List at least two source links at the bottom of each question. ***One source link is from a website, and the other source link is from YouTube.***

1. **Due 11.13:** Write down the problem statement for your case. (10 points)

APPENDIX G

TABLE OF SEVEN PBL TEACHING ELEMENTS

Seven Essential Project Teaching Elements	
Key knowledge, understanding & Success skills	**1. Design & plan** (1) See the seven elements of PBL design (2) Borrow and adapt (3) Remodel (4) Listen to student interest (5) Headlines (6) Connect to pop culture (7) Co-design with your students (8) Planning with sticky notes with one sticky note representing for one day
2. Align to standards (1) Criteria for products are clearly and specifically derived from standards and allow demonstration of mastery. Create assessments and rubrics that consistently support student achievement of specific standards.	**3. Build the culture** (1) Norms (2) Expectations (3) A shared belief (4) Flexible seating (5) Project wall (6) Sentence starter (7) "Ask three students before me" (8) Form a consistent work habit (9) Celebrations
4. Manage activities Think about **team, tools, and time**: form a team, calendars, team logs, task trackers, project wall, digital project center, technology tools, remove time bottlenecks, reflection at the end of the class [e.g., student interview each other], flip classroom, workshop model among students.	**5. Scaffold Student Learning** (1) Backward planning will help align scaffolding to learning goals (2) Differentiate with different levels of content, process, and products.
6. Assess student learning (1) Be transparent about criteria for success (2) Emphasize formative assessment (3) Balance individual and team assessment (4) Encourage feedback from multiple sources	**7. Engage & Coach** (1) Teachers' knowledge of individual student strengths, interests, backgrounds, and lives (2) Students' enthusiasm is maintained (3) Appropriately high expectations are clearly established, shared, and reinforced

APPENDIX H

CASE ANALYSIS – PBL TEACHING ELEMENTS

	Case 1	**Case 2**	**Case 3**
1. Design and plan			
2. Align to standards			
3. Build the culture			
4. Manage activities			
5. Scaffold student learning			
6. Assess student learning			
7. Engage and coach			

APPENDIX I

REFLECTIONS ON TEACHER CHANGE ENVIRONMENT

Mentor: _____

Researcher: _____

Outside Expert: _____

Web resource: _____

External Source: your mentor, the researcher, outside experts, web sources, etc.

What help have you sought from the external sources?

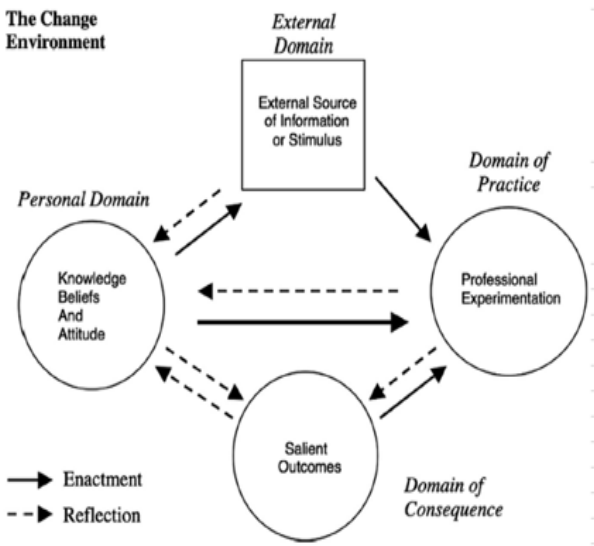
- What **k**nowledge of PBL implementation have I gained so far?
- What is my **b**elief and **a**ttitude towards PBL now? Still difficult, easier?
- How confident are you in PBL teaching?

K: _____

B/A: _____

_____

_____



Success: _____

Challenges: _____

Why? _____

- What are your **successes** during PBL implementation? What helped these successes to occur?
- What are your **challenges** during PBL implementation? What helped these challenges to occur?

APPENDIX J

RUBRIC OF LESSON DESIGN

Page 1

PROJECT DESIGN RUBRIC

	Score 1-2 **Lacks Features of Effective PBL** *The project has one or more of the following problems in each area:*	Score 3-4 **Needs Further Development** *The project includes some features of effective PBL but has some weaknesses:*	Score 5 **Includes Features of Effective PBL** *The project has the following strengths:*
Student Learning Goals: **Key Knowledge, Understanding & Success Skills**	• Student learning goals are not clear and specific; the project is not focused on standards. • The project does not explicitly target, assess, or scaffold the development of success skills.	• The project is focused on standards-derived knowledge and understanding, but it may target too few, too many, or less important goals. • Success skills are targeted, but there may be too many to be adequately taught and assessed.	• The project is focused on teaching students specific and important knowledge, understanding, and skills derived from standards and central to academic subject areas. • Success skills are explicitly targeted to be taught and assessed, such as critical thinking, collaboration, creativity, and project management.
Essential Project Design Element:			
Challenging Problem or Question	• The project is not focused on a central problem or question (it may be more like a unit with several tasks); or the problem or question is too easily solved or answered to justify a project. • The central problem or question is not framed by a driving question for the project, or it is seriously flawed, for example: – it has a single or simple answer. – it is not engaging to students (it sounds too complex or "academic" like it came from a textbook or appeals only to a teacher).	• The project is focused on a central problem or question, but the level of challenge might be inappropriate for the intended students. • The driving question relates to the project but does not capture its central problem or question (it may be more like a theme). • The driving question meets some of the criteria (in the Includes Features column) for an effective driving question, but lacks others.	• The project is focused on a central problem or question, at the appropriate level of challenge. • The project is framed by a driving question, which is: – open-ended; there is more than one possible answer. – understandable and inspiring to students. – aligned with learning goals; to answer it, students will need to gain the intended knowledge, understanding, and skills.
Sustained Inquiry	• The "project" is more like an activity or "hands-on" task, rather than an extended process of inquiry. • There is no process for students to generate questions to guide inquiry.	• Inquiry is limited (it may be brief and only occur once or twice in the project; information-gathering is the main task; deeper questions are not asked). • Students generate questions, but while some might be addressed, they are not used to guide inquiry and do not affect the path of the project.	• Inquiry is sustained over time and academically rigorous (students pose questions, gather & interpret data, develop and evaluate solutions or build evidence for answers, and ask further questions). • Inquiry is driven by student-generated questions throughout the project.

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APPENDIX K

PRE-QUESTIONNAIRE

Name: _____ Year of teaching: _____ Age: ____ Date: _____

Please take about 10 minutes to answer the 12 questions below:

1. What are the characteristics of PBL? Use bullet points to list them.

2. What are the procedures of teaching PBL? Use bullet points to list them.

3. Do you have any PBL teaching experience? If yes, what have been your successes implementing PBL so far? Use bullet points to list them.

4. What have been the challenges regarding PBL teaching so far? Use bullet points to list them.

5. From 1 to 5, rate your confidence level in your teaching skill of PBL. 1 is the least confident while five is the most confident.

6. From 1 to 5, rate your school's support for you to implement PBL. 1 is the least supportive, and five is the most supportive.

7. From 1 to 5, rate your mentor's support for you to implement PBL. 1 is the least supportive, and five is the most supportive.

8. From 1 to 5, rate your peer's support for you to implement PBL. 1 is the least supportive, and five is the most supportive.

APPENDIX L

PRO-QUESTIONNAIRE

Name: _____ Date: _____

Please take about 15 minutes to answer the 11 questions below:

1. What are the characteristics of PBL? Use bullet points to list them.

2. What are the procedures of teaching PBL? Use bullet points to list them.

3. Assign score from 1 to 5 about your opinions about the training program's descriptions. From Strongly disagree to strongly agree (R1, effectiveness).

1. Strongly disagree 2. Disagree 3. Uncertain 4. Agree 5. Strongly agree

1) I'm satisfied with the process of the training.
2) I'm satisfied with the results of the training.
3) I have gained knowledge about PBL.
4) I have gained PBL design skills.
5) I have gained PBL implementation skills.
6) I have applied PBL implementation elements to my classroom practice.
7) I have applied PBL knowledge to my own PBL design.
8) I have seen positive student learning outcome because of my PBL implementation.
9) This training program investigated your needs.

10) This training program had clear objective.
11) This training program had a well-designed instruction plan.
12) This training program used learning principles.
13) This training program was coherent with the job requirement.
14) This training program focused on using the teaching content.
15) This training program involved participants to learn actively.
16) This training program involved participants for collective participation.
17) This training program used the modeling of the practice.
18) This training program provided opportunities for participants to practice.
19) This training program allowed time for participants to reflect on their learning and be given feedback.
20) This training program had a sustained duration.

4. What have been the successes regarding PBL teaching so far? Use bullet points to list them.

5. What have been the challenges regarding PBL teaching so far? Use bullet points to list them.

6. From 1 to 5, rate your confidence level in using PBL. 1 is the least confident while five is the most confident.

7. From 1 to 5, rate your administrator's support for you to learn PBL. 1 is the least supportive, and five is the most supportive.

8. From 1 to 5, rate your mentor's (Mrs. Clark) support for you to learn PBL. 1 is the least supportive, and five is the most supportive.

9. From 1 to 5, rate your peer's (Jen/Greg) support for you to implement PBL. 1 is the least supportive, and five is the most supportive.

APPENDIX M

PRE-INTERVIEW

I'd like to thank you again for being willing to participate in the interview aspect of my study. Our interview today will last approximately half an hour.

You completed a consent form indicating that I have your permission to audio record our conversation. Are you still OK with me recording our conversation today?

___ Yes ___No

If yes: thank you! Please let me know if, at any point, you want me to turn off the recorder or keep something you said off the record.

If no: Thank you for letting me know. I will only take notes of our conversation.

If you have any questions about this study, feel free to ask me at any time. I would be more than happy to answer your questions.

If you do not feel comfortable, you can stop at any time.

1. What are your beliefs about PBL's influence on students?

2. Do you have any training on PBL before (outside of the school or at school)? If yes, what kind of training have you gone through? What have you learned from them?

3. What projects have you done so far? Can you describe them?

4. What is your current teaching style? Can you describe a typical school day when you are teaching?

5. What kind of supports have you received from your school so far for you to learn PBL?

6. What kind of supports have you received from your mentor so far for you to learn PBL?

7. What kind of supports have you received from your peers so far for you to learn PBL?

APPENDIX N

MID-INTERVIEW

I'd like to thank you again for being willing to participate in the interview aspect of my study. Our interview today will last approximately half an hour.

You completed a consent form indicating that I have your permission to audio record our conversation. Are you still OK with me recording our conversation today?

___ Yes ___No

If yes, thank you! Please let me know if, at any point, you want me to turn off the recorder or keep something you said off the record.

If no: Thank you for letting me know. I will only take notes of our conversation.

If you have any questions about this study, feel free to ask me at any time. I would be more than happy to answer your questions.

If you do not feel comfortable, you can stop at any time.

1. What do you think of our training program so far?

2. What have you applied what you learned from the training to your teaching so far?

3. What do you think of your implementation so far? Any successes and challenges?

4. Think about before this training, what change have you noticed in yourself in learning PBL, design PBL, implement PBL?

5. What other kinds of support do you still need to help you in PBL teaching?

APPENDIX O

POST-INTERVIEW

I'd like to thank you again for being willing to participate in the interview aspect of my study. Our interview today will last approximately half an hour.

You completed a consent form indicating that I have your permission to audio record our conversation. Are you still OK with me recording our conversation today? __ Yes __No

If yes: thank you! Please let me know if, at any point, you want me to turn off the recorder or keep something you said off the record.

If no: Thank you for letting me know. I will only take notes of our conversation.

If you have any questions about this study, feel free to ask me at any time. I would be more than happy to answer your questions.

If you do not feel comfortable, you can stop at any time.

1. You know the characteristics and procedure of PBL in terms of PBL knowledge.
   - What other knowledge about PBL have you gained? Can you describe them?
   - What other knowledge do you wish to know?

2. We talked about your beliefs about PBL's influence on students before. After you experienced the whole process of designing and implementing PBL lessons, do you still hold the same view towards PBL? Any there any changes in your belief?

3. Think about your PBL design,
   - Which part of your PBL design do you feel confident about?
   - Which part of your PBL design do you feel not confident about?

4. What do you think about our training program? Do you have any suggestions to make this training program better?
5. Is there any way in which this training program hasn't met your needs in terms of improving your PBL design?
   - Do you have any changes in yourself learning PBL design?

6. Is there any way in which this training program hasn't met your needs in terms of improving your PBL implementation?
   - Do you have any changes in yourself learning PBL implementation?

7. Which part did I do well as your mentor?

8. What part can I improve as your mentor?

9. Are there any other changes you see yourself as a teacher after experiencing the entire process of using PBL?

10. After this program, do you plan to continue using the knowledge and skills you gained from this training? And Why?

11. What have been your successes regarding PBL teaching so far? What are some factors you think have led to these successes?

12. What have been your challenges regarding PBL teaching so far? What are some factors do you think have led to these challenges?

To Greg:

13. We also talked about classroom management a lot. Can you tell me your idea of classroom management?
    - *What is classroom management to you?*
    - *What is the impact of classroom management on the classroom?*

To Greg and Jen:

14. You mentioned COVID-19 hinders PBL implementation. Can you elaborate on your experience with this?

15. You mentioned teaching online students is challenging. Can you elaborate on your experience with this?

16. What other kinds of support do you still need to help you in PBL teaching in the future?

APPENDIX P

SUMMATIVE OBSERVATION RUBRIC FOR PBL IMPLEMENTATION

Teacher_____ Observer _____Date/Time _____

PBL Title _____

PBL Description _____

_____

_____

To what extent was the following present? Please mark the box that best displays your response on a scale of 5 to 1. 5= to a great extent, 1 = no evidence.

1. The teacher clearly stated goals and tasks.

   Score: _____

   Justification:_____

   _____

   _____

2. The teacher asked effective open-ended questions within small groups.

   Score: _____

   Justification:_____

   _____

   _____

3. The teacher established a collaborative learning environment.

   Score: _____

   Justification:_____

   _____

   _____

4. The teacher provided management tools or strategies.

Score: _____

Justification:_____

_____

_____

5. The teacher provided scaffolding mini-lessons, activities, or materials.

   Score: _____

   Justification:_____

   _____

   _____

6. The teacher communicated clearly about the formative assessment.

   Score:

   _____.Justification:_____

   _____

   _____

7. The teacher identified and engaged the students around their interests and cultural contexts.

   Score: _____

   Justification:_____

   _____

   _____

Other comments or observations

_____

_____

_____

APPENDIX Q

DATA ANALYSIS FOR ONE-GLANCE VIEW

	Components	**Categories**	**Subcategories/ Codes**	pre-questionnaire	post-questionnaire	pre-interview	mid-interview	post-interview	daily reflection
R1 **How do teachers perceive the effectiveness of a PBL training program?**	**Trainee**	**Knowledge (acquired/ increased)**	Knowledge of PBL pedagogy	x	x	x		x	
		Belief (changed)	Beliefs about PBL teaching	x	x	x		x	
			Beliefs about student learning in PBL						
			Self-efficacy in teaching PBL	x	x	x	x	x	
		Job attitude (satisfied/ enjoy)	Attitudes towards PBL teaching	x	x	x		x	
		Change in practice (able to apply new learning to practice)	Applied teaching elements to PBL implementation						
			Applied design elements to own PBL design						
			Applied lesson design thinking				x	x	

		Categories	**Subcategories/ Codes**	pre-questionnaire	post-questionnaire	pre-interview	mid-interview	post-interview	daily reflection
	Training Program Design	**satisfaction (satisfied or not)**	12 items					x	
			four phases					x	
			management documents		x		x	x	x
			student outcome				x	x	
	Work Environment	**mentor support**	feedback				x	x	
			availability to support				x	x	

	Components	**Categories**	**Subcategories/ Codes**	feedback after each phase	filed notes	teacher reflection on change environment	summative observation rubric	lesson plan	evaluation form	researcher's journal
R1 **How do teachers perceive the effectiveness of a PBL training program?**	**Trainee**	**Knowledge (acquired/ increased)**	knowledge of PBL pedagogy							
		Belief (changed)	beliefs about PBL teaching							
			beliefs about student learning in PBL							
			Self-efficacy in teaching PBL							
		Job attitude (satisfied/ enjoy)	attitudes towards PBL teaching							
		Change in practice (able to apply new learning to practice)	applied teaching elements to PBL implementation		x		x			
			applied design elements to own PBL design					x	x	
			applied lesson design thinking							

		Categories	**Subcategories/ Codes**	feedback after each phase	filed notes	teacher reflection on change environment	summative observation rubric	lesson plan	evaluation form	researcher's journal
	Training Program Design	**satisfaction (satisfied or not)**	12 items							
			four phases	x						
			management documents	x		x				
			student outcome			x				
	Work Environment	**mentor support**	feedback							x
			other support							x

	Component	**Categories**	**Subcategories/ Codes**	pre-questionnaire	post-questionnaire	pre-interview	mid-interview	post-interview	daily reflection
R2 How do teachers' perceptions towards PBL change during the training program?	**Perception Change**	**Understanding**	Understanding of PBL pedagogy	x	x	x	x	x	x
		Belief	beliefs about PBL teaching	x	x	x	x	x	x
			beliefs about student learning in PBL	x	x	x	x	x	x
			belief about student maturity in PBL	x	x	x	x	x	x
			Self-efficacy in teaching PBL	x	x	x	x	x	

	Component	**Categories**	**Subcategories/ Codes**	feedback after each phase	filed notes	teacher reflection on change environment	summative observation rubric	lesson plan	evaluation form	researcher's journal
R2 How do teachers' perceptions towards PBL change during the training program?	**Perception Change**	**Understanding**	Understanding of PBL pedagogy	x		x				x
		Belief	beliefs about PBL teaching	x		x				x
			beliefs about student learning in PBL	x		x				x
			belief about student maturity in PBL	x		x				x
			Self-efficacy in teaching PBL							

	Components	**Codes/Categories**	**Subcategories/ Codes**	pre-questionnaire	post-questionnaire	pre-interview	mid-interview	post-interview	daily reflection
R3 What are the factors associated with the successes and pitfalls of the training program?	**Trainees**	**Belief**	beliefs about PBL teaching	x	x	x	x	x	x
			belief about student maturity in PBL	x	x	x	x	x	x
		Classroom management skills					x	x	x
		Time to participate in training						x	
	Training Program Design	**The design of progressive phases**						x	
		The design of management documents					x	x	
		Time to implement the training			x		x	x	
	Work Environment	**Organizational support**		x	x	x	x	x	x
		Mentor support		x	x	x	x	x	x
		Peer support		x	x	x	x	x	x

		COVID-19	Student absence and tardy				x	x	
			difficulty to engage online students				x	x	
			difficult to teach online at home				x	x	
		Test pressure						x	

	Components	**Codes/Categories**	**Subcategories/ Codes**	feedback after each phase	filed notes	teacher reflection on change environment	summative observation rubric	lesson plan	evaluation form	researcher's journal
R3 What are the factors associated with the successes and pitfalls of the training program?	**Trainees**	**Belief**	beliefs about PBL teaching	x		x				x
			belief about student maturity in PBL	x		x				x
		Classroom management skills			x	x				
		Time to participate in training								x
	Training Program Design	**The design of progressive phases**				x				
		The design of management documents		x		x				
		Time constraint								
	Work Environment	**Organizational support**		x	x	x				x
		Mentor support		x	x	x				x
		Peer support		x	x	x				x

		COVID-19	student absence and tardy		x	x				
			difficulty to engage online students		x	x				
			difficult to teach online at home		x	x				
		Test pressure								x