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Experiences of Teachers of the Deaf Using Project-Based Learning to Build Higher Order Thinking Skills

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Abstract

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by

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MA, Gallaudet University, 1977

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Project-based learning (PBL) is an instructional strategy used to develop higher order thinking skills (HOTS) with a range of student populations. Although all students need to build HOTS for success in the 21st century, PBL studies with deaf and hard of hearing (DHH) students were nearly absent; therefore, it was unknown how PBL could be used to develop HOTS with this population. The purpose of this qualitative study was to explore the lived experiences of teachers of the deaf using PBL to build HOTS with DHH students in the dimensions of pedagogy, product, and process. A self-designed conceptual framework called project-based learning and innovation for teachers and students (PB-LIFTS) was used to discover HOTS in PBL units. The central research question explored the lived experiences of teachers of the deaf designing and implementing PBL to build HOTS with DHH students. A sample of 4 licensed high school teachers of the deaf with a high level of comfort using PBL and at least 5 years of experience participated in this study. Data came from multiple interviews, learning objectives, and e-mailed journal responses. Following procedures for interpretative phenomenological analysis, emergent themes were applied in PB-LIFTS to reveal levels of HOTS that were shared with the teachers to gain their perspectives. Results showed that the teachers used social constructive pedagogy to build HOTS using PBL with academically diverse deaf high school students. This study may promote social change in deaf education by encouraging the adoption of PBL strategies to develop HOTS needed for success beyond high school. In addition, this study may support future research related to assessing HOTS in PBL using PB-LIFTS which could be flexibly adapted and applied in units across disciplines.

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Dedication

I dedicate this work to all curious deaf or hard of hearing students who thrive on making meaning and have the tenacity to overcome access barriers in a world designed for auditory learners. I also dedicate my work to the committed deaf education professionals who guide these students to develop the skills and self-determination needed to realize that anything is possible.

Acknowledgments

It has always been my dream to make sense of how instructional innovation can be applied to fuel the minds and spirits of deaf and hard of hearing learners for success in a complex world. Without the Teacher of the Year Program, Walden University, Disability Services, and the steadfast guidance of Dr. Darci J. Harland, this work would not have been possible. Dr. Darci, I want to express my profound gratitude for your patience, expertise, appreciation of deaf perspectives, and for believing in me and the value of this study. As a testament to your dedication, I fondly recall the night you guided me through a critical technology glitch while attending a family wedding reception. You will always have a special place in my heart as you have contributed to my growth as a scholar in ways that I never thought possible.

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Chapter 1: Introduction to the Study

This study was an exploration of how teachers of the deaf built higher order thinking skills (HOTS) such as critical thinking, problem-solving, communication, collaboration, and creativity with deaf and hard of hearing (DHH) students using project-based learning (PBL). There is widespread agreement in the scholarly literature that HOTS development is essential for all 21st century students worldwide (Germaine, Richards, Koeller, & Schubert-Irastorza, 2016; Wurdinger, 2018) including historically marginalized and underserved groups (Tan, Barton, & Schenkel, 2018). Research showed that constructive instructional pedagogy such as PBL developed HOTS with diverse learners across a broad range of learning contexts (Darling-Hammond, 2017; Ertmer, Schlosser, Clase, & Adedokun, 2014). In recent studies, researchers suggested that DHH students may benefit from social constructive learning strategies (Cawthon, Fink, Schoffstall, & Wendel, 2018; Pagano, Goik, Templeton, Ross, & Smith, 2016; Ross, Yerrick, & Pagano, 2020). However, implementation studies on PBL and HOTS with DHH students were absent in this review. Therefore, how teachers of the deaf might build HOTS with DHH students using PBL is unknown.

An abundance of research findings supported the use of PBL as an effective strategy for developing content knowledge and HOTS; yet researchers found that students often focused on finishing the product and neglected the learning processes that produce HOTS (Dole, Bloom, & Doss, 2017; Rudnitsky, 2013; Smith, 2016). Moreover, teachers lacked confidence in their ability to assess HOTS (Alves et al., 2016; Cook & Weaver, 2015; Kim, Sharma, Land, & Furlong, 2013; Schulz & FitzPatrick, 2016). Thus, a comprehensive method that could be flexibly applied to evaluate overlapping skills while emphasizing learning processes in PBL is a research gap that impacts PBL teachers and students worldwide (Smith, 2016; Zhao, Zhang, & Du, 2017).

The conceptual framework I developed for this study is project-based learning and innovation for teachers and students (PB-LIFTS). This framework provided a focusing lens to study HOTS in three dimensions of PBL, including pedagogy, product, and processes. To assess HOTS in PBL, I incorporated several researched strategies in the PB-LIFTS framework, for which I provide details in Chapter 2. Thus, for this study, I explored PBL experiences described by teachers using the PB-LIFTS framework to assess levels of thinking skills to reveal how teachers of the deaf used PBL to build HOTS with DHH students.

This study was needed to fill a research gap regarding how DHH students can demonstrate HOTS given constructive social learning opportunities guided by experienced teachers. The study expands the existing body of research on PBL to DHH students. It may influence professionals who work with other traditionally underserved students to consider adopting PBL to build HOTS needed for college and careers. The study may also increase awareness to prompt a change in service delivery systems to meet the social learning needs of DHH students and teachers of the deaf.

In this chapter, I introduce the study designed to explore the lived experiences of teachers of the deaf using PBL to build HOTS with DHH students. Background from recent scholarly literature revealed research gaps, established the need for this study, and showed the potential to promote social change in education. The chapter includes a problem statement, the purpose of the study, the central research question and four related research questions, the conceptual framework, the nature of the study, key definitions, assumptions, the scope of the study, limitations, and significance of the study. The chapter concludes with a summary.

Background

As the technical revolution of the 21st century continues to impact learning, communication, and information systems around the globe, educators face constant social and political demands for instructional change to better prepare young people for success in the modern workplace. PBL has gained popularity in recent years as a comprehensive instructional method for acquiring content knowledge and building 21st century skills for all students (Häkkinen et al., 2017; Kivunja, 2014a; Kokotsaki, Menzies, & Wiggins, 2016; Lin, Ma, Kuo, & Chou, 2015; Wurdinger & Qureshi, 2015) including students with disabilities (Hovey & Ferguson, 2014; Lambert, 2015; Zhao, 2018). As a deaf individual and former teacher of the deaf interested in rigorous constructivist learning, I developed a primary research question and four subquestions. The central research question asked,

> CRQ: How do teachers of the deaf describe their lived experiences designing and implementing PBL to build HOTS with DHH students?

To identify gaps and thoroughly understand the potential implications of recent studies for social change, I situated PBL and deaf education within the historical context. As a result, multiple subtopics for the literature review emerged. Thus, with the hope that the scholarly literature might illuminate a path for increasing the skills and knowledge students need for the future, I first sought to understand the present by considering the past. Hence, the literature review for my study grew to seven main topics, and what follows are summaries of each.

The introduction to the literature review is a description of the need for student-centered PBL to support the development of 21st century skills for career readiness. The changing technology-infused workplace demands innovative employees capable of collaborating, communicating, and problem-solving (Dole et al., 2017; Henshon, 2017; Wagner & Dintersmith, 2015; Wurdinger, 2018). A shift away from traditional rote learning was required to prepare interdependent knowledge builders. New needs prompted education scholars to debate the skills, knowledge, and dispositions students could acquire using constructivist learning strategies (Kereluik, Mishra, Fahnoe, & Terry, 2013; Silva, 2009; Trilling & Fadel, 2009). In PBL, students collaboratively produce a final product. In constructive learning students engage in inquiry, research, and collaborative problem-solving; therefore, scholars have identified PBL as having the most significant potential to produce rigorous learning outcomes (Dole, Bloom, & Kowalske, 2016; Galvan & Coronado, 2014; Larmer, Mergendoller, & Boss, 2015).

Research on the history of PBL in the United States showed that political swings caused constructivist learning strategies to fall in and out of favor throughout the 20th century; however, PBL has emerged as a popular topic in the current scholarly literature. Modern-day PBL, as described by Larmer et al. (2015), is called the gold standard. Larmer and colleagues described skills students could acquire through PBL processes such as communication, collaboration, critical thinking, and creativity that align with the experiential learning outcomes promoted by Dewey (1938). Thus PBL is not new but is gaining popularity as an instructional method for preparing students with valuable workplace skills referred to as 21st century skills, communication, collaboration, critical thinking, and creativity (4Cs), and career readiness skills across multiple frameworks

(Dede, 2010; Jerald, 2009; Kereluik et al., 2013; Kivunja, 2015; Organization for Economic Cooperation and Development, 2005; Partnership for 21st Century Skills, 2004; Voogt & Roblin, 2012). The scholarly literature on PBL during the first decade of the 21st century was weak. Still, studies in the second decade provided strong evidence that PBL and student-centered constructivist learning supported the development of 21st century HOTS valued by employers.

Recent findings in the PBL literature indicated an abundance of benefits that provided significant support for this teaching strategy in a range of educational settings. Although researchers found that the shift away from teacher-centered strategy and the implementation of PBL was not smooth, the benefits far outweighed the traditional teacher-centered approach (Bilgin, Karakuyu, & Ay, 2015; Catapano & Gray, 2015; Tamim & Grant, 2013). PBL had a motivational effect on students due to engagement in real-world education while exercising greater autonomy (Chiang & Lee, 2016; Ilter, 2014; Martelli & Watson, 2016; Shin, 2018; Summers & Dickinson, 2012). Other findings related to PBL were higher attendance rates (Catapano & Gray, 2015; Creghan & Adair-Creghan, 2015; Shuptrine, 2013; Tamim & Grant, 2013), and improved learning behaviors (Chiang & Lee, 2016; Erdoğan & Dede, 2015; Hung, Hwang, & Huang, 2012; Ilter, 2014). Moreover, studies showed a positive relationship between PBL engagement and academic achievement (Han, Capraro, & Capraro, 2015; Ilter, 2014; Karaçalli & Korur, 2014) and greater long-term knowledge retention (Karaçalli & Korur, 2014; Summers & Dickinson, 2012). Lastly, several studies found improved cognitive-affective behaviors when students engaged in PBL (Ahonen & Kinnunen, 2015; Ilter, 2014; Moalosi, Molokwane, & Mothibedi, 2012; Wurdinger & Qureshi, 2015).

PBL instructional strategies are highly adaptable for use in a wide variety of learning contexts and an excellent method for developing 21st century skills needed for college and career readiness (Ahonen & Kinnunen, 2015; Ainsworth, 2016; Cho & Brown, 2013; DeWaters, Andersen, Calderwood, & Powers, 2014; Summers & Dickinson, 2012). Researchers also found that PBL could be used to promote the development of digital literacy, which is a highly valued workplace skill in the globalized marketplace (Hao, Branch, & Jensen, 2016; Hsu, Van Dyke, Chen, & Smith, 2015; Moalosi et al., 2012; Shuptrine, 2013). Also, studies showed that PBL could be easily differentiated (Du & Han, 2016) for all students including language learners, low achievers, and diverse learners with special needs of all ages (Catapano & Gray, 2015; Chiang & Lee, 2016; Hovey & Ferguson, 2014; K. Kim et al., 2013; Lambert, 2015; Martelli & Watson, 2016). Despite the many studies documenting positive learning outcomes with a wide variety of student populations, PBL implementation studies with DHH students were absent. This gap in the literature was important because it remained unknown how these students might benefit from engagement in PBL and acquire 21st century skill sets needed for college and workplace success.

In recent studies, researchers reported an array of challenges that teachers face when implementing PBL. The literature revealed that resistance to adopting PBL could stem from various problems at many levels of the education system. Yet, studies showed that committed teachers who believed in the benefits of PBL find ways to overcome these barriers. Challenges related to long-standing teacher-centered practices and cultural traditions caused resistance to PBL (Chiang & Lee, 2016; Lee, Blackwell, Drake, & Moran, 2014; Pham & Renshaw, 2015; Stolk & Harari, 2014; Yin, 2013; Zhang & Liu, 2014). Other problems included institutional requirements that placed limits on instructional time and curricular flexibility (Cho & Brown, 2013; Dole et al., 2016; Tamim & Grant, 2013). There was also the need for administrative support (Vega & Brown, 2013). Studies found that teachers needed PBL training and ongoing guidance (Cho & Brown, 2013; Hovey & Ferguson, 2014; K. Kim et al., 2013; Summers & Dickinson, 2012; Tamim & Grant, 2013). Several other areas of need were identified such as planning PBL units and adjusting to the role of PBL facilitator (Dole et al., 2016; Kim, 2015; Lee et al., 2014; Martelli & Watson, 2016; Tamim & Grant, 2013; Vega & Brown, 2013).

Multiple studies reported that students at every age level were unprepared to engage in PBL groups productively and needed training in self-regulation, accountability, teamwork, and conflict resolution (Ainsworth, 2016; Cho & Brown, 2013; Dole et al., 2016; Lee et al., 2014; Shuptrine, 2013; Vega & Brown, 2013; Wilson, Ho, & Brookes, 2017). Cho and Brown (2013) asserted that students needed formative assessment feedback at every stage of PBL, and because assessment can drive learning, experts in PBL posited that formative assessment should be multidimensional (Boss & Kraus, 2014; Greenstein, 2012; Larmer et al., 2015; Marzano & Heflebower, 2012). Studies identified multiple layers of soft skills students needed for PBL, including learning processes, group work, product development, presentation, and reflection that require various methods to assess (Lee et al., 2014). Further, Cho and Brown (2013) asserted that instructors in K-12, as well as college settings, needed help with how to evaluate PBL. Students must use many skills over a PBL unit, and a method of organizing and assessing these skills was lacking.

Recent studies on teacher perceptions of PBL indicate that they generally agree on the capacity of PBL to prepare students for higher education and careers; however, they are overwhelmed with the significant changes PBL imposes on instructional practices and assessment strategies that require time, resources, and support to design and implement. For example, studies showed that teachers need ongoing PBL training and assistance for planning, implementation, and assessment (Ertmer et al., 2014; Habók & Nagy, 2016; Lee et al., 2014; Nariman & Chrispeels, 2016). Teachers benefited from having support when adapting to new PBL roles and learning processes (Dole et al., 2016; Lee et al., 2014; Martelli & Watson, 2016; Wilson et al., 2017). They struggled to find appropriate resources (Cook & Weaver, 2015; Rudnitsky, 2013; Scholl, 2014) and integrate technology (Lasry, Charles, & Whittaker, 2014; Nariman & Chrispeels, 2016; Rahimi, van den Berg, & Veen, 2015).

Studies also showed that teachers need time to collaborate to overcome PBL challenges and promote rigorous learning (Gómez-Pablos, del Pozo, & Muñoz-Repiso, 2017; Vrikki, Warwick, Vermunt, Mercer, & Van Halem, 2017). Regarding PBL assessment, several studies showed that teachers were experimenting with strategies such as Buck Institute for Education (BIE, 2013) rubrics (Cook & Weaver, 2015; Dole et al., 2016; Ertmer et al., 2014; Habók & Nagy, 2016; Lee et al., 2014; Mahmood & Jacobo, 2019; Vega & Brown, 2013). They were also creating peer and self-assessments (Alves et al., 2016; Hao et al., 2016; Lee et al., 2014; Tamim & Grant, 2013), yet they are not confident. Studies of teacher perceptions on PBL revealed that some teachers were able to successfully overcome PBL implementation and assessment challenges (Martelli & Watson, 2016; Tamim & Grant, 2013) when others were not (Cook & Weaver, 2015).

There remains a gap in understanding how teachers were able to navigate the challenges of PBL implementation and assessment. This gap is significant because teacher perceptions of successful PBL implementation may illuminate how problems related to time, resources, PBL learning processes, and evaluation can be overcome.

Findings from recent studies showed a relationship between student engagement in PBL and HOTS. Scholars repeatedly concluded that PBL processes foster HOTS, yet it was not always clear how HOTS were measured or if the method of measurement was context-specific and, therefore, not transferrable. Many recent studies reported that collaborative learning promotes HOTS mainly due to the authentic focus and social nature of PBL (Hasni et al., 2016; Kivunja, 2013; Przybysz-Zaremba, Rimkūnienė, & Butvilas, 2017; Wurdinger, 2018; Zhao et al., 2017). A significant number of PBL studies reported high levels of cognitive rigor when students engaged in connected learning using Web 2.0 tools to collaborate (Allison & Goldston, 2016; Boss & Kraus, 2014; Ertmer & Ottenbreit-Leftwich, 2013; Gómez-Pablos et al., 2017; Lin et al., 2015; Thamarasseri, 2014; Voogt, Erstad, Dede, & Mishra, 2013). Interacting in global learning networks promoted 21st century skills, self-direction, and deeper learning using Web 2.0 tools (Allison & Goldston, 2016; Lasry et al., 2014; Lin et al., 2015). Learning and working constructively with others in virtual environments adds complexity to communication and collaboration processes; thus, connected learning is considered the most rigorous of the constructivist pedagogies (Lin et al., 2015). Researchers also cautioned that students often focus upon finishing their project and neglect the learning processes that are critical to high-quality products; therefore, Rahimi et al. (2015) warned that engagement with technology or producing a product does not necessarily indicate HOTS. Because learning processes are critical to product innovation, formative assessment should include learning processes. Overall, recent research documents widespread agreement that PBL promotes the development of HOTS and this is dependent upon the skills of the teacher, the pedagogical approach, and learning processes used to produce the product; however, the need for additional research on methods of assessing HOTS in these dimensions that can be easily adapted and applied in a range of contexts is a gap that remains (Alves et al., 2016; Du & Han, 2016; Schulz & FitzPatrick, 2016; Smith, 2016; Williams, 2017; Zhao et al., 2017).

The literature related to pedagogy in classrooms with DHH students revealed a lack of consensus in the field of deaf education. A review of the history of deaf education provided background to understand current philosophical, political, linguistic, and cultural divisions among families, the deaf community, practitioners, special interests, and policymakers that have led to a fragmented education system for DHH students. Technical advances and sociopolitical trends in special education, such as increased mainstreaming, have also impacted placement and service delivery models. Currently, nearly 60% of DHH students receiving services under special education law spend 80% or more of the day in general education classes (National Center for Education Statistics [NCES], 2016). Deafness is a low incidence category of special education; therefore, students with hearing loss attending their neighborhood school are often the only DHH student in the school. To serve these students, there has been a sharp increase in itinerant services from teachers of the deaf (Antia & Rivera, 2016; Johnson, 2013; Luckner & Ayantoye, 2013; Luckner & Dorn, 2017) and declining enrollments in residential schools (Nagle, Newman, Shaver, & Marschark, 2016) that have been in operation since the

1800s and are the center of deaf culture (Reagan, 2018). Research suggests that placing DHH students physically in a general education classroom does not necessarily indicate that they have equitable access to social and academic learning (Kurz, Schick, & Hauser, 2015; Miles, Khairuddin, & McCracken, 2018; Olsson, Dag, & Kullberg, 2017).

Overall, across placements, deaf education has a long history of failure with low academic achievement (Marschark, Shaver, Nagle, & Newman, 2015; Power & Leigh, 2000; Qi & Mitchell, 2011) and low expectations (Alofi, Clark, & Marchut, 2019; Meinzen-Derr et al., 2018; Salter, Swanwick, & Pearson, 2017; Tucker, 2014). Studies have reported that DHH students can make academic gains similar to hearing peers (Bartlett, 2017; Convertino, Marschark, Sapere, Sarchet, & Zupan, 2009; Hrastinski & Wilbur, 2016; Marschark, Spencer, Adams, & Sapere, 2011); however, this is most often not the case. DHH students usually begin school with language and academic delays that persist (Pagliaro & Kritzer, 2013; Segers & Verhoeven, 2015). Further, DHH students frequently graduate from high school unprepared for college or careers due to lags in psychosocial development (Hintermair, 2014), low achievement in core subjects (Nagle et al., 2016), and undeveloped 21st century skills (Kelly, Quagliata, DeMartino, & Perotti, 2016). Researchers concluded in recent literature that social learning strategies might be effective with DHH students who often feel left out in general education (Braun et al., 2018; Majocha, Davenport, Braun, & Gormally, 2018; Oliva, Lytle, Hopper, & Ostrove, 2016; Olsson et al., 2017). Oliva et al. (2016) asserted that when DHH students learn together in a socially accepting environment, they can develop a sense of belonging and confidence; perhaps this can empower them to master transferrable skills in environments with hearing students. Kurz et al. (2015) found that knowledge acquisition for DHH students is higher when receiving direct instruction from a teacher of the deaf rather than using an interpreter in inclusive environments. This study focuses on DHH students learning together under the guidance of a teacher of the deaf. Perhaps by discovering how experienced teachers of the deaf can foster the development of HOTS using PBL with groups of DHH students, other teachers of the deaf may be inspired to adopt constructivist learning strategies. If DHH students have opportunities to build confidence using HOTS, they may be better prepared to transfer these skills in general education environments and life beyond high school graduation.

Problem Statement

The global imperative to meet the new demands of 21st century education may be particularly challenging for teachers in a branch of special education with a long history of poor academic outcomes. Academic achievement rates in deaf education have been consistently low for decades (Marschark et al., 2015; Power & Leigh, 2000; Qi & Mitchell, 2011). In the second decade of the 21st century, scholars began assessing the evidence-base for instructional practices in deaf education and found severe limitations (Beal-Alvarez & Cannon, 2014; J. E. Cannon, Guardino, Antia, & Luckner, 2016; Luckner, Bruce, & Ferrell, 2016; Spencer & Marschark, 2010). Further, the field of deaf education is fragmented; currently, teachers of the deaf serve a diverse low-incidence population of students in a variety of placements with competing philosophies and deliver a medley of services (Crowe, Marschark, Dammeyer, & Lehane, 2017; Johnson, 2013; Luckner & Ayantoye, 2013; Marschark et al., 2015; Shaver, Marschark, Newman, & Marder, 2014).

In recent literature, deaf education researchers showed a growing interest in 21st century skills and learning strategies. Scholars advocated for teachers of the deaf to set high expectations and to implement evidence-based practices (Marschark et al., 2011; Segers & Verhoeven, 2015). Others suggested integrating 21st century skills education (Ayantoye & Luckner, 2016; Johnson, 2013; Swanwick, 2017) and supporting the development of self-determination and problem-solving skills through social learning (Millen, Dorn, & Luckner, 2019) to foster HOTS through collaborative education (Easterbrooks & Stephenson, 2012; Swanwick et al., 2014). It remains unknown how teachers of the deaf are adopting and implementing innovative instructional strategies such as PBL to prepare DHH students for higher education and the 21st century workforce. To this end, it is imperative to discover the experiences and perceptions of skilled teachers firsthand (see Smith, Flowers, & Larkin, 2009).

PBL is a popular instructional strategy implemented in classrooms around the world. An abundance of recent research studies have supported the use of PBL as a comprehensive strategy for developing 21st century skills and HOTS across a range of student populations, yet PBL implementation studies in deaf education are nearly absent. To study PBL and HOTS with DHH students required a method of assessing HOTS. Studies showed that teachers often assume that students apply HOTS when engaged in PBL (Alves et al., 2016; Dole et al., 2016; Habók & Nagy, 2016); however, there is no comprehensive method for measuring HOTS in the areas of PBL pedagogy, product, and process (Du & Han, 2016; Schulz & FitzPatrick, 2016; Smith, 2016; Zhao et al., 2017). Therefore, the research problem I addressed in this study was that little is understood about how teachers of the deaf use PBL with DHH students to foster HOTS development.

Purpose of the Study

The overarching phenomenon of interest in this study was how teachers use PBL strategies to promote HOTS. The purpose of this qualitative study was to explore the lived experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the dimensions of pedagogy, product, and process. To accomplish this purpose, I developed a conceptual framework called PB-LIFTS to examine how teachers of the deaf integrated HOTS in a previously implemented PBL unit.

Research Questions

One central research question (CRQ) and four related research questions (RRQs) guided this study and were aligned with the conceptual framework, which was based upon findings from the literature review. The CRQ addressed the overarching focus of the inquiry and the four RRQs targeted specific aspects of the conceptual framework. The following CRQ and RRQs guided this study:

CRQ: How do teachers of the deaf describe their lived experiences designing and implementing PBL to build HOTS with DHH students?

RRQ1: How do teachers of the deaf describe HOTS in their pedagogical approach for PBL?

RRQ2: How do teachers of the deaf describe HOTS in student PBL products?

RRQ3: How do teachers of the deaf describe HOTS in student PBL processes?

RRQ4: In what ways could the PB-LIFTS framework be useful to teachers for assessing HOTS?

Conceptual Framework

PBL derived from constructive learning theory in which teachers engage students in active learning to solve a problem or explore a topic of authentic interest over a period; students become collaborative meaning makers and knowledge builders who produce a product representative of their learning for presentation at the end of the PBL unit. The conceptual framework I developed for this study, PB-LIFTS, provided a contextual lens through which I could explore teachers' experiences using PBL to build HOTS in the dimensions of the teacher's pedagogical design, the students' final product, and the students' learning processes.

To create the three dimensions of PB-LIFTS, I adapted existing assessment models that delineate levels of cognitive skills in PBL pedagogical design, product innovation, and learning processes. The face of PB-LIFTS is a matrix of 16 cells representing four types of constructive pedagogy in the horizontal dimension and four levels of product innovation in the vertical dimension. Anderson and Krathwohl's (2001) revised Bloom's taxonomy (RBT) was embedded in each of these two dimensions and can be used to identify cognitive demands in the teacher's pedagogical design and the student product. The progression of HOTS across the horizontal and vertical dimensions of the framework are shown in Figure 1.

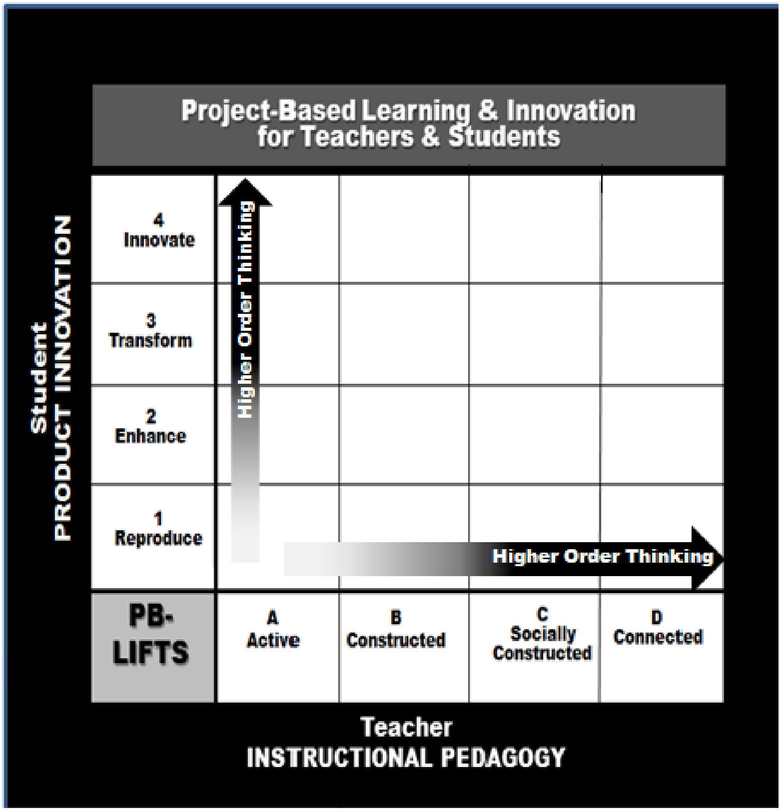


Figure 1. Project-based learning & innovation for teachers & students framework and higher order thinking skills.

The third dimension is conceptually behind the product dimension; this dimension consists of four learning processes used to achieve the final product. Each of the four processes, including task, thinking, teamwork, and tools (4Ts), has four levels ranging from lower order thinking skills to HOTS. The results of assessing 4Ts revealed the level of innovation students applied to produce the product.

The framework is a contextual lens through which the phenomenon of how PBL strategies build HOTS was explored regarding the three dimensions of PB-LIFTS pedagogy, product, and processes. PB-LIFTS can be used to illuminate the ways in which a PBL unit promoted the development of HOTS with students. PB-LIFTS can be used to help guide the development of PBL units, to assess levels of student innovation and PBL processes to provide students with feedback to set mastery goals and track progress across PBL engagement. Elements of this framework were used in previous research to

- examine student-centered constructivist pedagogy (Alves et al., 2016; Cook & Weaver, 2015; Habók & Nagy, 2016; Pellegrino, 2017; Perry-Smith & Mannucci, 2017; Scholtz, 2016; Schulz & FitzPatrick, 2016; Wagner & Compton, 2015);
- study creative product assessment based upon Bloom's (1956) taxonomy of cognitive objectives (Azizan, Mellon, Ramli, & Yusup, 2017; Chua, Yang, & Leo, 2014; Pantiwati, Wahyuni, & Permana, 2017) and Anderson and Krathwohl's (2001) RBT (Baser, Ozden, & Karaarslan, 2017; Ellis, 2016; Özer, Güngör, & Özkan, 2015; Siew, Chin, & Sombuling, 2017; Valgeirsdottir, Onarheim, & Gabrielsen, 2015);
- measure learning rigor using Webb's depth of knowledge (DOK; Branscome & Robinson, 2017; Darling-Hammond et al., 2013; Ellis, 2016; Harris & Patten, 2015; Hess, Jones, Carlock, & Walkup, 2009; Sondergeld, Peters-Burton, & Johnson, 2016);
- study team development using Tuckman's model of team development (Bonebright, 2010; Haines, 2014; Kearney, Damron, & Sohoni, 2015; Natvig & Stark, 2016);
- implement and assess PBL using BIE resources (Cook & Weaver, 2015; Dole et al., 2016; Ertmer et al., 2014; Habók & Nagy, 2016; Lee et al., 2014; Martelli & Watson, 2016; Vega & Brown, 2013); and

- differentiate levels of technology use (Cherner & Smith, 2017; Hamilton, Rosenberg, & Akcaoğlu, 2016; Hilton, 2016; Jude, Kajura, & Birevu, 2014; Romrell, Kidder, & Wood, 2014) applying Puentedura's (2006) SAMR model.

The horizontal dimension of PB-LIFTS is a progression of four types of constructive pedagogies: active, constructed, social, and connected. The first three are based upon Schallert and Martin's (2003) pedagogy descriptions, and the last one, connectivism, was described by Siemens (2004) for online learning. The four pedagogical types are differentiated according to the teacher's role, students' role, and the learning design. In the vertical dimension, there are four student product innovation levels arranged in progressive levels of originality, creativity, and content complexity. These indicators were borrowed from BIE (2013) rubrics. The 4Ts of PBL processes are task, thinking, teamwork, and tools; each of the 4Ts has four levels of difficulty from lower order thinking skills to HOTS. Task evaluation indicators were borrowed from BIE (2013) rubrics: planning, organization, and accountability. Thinking processes incorporated Webb's (1997) DOK. Teamwork evaluation included Tuckman's (1965) four levels of team development. Tools were divided into two evaluation components, including resources and technology use. Student use of resources was evaluated using indicators from BIE (2013) rubrics, and student technology use was evaluated using the four levels of Puentedura's (2006) SAMR model. The PB-LIFTS framework is further described in Chapter 2.

For this study, I used the PB-LIFTS framework to help answer the CRQ and aid in the process of interpretative phenomenological analysis (IPA). I used the framework to guide cycles of semistructured interviews with teachers to explore their experiences in depth using PBL to build HOTS with students. I conducted interviews one-on-one with each teacher participant using Zoom technology to record interviews remotely. In the first interview, questions were aimed at exploring teacher reflections on a favorite PBL unit in the dimensions of their pedagogical approach and the product students produced. The second interview focused on the third dimension of PB-LIFTS, and questions were designed to more deeply understand each teacher's perspective of the processes students engaged in over the PBL unit to produce the product.

Teachers reviewed the text excerpts and emergent themes for accuracy. Next, using a PBL-HOTS analysis packet, I added the results of Phase 1 and 2 data in the PB-LIFTS framework for the third debriefing interview with each teacher to discuss the findings and answer the research questions. Thus, using the PB-LIFTS framework as a guide for three study phases, rich data were gathered and analyzed using cycles of IPA analysis to understand each teacher's experience in depth.

A hallmark of IPA is that it is an ideographic research method that allows the researcher to gain deep insights from detailed personal accounts; the intent is to understand perceptions of phenomena within a given context from the participant's point of view. Moustakas (1994) referred to his participants as "coresearchers" and believed that the art of phenomenological research required that he join in partnership with his participants to explore personal meanings (p. 19). For this reason, I engaged with each teacher in joint interpretation, exploring the meaning of the research results using PB-LIFTS in the final debriefing interview. Thus, as coresearchers, we used PB-LIFTS to assess a PBL unit for HOTS in the pedagogical design, student product, and PBL processes to answer the research questions.

Nature of the Study

For this qualitative study, I used the IPA method described by Smith et al. (2009) as a strategy for systemic interpretation of participant reflections on a personally meaningful experience or phenomenon. The key phenomenon explored was how PBL strategies were used to build HOTS with DHH students. According to Smith (2011), IPA provides a method for participants to make meaning of their experiences within a bounded study while the researcher tries to make sense of what the experiences are like from each participant's perspective. As described by Smith, IPA involves in-depth data collection regarding how individuals experienced a phenomenon with a small number of purposefully selected participants, usually through one-on-one semistructured interviews. The IPA design for this study is ideal for exploring how teachers of the deaf experienced using PBL to build HOTS with DHH students. Participants should be homogeneous and can be selected using specific criteria to assure that they have experience with the phenomenon of interest. It was anticipated that finding qualified participants would be challenging as teachers of the deaf are scattered across a range of settings serving a low incidence population and many teachers of the deaf provide pull-out services to DHH students one-on-one (Luckner & Ayantoye, 2013) which would not be conducive for collaborative learning. It is unknown how many teachers of the deaf are skilled in implementing PBL with DHH middle and high school students, but the goal was for a minimum of three and a maximum of four participants for the study as IPA is typically conducted with a small number of participants due to volume of data that is collected and the intensity of analysis.

The first two phases of data collection included a PBL overview form and one journal prompt for each phase that I sent and received from teachers via e-mail, as well as semistructured interviews I held remotely from my home office using recorded Zoom video conferencing technology. The interviews were conducted in American Sign Language (ASL) then the video footage was interpreted by a certified interpreter to an audio recording and sent electronically to a professional captioning agency via a secure link. The captioning agency produced transcripts of the interviews and sent them to me as an e-mail attachment. I compiled all the data and organized it according to the three dimensions of PB-LIFTS, pedagogy, product, and process. After several rounds of IPA analysis and member checking, the data were applied in the PB-LIFTS framework using a PBL-HOTS Analysis Packet to identify HOTS and share with teachers in Phase 3 of the study that culminated in a debriefing interview.

Regarding data analysis, Smith et al. (2009) described IPA as having five steps that involve reading and rereading the transcripts, taking notes, and coding for themes. The IPA data analysis process can be summarized as detailed cycles of examination in which the researcher seeks emergent themes within each case then searches for patterns across all cases. Thus, IPA follows a convergent to a divergent process of data analysis. This research method allowed me to explore each teacher's experience in-depth and to engage in coresarch with participants in the third interview applying the study results using PB-LIFTS to answer the central research question and related questions

Definitions

Active learning: This form of constructive pedagogy is the least cognitively demanding on the PB-LIFTS framework for this study. In active learning, the teacher created structured activities and worksheets; students discover facts, organize, and process information to aid recall (de Corte, 2010; Schallert & Martin, 2003). Key indicators of active learning pedagogy are that the learning process is directed by the teacher, students are to complete specific tasks following the structure and sequence provided, and students' PBL products in active learning are typically predetermined

Connected learning: In connected learning teachers serve as mentors to students who direct the learning process and produce unique products through networked construction. This form of constructive pedagogy is the most cognitively demanding of the four types on the PB-LIFTS framework. Connectivism is an expansion of constructive learning for a digital age (Siemens, 2004) in which internet technologies impact the learning process, including how learners access, share, and create new knowledge across networks.

Constructive learning: This is the second of four pedagogies in cognitive demand on the PB-LIFTS continuum. In constructive learning, the teacher serves as a cognitive guide who facilitates the learning process. Students actively create knowledge from their learning experiences and attempt to make sense of it (de Corte, 2010; Ultanir, 2012). Key indicators of constructed pedagogy are that teachers assume the role of facilitator, students manipulate materials and discover knowledge, and products are produced through hands-on construction and are usually predictable.

Deaf and hard of hearing (DHH): The DHH acronym is used in this dissertation in place of deaf and hard of hearing and includes an array of terms commonly used to indicate hearing loss degree, etiology, or cultural affiliation such as Deaf, deaf, hard of hearing, late-deafened, hearing handicapped, and hearing impaired. DHH is frequently used in deaf education research. DHH students refers to students identified as having an educationally significant hearing loss who receive special education services or oversight and consultation according to the Individualized Education Plan (IEP) (Antia & Rivera, 2016).

Higher order thinking skills (HOTS). Twenty-first century skills and HOTS are often used interchangeably and can be defined as constructive learning behaviors such as problem-solving, critical thinking, metacognition, collaborative communication, creativity, digital literacy, and meaning-making (Germaine et al., 2016; Kivunja, 2015; Pellegrino, 2017).

Innovation: Cognitive processes and 21st century skills performed to produce an artifact that is original in some way and valued as satisfying a need (Amabile, 1988; Pellegrino, 2017; Shalley, Hitt, & Zhou, 2015). When applied to PBL learning processes, this definition may imply that innovative thinking can be observed and assessed when individuals engage constructively applying 21st century skills to produce a product that is appropriate to the task.

Itinerant teacher of the deaf: These teachers travel from school to school providing IEP services to DHH students. They usually serve all levels of students from preschool through high school located within a geographical area and in many cases, they do not have dedicated space. Due to scheduling constraints they most often provide pull-out services to students one-on-one in available areas such as hallways, staircases, and lunchrooms rather than push-in services in general education. Students in neighborhood school placements receive an average of 2 to 2.5 hours per week of direct services time from an itinerant teacher and spend approximately 76% of their time in general education classes (Luckner & Ayantoye, 2013).

Project-based learning (PBL): PBL is a constructivist instructional approach that includes five key features: (1) complex authentic learning aligned with curriculum content and standards; (2) Students focus on an authentic essential question that is revisited over an extended period of time; (3) learning is constructed by small teams of students through collaborative inquiry and knowledge building; (4) students are given the responsibility to research, design, organize, and manage their project while exercising autonomy and collaborative decision making; (5) PBL culminates in the production of a realistic product that is a tangible representation of student learning for public presentation (Chowdhury, 2015; Condliffe, Visher, Bangser, Drohojowska, & Saco, 2016; Larmer et al., 2015).

Project-based learning and innovation for teachers and students (PB-LIFTS): The conceptual framework developed for this study is PB-LIFTS. The face of PB-LIFTS is a matrix of 16 cells. The horizontal dimension is a continuum of four constructivist instructional strategies ranging from teacher-centered learning associated with lower ordered thinking skills to student-centered practices associated with HOTS. The vertical dimension is a continuum of four levels of product innovation ranging from lower ordered thinking skills to HOTS in cognitive complexity. Behind the face of PB-LIFTS is a third dimension composed of four student learning processes that support the development of the product evaluated in the vertical dimension of PB-LIFTS. The four learning processes are called task, thinking, teamwork, and tools (4Ts). There are four levels of cognitive demand for each of the 4Ts from lower ordered thinking skills to HOTS. Using the three dimensions of PB-LIFTS to evaluate a described PBL unit, both teachers and students may become aware of present levels in the three dimensions and identify how they might *lift* or increase HOTS in future PBL units.

Social learning: Socially constructed learning is the third most cognitively demanding of four types on the PB-LIFTS framework for the study. In social learning, knowledge is generated via dialog and interaction fostered by teacher guided engagement in real-world contexts (Doolittle, 2014). Students take more responsibility for learning from one another, respecting personal and cultural differences, and learning is driven through collaboration (Roessingh & Chambers, 2011; Scheer, Noweski, & Meinel, 2012; Skinner, Braunack-Mayer, & Winning, 2016). Key indicators of social learning pedagogy are that teachers assume a supportive role, students take leadership roles and collaborate, knowledge is co-constructed through social interaction and collaboration, and student products cannot be predicted in advance of social learning engagement.

Teacher of the deaf: Special education teachers who are licensed to support and instruct students who are deaf or hard of hearing (DHH) according to Individualized Education Programs (IEPs) providing services in a number of environments such as separate schools, self-contained classes within a public school, general education classes, charter schools, or private institutions. (Antia & Rivera, 2016; Luckner & Ayantoye, 2013; Luckner & Dorn, 2017).

Traditional instruction: A long-standing widely used teacher-centered pedagogy associated with behaviorist philosophy. Typically, traditional instructors transmit knowledge to passive students who are tested on recall of facts using paper and pencil tests containing right or wrong answers (Brownell, Sindelar, Kiely, & Danielson, 2010; Ware, 2013).

Transformative learning: When students use HOTS, transformative learning generally occurs. This is a process in which learners are meaning makers who apply critical thinking skills and develop new perspectives that guide action (Mezirow, 1997). Metacognitive processes are applied in transformative learning to challenge previous assumptions, frames of reference, or habits of mind and through reflective thinking and discourse learners develop new insights that support the assimilation of knowledge for decision making.

Assumptions

This IPA study is based on several assumptions. The first assumption is related to the IPA theoretical principle that humans are naturally compelled to make sense of experiences that they care about (Smith et al., 2009); therefore, it is assumed that teachers of the deaf would be open to explore a previous teaching experience in-depth and be open to gaining new insights. A second assumption is that teachers will respond openly and honestly to interview questions and journal prompts, reflecting upon a single PBL unit previously implemented. This assumption is important to identify levels of thinking in the three dimensions of PB-LIFTS to gain an understanding of how teachers experienced using PBL to build students' HOTS. A third assumption is related to differentiated instruction and teacher reflections on experiences implementing PBL. Typical classes of

DHH students are heterogeneous regarding several student characteristics such as language and communication skills, communication modes, prior knowledge, social skills, academic skills, and the presence of additional conditions. Therefore, it is assumed that experienced teachers differentiate instruction to include all students in the learning context, and methods of differentiating the PBL unit would be part of their interview responses. This information may add important insight regarding how teachers of the deaf build HOTS with all students.

Scope and Delimitations

PBL is a comprehensive multilayered instructional strategy that has been studied in a multitude of learning environments around the world with students of all ages, yet PBL research in deaf education is scarce, and studies that focus upon levels of cognitive demand manifested as HOTS in multiple dimensions of PBL were not found in the literature review. This study addressed both gaps in the body of PBL research by focusing upon the experiences of teachers of the deaf using PBL to build HOTS with DHH students. Thus, the design of this study was narrowed by a purposeful selection of participants and the features of PBL examined in the selected dimensions of the conceptual framework; additional delimitations include temporal aspects of the study and resources. In IPA studies, the participants should be reasonably homogeneous, and for this reason, middle and high school teachers of the deaf who used PBL were sought for this study; however, even within these boundaries, significant diversity may be present among the participants. Teachers of DHH students may also be deaf or hard of hearing and would have a preferred communication mode. They may serve DHH students in a variety of placements such as separate schools for the deaf, center-based programs in public schools, day schools, neighborhood schools, and private schools. DHH students receive an assortment of services within the purview of the IEP provided via a range of communication modes. Smith et al. (2009) suggest that novice IPA researchers have a small sample size "between three and six participants" (p. 51). This study was limited to three or four teachers of the deaf who met the following criteria: (a) had five or more years teaching experience, (b) taught DHH middle or high school students, (c) had experience using PBL with DHH students. There were no restrictions regarding teachers' hearing status, the school location within the United States, type of service provision, or communication mode such as ASL, listening and spoken language, or simultaneous communication.

While the framework chosen for this study supports the purpose of this investigation, it also limits the study. Thus, three dimensions of PBL were explored, including the teachers' pedagogical design, the student product, and student processes. Other aspects of PBL, such as student presentations, were not within the boundaries of the study. Participants were asked to reflect upon one favorite PBL implemented in the past with DHH students. Reflecting upon a previous teaching experience imposes a temporal constraint as teachers needed to remember details. Another boundary of this study was that teachers were to describe PBL units implemented with groups of DHH students only. Thus, teachers of the deaf who wished to select an experience using PBL with DHH and hearing peers together were eliminated from the participant pool. The reason for this was that PBL is a social learning strategy and when DHH students are grouped with hearing peers, this adds communication complications (Antia, Kreimeyer, & Reed, 2010; Ayantoye & Luckner, 2016; Bartlett, 2017; Braun et al., 2018; Oliva et al., 2016; Olsson et al., 2017) that can impact PBL outcomes. Secondly, one of the aims of this study was to explore teacher perceptions of how DHH students exhibited HOTS when engaged in PBL; therefore, students with typical hearing were excluded.

Limitations

In IPA research, there are limitations inherent in the design; however, study design limitations can also be viewed as strengths. First, IPA studies typically have a small sample size, which may be perceived as a limitation because the results cannot be generalized. Secondly, IPA studies are usually pursued by a lone researcher responsible for collecting data one-on-one with each participant; therefore, perceptions of researcher bias can threaten the credibility of the study. The hallmarks of IPA studies are rich descriptions and detailed analysis of a large volume of data generated case-by-case typically through semistructured interviews with a small number of participants who have experience with a phenomenon of interest. This allows the researcher to gain deep insights into participants' experiences that cannot be gained via many other research methods; hence a small sample size is necessary to achieve the purpose of an IPA study. A small sample size may also limit transferability; therefore, careful documentation of data collection and analysis procedures increased the transferability of the study to other settings. Also, the theories behind PB-LIFTS have been tested in prior research and can be easily replicated as the assessment procedures and documents were provided in the appendix to support transferability. Another limitation of the study design was that I was the sole researcher with limited time and resources. As the researcher, I was responsible for collecting and analyzing data; this presents the possibility of researcher bias and raises questions related to the trustworthiness of the study. To minimize bias and to support the credibility, dependability, and confirmability of the study, several research conventions were used, such as member checking, including outside experts, keeping an audit trail, and triangulating multiple sources of data. These are described in detail in Chapter 3 in the section titled Issues of Trustworthiness.

Significance

The significance of a study is determined in relation to advancing knowledge in the field, improving practice, encouraging innovative strategies, and contributing to positive social change. The purpose of this qualitative study was to explore the experiences teachers of the deaf in using PBL to build HOTS with DHH students in the dimensions of pedagogy, product, and process. Little is understood about how teachers of the deaf use PBL with DHH students to foster the development of HOTS. The result of this study may provide a new awareness of how innovative practices that are beneficial to students with average hearing acuity can also be effective with DHH students. The conceptual framework I developed for the study addressed the need for a flexible research-based method for identifying and evaluating HOTS in teacher pedagogical designs as well as student PBL products and processes. Thus, in relation to advancing knowledge, demonstrating how HOTS can be assessed in PBL could alleviate some of the difficulty teachers experience with PBL assessment and support goal setting for both teachers and students for future improvement.

In relation to improving practice, as a group, DHH students are traditionally underserved, but like other students, they also need opportunities to develop HOTS for life in the 21st century. The study expanded the body of research on PBL and HOTS to teachers of the deaf who teach a low incidence population of students. This increases awareness that PBL can be applied in any context to promote rigorous learning and the development of 21st century skills for career readiness. Addressing these two gaps and answering the research questions provides insights to bridge theory and practice; further, this understanding may have social and perhaps universal significance for PBL teachers and teacher training programs everywhere.

In relation to contributing to innovative practices, findings from this study showed that when DHH students are given innovative, constructive learning opportunities with skilled teachers, they can demonstrate HOTS. This awareness may prompt researchers to extend this study and influence more teachers to adopt PBL with the DHH population as well as other underserved groups. Further, this study illuminated the need for the development of lessons designed to prepare students to focus upon PBL processes that promote HOTS.

In relation to potential positive social change, findings from this study may encourage educators to place greater emphasis on learning processes as a precursor for innovative products, support student-centered formative assessment practices, and promote awareness that educational strategies such as PBL have the capacity to promote rigorous learning that can prepare students for 21st century careers and higher education. This may highlight the need for the learning environment and service delivery changes that are conducive to social constructive and connected learning for DHH students. Providing all students with opportunities to develop 21st century skills is not an option, it is an imperative and such awareness may garner the support of policymakers, teacher trainers, stakeholders, and educators at every level to change the course of history for the oldest branch of special education.

Summary

In this introductory chapter, I summarized the major sections of this qualitative study, which used the IPA research design. The background section and problem statement established the need for this study. The purpose of this study was to explore the lived experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the dimensions of pedagogy, product, and process. The CRQ and RRQs guided this study and aligned with the conceptual framework I developed, called PB-LIFTS (described in Chapter 2). The nature of the study included the rationale for choosing IPA as the research method for this study. Following these are key definitions that were used in the study. The assumptions describe aspects of the study that were assumed but cannot be proven. The sections on scope and delimitations, as well as limitations, frame the boundaries of this study. The final section of Chapter 1 highlights the significance of this study with a description of its potential impact on general education, deaf education, and social change.

Chapter 2 is a literature review that begins with an outline of the research strategy followed by a detailed description of the conceptual framework for the study. The literature review is a thorough examination of the scholarly writing and empirical studies related to PBL, HOTS, and deaf education, including a historical background as it relates to the most recent research on these topics. This review was exhaustive and revealed several gaps that established the need for this study as well as the potential of this study to impact social change in education.

Chapter 2: Literature Review

PBL is a popular teaching strategy for engaging students in constructive social learning that promotes the development of valuable workplace skills needed for the 21st century, such as communication, collaboration, critical thinking, and creativity. PBL has been implemented across a range of learning contexts, and experts support using PBL to develop HOTS with all students, including diverse learners with special needs (Du & Han, 2016; Hovey & Ferguson, 2014). Despite an extensive body of research on PBL, studies with DHH students were nearly absent in the literature; therefore, the research problem I addressed in this study was that little is understood about how teachers of the deaf use PBL with DHH students to foster the development of HOTS. The purpose of this qualitative study was to explore the lived experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the dimensions of pedagogy, product, and process.

Since 2010, a wide body of research on PBL has emerged, ranging from studies of kindergarteners learning science concepts using active learning PBL strategies to high school and college students from multiple countries developing HOTS through connected learning using PBL strategies (Condliffe et al., 2016). Although studies often reported that students developed HOTS using PBL, collectively, the research was often unclear about how HOTS were measured, studies were limited in scope, or studies were context-specific. Researchers indicated that a comprehensive method of assessing HOTS in PBL that could be adapted to a variety of learning contexts was needed. Secondly, in recent literature, scholars suggested that new approaches to teaching DHH students were needed to prepare them with 21st century skills for college and careers, yet empirical studies applying PBL with DHH students were scarce. However, peer-reviewed literature related to the need for constructivist instructional approaches at the college level with DHH students to increase participation in STEM fields recently appeared in the literature and might indicate that PBL studies with DHH students will be forthcoming. My study might support efforts among general educators at all levels and subject areas, as well as teachers of the deaf, to implement PBL and promote the development of HOTS; further, the conceptual framework for this study might increase understanding of how HOTS can be identified and measured using a systemic examination of teacher PBL pedagogy, student PBL products, and student PBL learning processes.

To prepare for this study, I pursued an extensive literature review to gain an in-depth understanding of the background and current research related to PBL, HOTS, and deaf education. The sections in this chapter include a description of the literature search strategy, literature used to build the conceptual framework for the study, and literature reviewed to gain a holistic and multidimensional understanding of PBL and HOTS with attention to pedagogy, products, and processes, as well as the relationship of these topics to the experiences of deaf educators. Thus, this literature review addresses the following topics in detail: (a) PBL, (b) history of PBL, (c) benefits of PBL, (d) challenges of PBL, (e) teacher perceptions of PBL, (f) relationship between PBL and HOTS, and (g) pedagogy in classrooms with DHH students. The chapter ends with a summary.

Literature Search Strategy

To obtain literature for this review, I used several library databases and search engines. The central research question, related questions, and Level 1 dissertation headings for the study were used as the starting point to generate keywords for the library search of academic journals from the past 5 years. This review of educational literature began by searching the Walden University Library Thoreau Multi-Database, which allowed me to locate scholarly studies according to requested parameters including search terms, a range of dates, full-text access, and peer-reviewed status. I also used Google Scholar. My preferred databases were Academic Search Complete, Education Source, ERIC, ProQuest Central, SAGE Journals, and Taylor and Francis Online.

As with every search engine, Google Scholar has advantages and disadvantages. Google Scholar did not allow me to limit searches to peer-reviewed studies, so it was necessary to consult Ulrich's Periodicals Directory. I judged that approximately 850 articles had potential value to my study and therefore I read and annotated them. More than 510 articles were included in this literature review, and of these, approximately 140 were published in peer-reviewed journals within the last 3 years.

In order to conduct a thorough search of existing literature on deaf education and pedagogical practices, two subscriptions were needed including, the *Journal of Deaf Studies and Deaf Education* and *JSTOR* as well as recent volumes of *Oxford Handbooks* and the *Perspectives on Deafness* series published by the Oxford University Press. Authors of recent studies in deaf education frequently refer to events and individuals from the past who contributed to modern pedagogical approaches with DHH students; therefore, to gain a deep understanding of current issues in deaf education, it was necessary to research the early years of this field in the United States. Primary sources of literature from the 19th century were available from the online archive of *American Annals of the Deaf and Dumb*.

The literature review was an iterative process as the study progressed through several topics; consequently, many search term combinations and semantic variations were used. I used four broad themes and associated search terms to identify appropriate scholarly articles follow.

- Pedagogy: *learning, instruction, active, student-centered, teacher-centered, traditional, behaviorism, constructive, social constructive, connectivism, disability studies, critical pedagogy, special education, paradigm shift.*
- 21st century skills: *education reform, higher order thinking, cognition, domains, critical thinking, digital literacy, education technology, collaborative, teamwork, Web 2.0, common core, 4Cs.*
- Project-based learning: *project method, design-based, experiential learning, problem-based learning, discovery learning, cooperative learning, backward planning, flipped classrooms, service learning, situational learning, distance learning, benefits, challenges, assessment, higher order thinking, teamwork, process, product, implementation, beliefs, perceptions, peer feedback, rubric, technology.*
- Deaf education: *history, student outcomes, academic, programs, inclusion, general education, itinerant, residential, teacher training, audism, inclusion, mainstream, deaf residential, oral, manual, individualized education plan, social skills, assessment, instructional approach, strategies.*

Because there was little current research on the topic of PBL with DHH students, I searched many variations of PBL such as experiential, discovery, and service-learning with a variety of terms related to deaf individuals such as *hard of hearing*, *hearing impaired*, and *hearing loss* entered to assure that the literature review was thorough.

Conceptual Framework

The purpose of this qualitative study was to explore the experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the dimensions of pedagogy, product, and process. The conceptual framework served as a guide to collect data and answer the research questions. PBL is an instructional strategy based upon the overarching theory of constructivism popularized by Dewey (1938), who believed that learning is an active process in which learners interact and construct their own understandings. Political agendas impacted the growth and development of social constructive learning throughout the 20th century; however, scholarly literature indicates that PBL and similar instructional methods have evolved significantly since the turn of the 21st century. A rapid surge in PBL studies occurred between 2010 and 2019; this literature revealed that PBL had been implemented globally across all age groups in a multitude of learning contexts to build skills needed for college and career readiness. Engagement in PBL calls for students to collaboratively focus on a challenging problem or question of authentic interest over a sustained period. Working in small teams, students investigate the topic and cooperatively become *meaning makers* by developing a product representative of their learning to share with a public audience (Larmer et al., 2015). Over the course of a PBL unit, students can engage in using process skills that are in high demand by employers in the modern workplace; however, PBL process skills are multilayered and can be challenging for teachers to evaluate. PB-LIFTS is the conceptual framework I developed for this study to identify levels of cognitive skills in PBL.

As a general overview, PB-LIFTS is a conceptual framework designed to explore how teachers of the deaf used PBL to build HOTS with DHH students in three dimensions of a PBL unit previously implemented. The face of the PB-LIFTS framework is a 16-cell matrix. The horizontal dimension is a continuum of four types of instructional pedagogy, including (a) active, (b) constructed, (c) social, and (d) connected. The vertical dimension of PB-LIFTS is a continuum of four levels of student product innovation, including (a) reproduce, (b) enhance, (c) transform, and (d) innovate. Progressive levels of cognitive demand were embedded within each of these two dimensions ranging from lower order thinking skills to student-driven learning requiring HOTS (Figure 2).

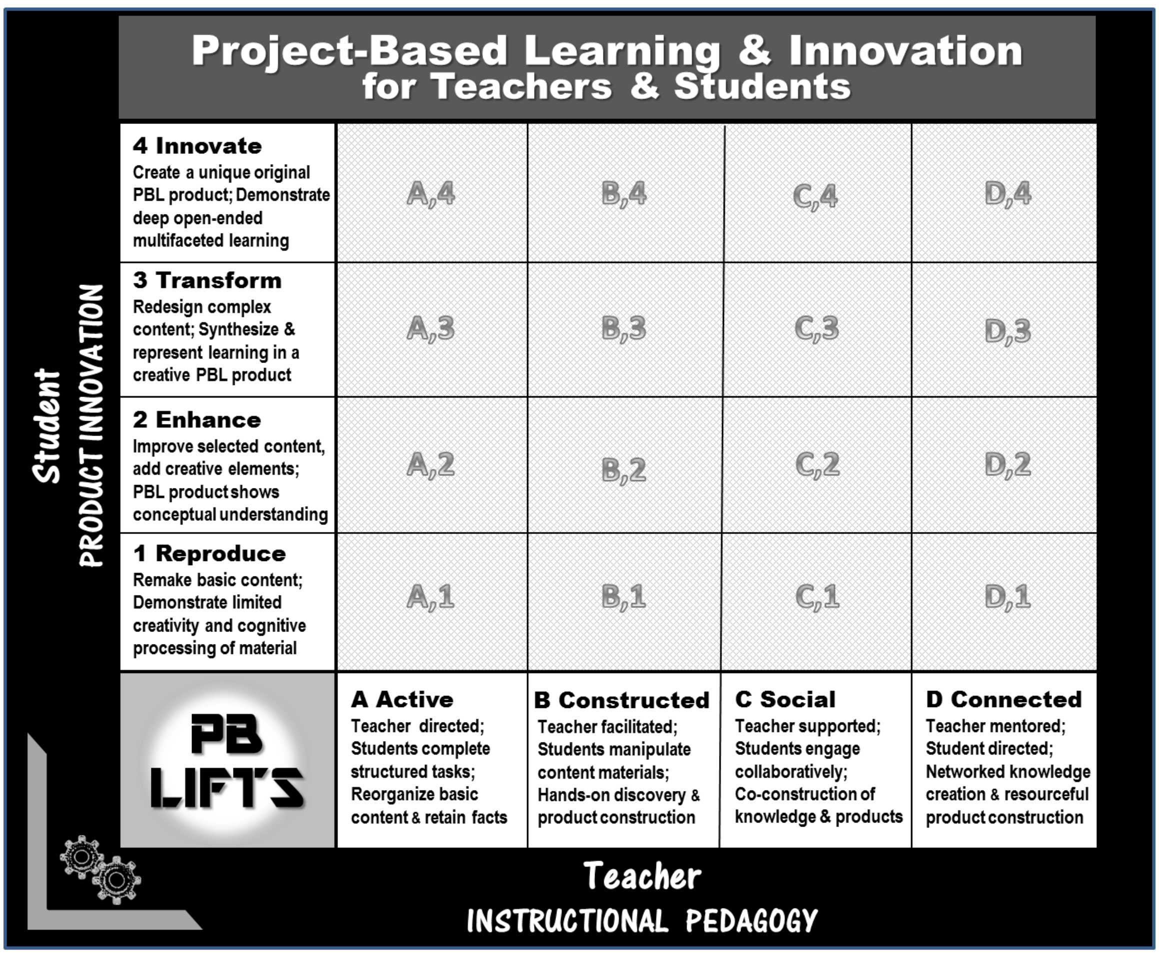


Figure 2. Project-based learning and innovation for teachers and students framework

Embedded in the student product innovation dimension is a less tangible third dimension of PB-LIFTS composed of key *learning processes* in which students engage over the course of a PBL unit. The third dimension of PB-LIFTS is composed of four learning processes, including how students approach the PBL task, engage in thinking, function as a team, and use resources as tools to develop and produce the final PBL product. I refer to these processes as the 4Ts: task, thinking, teamwork, and tools. Each process is described in the PB-LIFTS conceptual framework as having four levels ranging from lower ordered thinking skills to HOTS. A visual representation of the PBL learning processes in the third dimension of PB-LIFTS that support the development and production of a student product is provided in Figure 3.

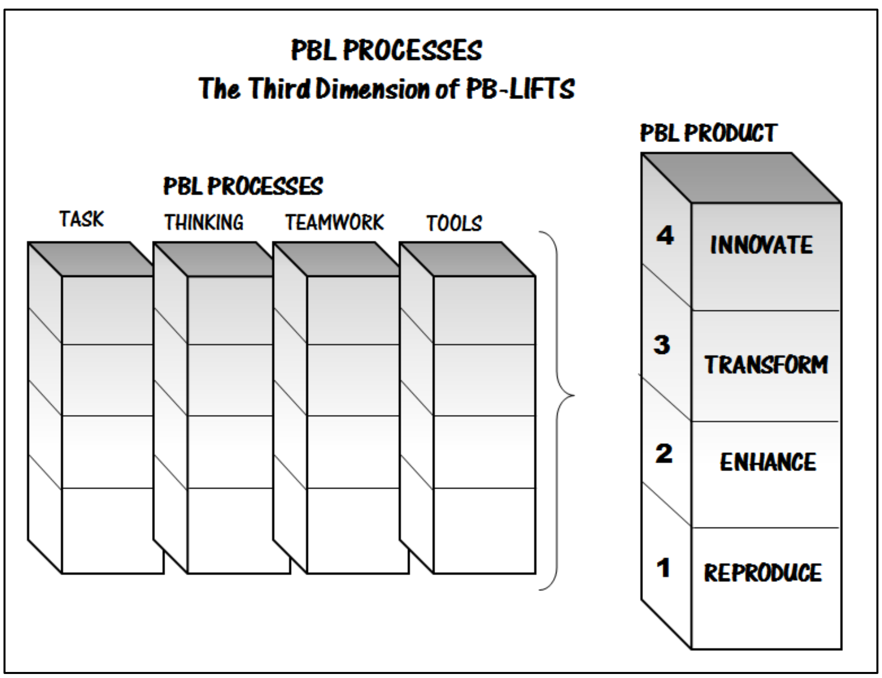


Figure 3. Project-based learning and innovation for teachers and students third dimension of project-based learning processes.

Although it is widely acknowledged that learning processes are crucial to PBL outcomes, it is often reported in the literature that teachers are not confident in assessing them. Thus, I incorporated four PBL processes to explore the third dimension of PB-LIFTS to gain a deeper understanding of HOTS. Each process skill has four levels of difficulty. The three dimensions of PB-LIFTS have a dynamic relationship; the teacher's pedagogical learning design serves as a springboard to immerse students in PBL learning processes, which culminate as a collaboratively produced product representing student learning. Therefore, PB-LIFTS is designed as a lens to explore three dimensions of a PBL unit and to identify levels of HOTS in the pedagogical design, the final product students produced, and the PBL processes in which students engaged to produce the product. The PB-LIFTS framework includes brief descriptions of four levels from lower ordered thinking skills to HOTS in each dimension; therefore, the framework can be used to illuminate the current status of HOTS, and descriptions of the next level could be used for goal setting. Thus, the PB-LIFTS acronym for project-based learning and innovation for teachers and students implies that this conceptual framework may promote greater awareness of personal contributions in PBL for both teachers and students to *lift* or increase HOTS in future PBL units.

Using the PB-LIFTS conceptual framework allowed me to explore HOTS in multiple dimensions of PBL experiences. Another benefit of using PB-LIFTS is that it could be used to explore HOTS in any teacher's described PBL experience regardless of the age level or subject taught. In any PBL unit, teachers implement constructivist learning in which students actively engage; thus, to some degree, all PBL units will have components of collaborative learning and use of resources to develop and produce a product in response to the essential question or authentic problem. All these aspects of PBL can be flexibly explored using the PB-LIFTS framework and assessment tools to illuminate HOTS.

The next section is a literature review, where I provide details regarding the PB-LIFTS framework. With an overarching focus on HOTS, the basis for the development of this conceptual framework, I clarify how HOTS can be assessed in PBL units. The section includes background on theorists, theoretical constructs, assessment tools, and research related to the three dimensions of PB-LIFTS.

Higher Order Thinking and Project-Based Learning and Innovation for Teachers and Students

Wagner and Dintersmith (2015) argued that the industrial world had entered the age of innovation, where HOTS is central to the 21st century skillset essential for success. The global education imperative to develop students' *super skills* (Kivunja, 2015, p. 225) or 21st century skills such as critical thinking, problem-solving, creativity, communication, collaboration. Learning these skills requires HOTS (Cobo, 2013; Kalelioğlu, & Gülbahar, 2014) as they demand meta-knowledge or awareness and actions that promote learning (Kereluik et al., 2013). The 21st century skills movement in education has drawn attention to HOTS and how teachers can foster the development of students' 21st century skills. This shifts attention from *what* one knows or submits for a grade to *how* one learns or the processes of learning. Kivunja (2015) asserted that all the features of HOTS could be observed and evaluated when students engage in quality constructivist learning such as PBL.

PBL engages students in applying 21st century skills as they must work in teams and strive to communicate and collaborate effectively while applying critical thinking skills to build upon one another's ideas to create projects using appropriate resources and tools. This engagement requires HOTS to produce products representative of their learning that is of authentic value to an audience. Amabile (1993) maintained that such team engagement requires creativity, and creativity requires HOTS. The PB-LIFTS is a tool for identifying levels of HOTS in a teacher's described pedagogical design for a PBL unit, student product innovation, and student learning processes.

The purpose of this qualitative study was to explore the experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the areas of PBL pedagogy, product, and process. Levels of thinking were embedded in both the pedagogy and student product innovation dimensions of the PB-LIFTS and were based upon revisions of Bloom's (1956) famous taxonomy of cognitive objectives. Numerous studies had shown that careful analyses of the language teachers used to describe educational objectives and student engagement in learning revealed levels of thinking (H. M. Cannon, Cannon, Geddes, & Feinstein, 2016; Dwyer, Hogan, & Stewart, 2014; FitzPatrick, Hawboldt, Doyle, & Genge, 2015; Ganapathy, Singh, Kaur, & Kit, 2017; Nkhoma et al., 2017; Schaffernicht & Groesser, 2016).

To clarify how the PB-LIFTS conceptual framework could be used to answer the research questions related to teacher pedagogy and student products, a description of the theoretical underpinnings follows. Anderson and Krathwohl (2001) revised Bloom's (1956) original taxonomy and asserted that a sequence of six verbs and associated synonyms could be used to identify cognitive processing. From lowest to highest, these were: remember, understand, apply, analyze, evaluate, and create. It is important to mention that the six verbs are used to semantically represent each level of cognitive processing, and many synonyms could be used interchangeably, such as recite for *remember* and design for *create*. Churches (2007) expanded upon Anderson and Krathwohl's (2001) work by applying cognitive verbs related to levels of thinking when technology is used as a learning tool and called this Bloom's Digital Taxonomy (Churches, 2007). He maintained the same sequence of six verbs from RBT and added synonyms related to technology. For example, Churches identified bookmarking, Tweeting, and Boolean searches as lower order thinking skills associated with remembering and understanding; examples of HOTS in the digital taxonomy are Wiki building, video blogging, and podcasting. These are related to the highest level of the taxonomy, which is *create*. Hence, levels of thinking can be identified by analyzing action words teachers use to describe a PBL unit, whether technology is used. Verbs from RBT (Anderson & Krathwohl, 2001) and the digital taxonomy (Churches, 2007) were flexibly embedded in both dimensions of PB-LIFTS. A diagonal arrow across the framework shows the direction of HOTS on the matrix. (Figure 4).

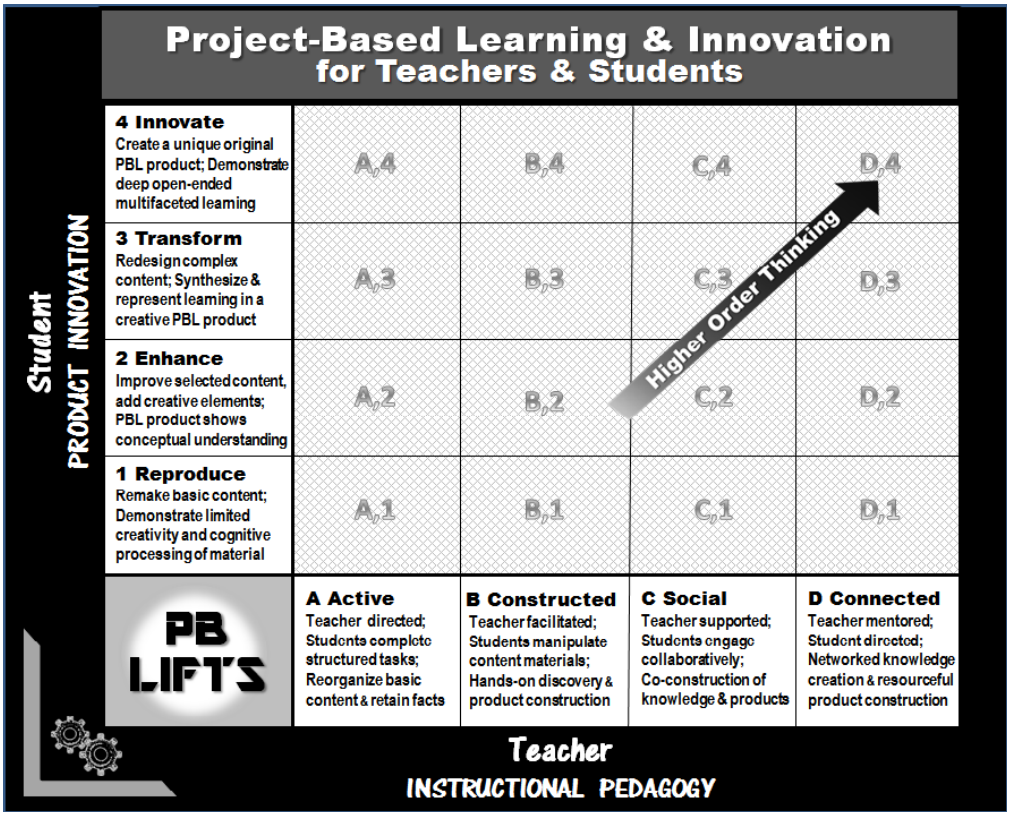


Figure 4. Project-based learning and innovation for teachers and students framework showing higher order thinking is embedded in both the pedagogy and product dimensions.

The HOTS arrow on the PB-LIFTS indicates that as both continua of teacher pedagogy and student product innovation advance, so do HOTS. Within one PBL activity requiring multisteps, several of the RBT verbs may be identified. PB-LIFTS framework does not suggest that HOTS using PBL is a lockstep process; across the phases of a PBL project, all levels of thinking may be demonstrated. Students should be flexible and engage in cognitive processes appropriate to the task. This study focused on levels of thinking students demonstrated in the development and production of a PBL product as described by teachers reflecting upon PBL experiences in semistructured interviews. To understand the revisions of Bloom's (1956) taxonomy that were applied in the study, I provided an overview of the original work that led to the revisions.

Bloom's Taxonomy of Cognitive Objectives

Bloom (1956) and his team of scholars developed a method of classifying levels of cognition that is a well-known conceptual framework among educators around the world; the taxonomy henceforth referred to as Bloom's taxonomy has been applied at every instructional level across all content areas for over half a century (Bouchard, 2011; Cochran, & Conklin, 2007; Krathwohl, 2002). Bloom's taxonomy provided a common language for teachers and was intended to be used for a variety of educational purposes such as planning for learning, setting goals, measuring outcomes, and sharing teaching experiences (Candela, 2014; Krathwohl, 2002; Munzenmaier & Rubin, 2013).

Bloom's (1956) taxonomy provided teachers with a tool that could be used to assess instructional levels of rigor and identify students' levels of thinking based upon observable behaviors when engaged in constructive learning. The six original levels of Bloom's taxonomy were stated as nouns: knowledge, comprehension, application, analysis, synthesis, and evaluation. These categories were organized as a progression from simple concrete learning to complex abstract learning. The first three levels were referred to as lower ordered thinking skills, and the upper three categories were designated as HOTS.

Bloom (1956) and his colleagues included action words and activities associated with each level of the taxonomy as a means of identifying the cognitive complexity of learning that could be applied regardless of content, setting, or instructional approach. Teachers typically use action words in instructional plans and assessments; therefore, levels of thinking and curricular rigor could be identified by matching action words from learning objectives, activities, and outcomes to cognitive levels of the taxonomy. For example, at the lowest level labeled knowledge, students recognize, recall, and remember facts. An educational objective stating that the learner will recite the Preamble to the United States Constitution would be considered a low-level cognitive objective because the action word, recite, aligns semantically with the action words recognize, recall, and remember. The simplicity of the taxonomy and its practical use of action words to identify levels of thinking was a feature that resonated widely with teachers and teacher trainers (Cochran & Conklin, 2007; Doughty, 2006; Munzenmaier & Rubin, 2013).

By 1971 Bloom's taxonomy was one of the most influential works in education (Adams, 2015; Shane, 1981) but not without critics (Seaman, 2011). One of the most significant criticisms was that the taxonomy was ambiguous when terms were applied in different contexts. For example, a student activity could be described as creative, which is the highest level on the cognitive processes continuum, yet students could be working with simple factual material. Thus, using the six terms alone to identify levels of thinking was insufficient; therefore, the original taxonomy had serious practical limitations (Amer, 2006). Booker (2007) argued that the use of Bloom's taxonomy caused teachers to devalue memorization of basic facts that support HOTS. Another criticism was that the taxonomy kept teachers' expectations low as the hierarchy or ladder of cognitive skills implied that lower levels of thinking must be mastered before students could advance to higher levels (Case, 2013). Doughty claimed that the hierarchical ladder promoted traditional behaviorist instructional pedagogy and did not support constructivism (2006). After much debate, it was determined that students should have experiences functioning at all levels of the taxonomy, and strict adherence to following the sequence of the taxonomy should be avoided (Bouchard, 2011; Case, 2013).

After Bloom's death in 1999, Anderson and Krathwohl developed the RBT in which they introduced new terms for the levels of thinking with an emphasis on flexibility and added a new dimension for analyzing levels of thinking in context (Anderson & Krathwohl, 2001). The authors of RBT maintained six levels of cognitive processes, but the level titles were changed from nouns to verbs. The levels were renamed: remember, understand, apply, analyze, evaluate, and create. Anderson and Krathwohl also supplied clarifying verbs stated in the progressive for each level. To make the cognitive processes more meaningful and to ameliorate the problem of ambiguity using Bloom's (1956) one-dimensional taxonomy, Anderson and Krathwohl added a vertical dimension consisting of four knowledge levels. The six cognitive processing verbs ranged from low to high horizontally, and the four knowledge levels were arranged vertically, creating a matrix for evaluating the rigor of learning objectives and activities. Anderson and Krathwohl demonstrated how the matrix could be used to map levels of thinking for learning objectives and activities. The knowledge levels were mainly four ways students might work with content from simple factual manipulation to rigorous engagement requiring meta-awareness. From lower to higher order thinking, the four levels were *factual*, *conceptual*, *procedural*, and *metacognitive*. I provided the two dimensions side by side (Figure 5).

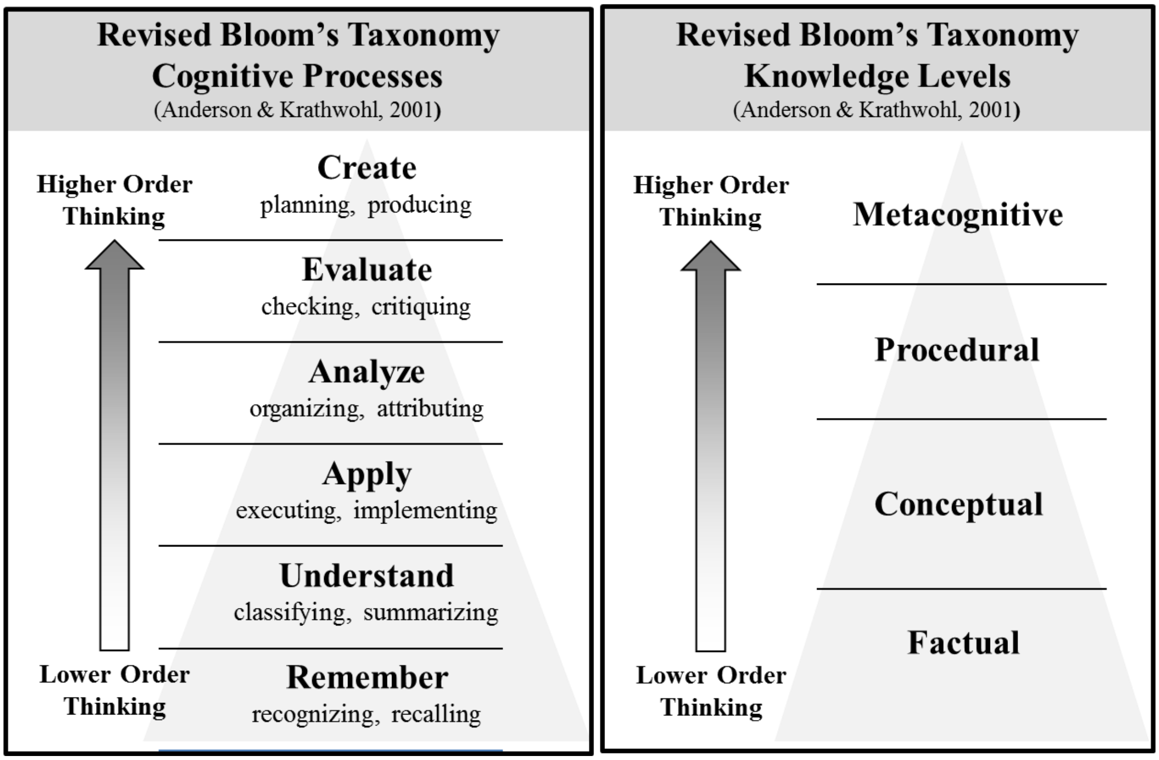


Figure 5. Revised Bloom's taxonomy cognitive processes and knowledge levels. Adapted from *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives* (pp. 29 and 31), by L. W. Anderson and D. R. Krathwohl, (Eds.), 2001, New York, NY: Longman. Used with permission from Pearson Education, Inc., New York, NY (see Appendix A).

Anderson and Krathwohl (2001) created a matrix of cognitive processes and knowledge levels to analyze lesson vignettes for grades 4-12, including content from science, social studies, math, and language arts. They mapped objectives from units on topics such as volcanos, nutrition, addition facts, and *Macbeth* to give their framework greater credibility and to demonstrate how the matrix illuminated the complexity of learning. From these lesson analyses, it appeared the knowledge levels might have a greater impact on the rigor of learning than the cognitive process verbs teachers used. This can be seen by comparing objectives that were assessed as high cognition/low knowledge as opposed to low cognition/high knowledge. The latter appeared to be more rigorous in the vignettes. This concept is shown in a four-quadrant graphic; darker shading indicates higher rigor (Figure 6).

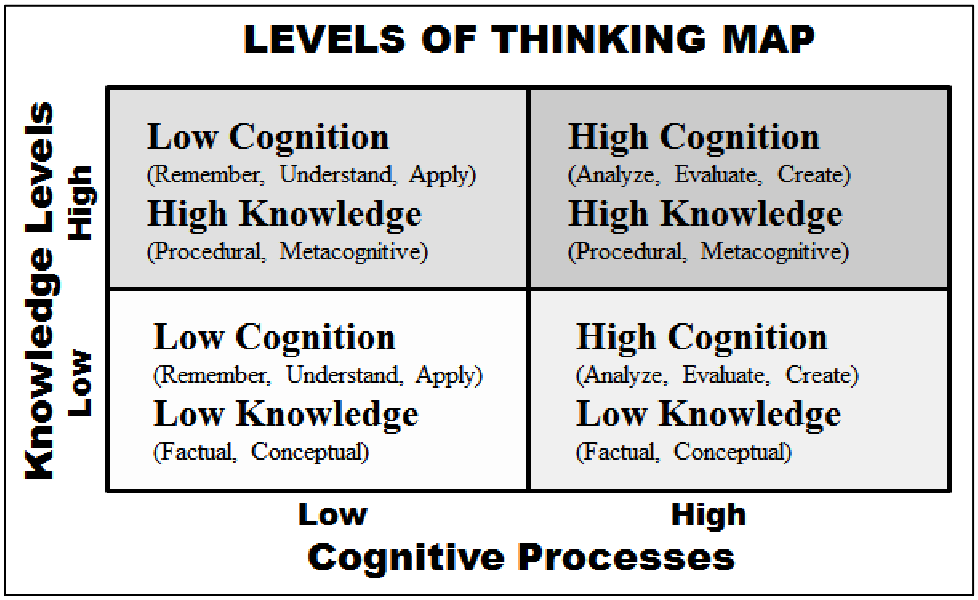


Figure 6. Levels of thinking quadrants. Adapted from *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives* (p. 28), by L. W. Anderson and D. R. Krathwohl, (Eds.), 2001, New York, NY: Longman. Copyright 2001by Addison Wesley Longman Inc. Adapted with permission Pearson Education, Inc., New York, NY.

The impact of using the knowledge levels can be seen in the example American history vignette analysis provided by Anderson and Krathwohl (2001, p. 174), which I simplified and presented in Table 1 to demonstrate the value of using two dimensions to identify levels of thinking. I added shading to the quadrants to show levels of thinking and to demonstrate the impact that the knowledge levels can have upon understanding the rigor of a final product. In this example vignette called Parliamentary Acts (see Table 1), the first- and second-unit objectives targeted lower ordered thinking skills in both the cognitive processing and knowledge levels. The first objective required students to remember parts of a prerevolutionary war act. This objective was mapped in the taxonomy table as *factual* knowledge to remember. For the second objective, students were to explain the consequences of the act which were mapped as *conceptual* thinking requiring students to understand. The third and fourth objectives required higher order cognitive processes at lower order knowledge levels. The third objective included multiple steps to write a persuasive editorial about individuals involved in the act describing their point of view and including information that was not presented in class. Thus, the third objective was broken into two parts, and both were mapped at the level of *create*, the highest cognitive process, but the knowledge levels were *factual* and *conceptual,* indicating that the creativity was not based upon challenging content. Consequently, the project objectives were less rigorous because the knowledge level remained low. If the original taxonomy were used, the third objective would simply be assessed at the level of *create* without supplying awareness that the creative effort was based upon concrete knowledge and was, therefore, less demanding. The fourth objective was for students to engage in self and peer editing, which was judged as *conceptual* knowledge requiring students to *evaluate* which is a higher ordered thinking process using lower level knowledge.

Table 1

Revised Blooms Taxonomy Learning Objectives Analysis

RBT knowledge levels	RBT cognitive process verbs					
	Remember	Understand	Apply	Analyze	Evaluate	Create
D. Metacognitive						
C. Procedural						
B. Conceptual		Objective 2			Objective 4	Objective 3
A. Factual	Objective 1					Objective 3

Note. “The Taxonomy Table” From *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom’s Taxonomy of Educational Objectives*, by L. W. Anderson and D. R. Krathwohl, (Eds.), 2001, New York, NY: Longman (p. 28) Used with permission Pearson Education, Inc., New York, NY.

Krathwohl (2002) wrote an overview of RBT and asserted that the two-dimensional table could serve several purposes, “Using the table to classify objectives, activities, and assessments provides a clear, concise visual representation of a particular course or unit” (p. 218). The table provided a method of breaking complex objectives or activities into component parts for analysis. Further, by mapping the components into a table, an instructional unit could be viewed as a whole and the dominant quadrant for thinking identified. This method of identifying levels of thinking can easily be applied to determine higher or lower order thinking embedded in the language of unit design, instructional objectives, and description of a final product.

With the addition of the knowledge levels in the RBT, Anderson and Krathwohl (2001) made essential connections regarding levels of thinking, pedagogy, and what students do relative to learning. The knowledge levels align conceptually with the two dimensions of the PB-LIFTS framework for teacher pedagogy and student product levels. This alignment is shown in Table 2.

Table 2

Alignment of Revised Blooms Taxonomy Knowledge Levels with PB-LIFTS

RBT knowledge levels	PB-LIFTS teacher instructional pedagogy	PB-LIFTS student product innovation
Metacognitive	D. Connected	4. Innovate
Procedural	C. Social	3. Transform
Conceptual	B. Constructed	2. Enhance
Factual	A. Active	1. Reproduce

To clarify how Anderson and Krathwohl's (2001) knowledge levels align with both dimensions of the PB-LIFTS, examples from either end of the continua may be helpful. The lowest level of knowledge is factual, and this is the centerpiece of active learning in the teacher instructional pedagogy dimension, as well as *Level 1, Reproduce* of the student product innovation dimension of PB-LIFTS. Similarly, the highest level of knowledge is metacognitive, which aligns with the highest levels of the two PB-LIFTS framework dimensions. Metacognition requires HOTS and is essential to social constructive and connected learning on the PB-LIFTS pedagogy continuum as well as the two highest levels of student product innovation. Metacognition is integral to creativity, innovation, problem-solving, critical thinking, communication, and collaboration (Fadel, Bialik, & Trilling, 2015; Kereluik et al., 2013). For face-to-face or virtual collaborative learning to be successful, participants must be cautiously aware of their thought processes and how to communicate ideas in ways that are collaboratively constructive.

With the knowledge levels embedded in the PB-LIFTS, instructional pedagogy types, and the RBT taxonomy table can be applied to evaluate rigor, as shown in Table 3.

Table 3

Instructional Pedagogy and Cognitive Processes

Teacher instructional pedagogy types	RBT Cognitive process verbs					
	Remember	Understand	Apply	Analyze	Evaluate	Create
D. Connected						
C. Social						
B. Constructed						
A. Active						

Note. RBT knowledge levels are embedded in the teacher instructional pedagogy types. Similarly, the language used to describe a final PBL product could be used to identify the level of student product innovation using the RBT cognitive process verbs (Table 4).

Table 4

Product Innovation and Cognitive Processes

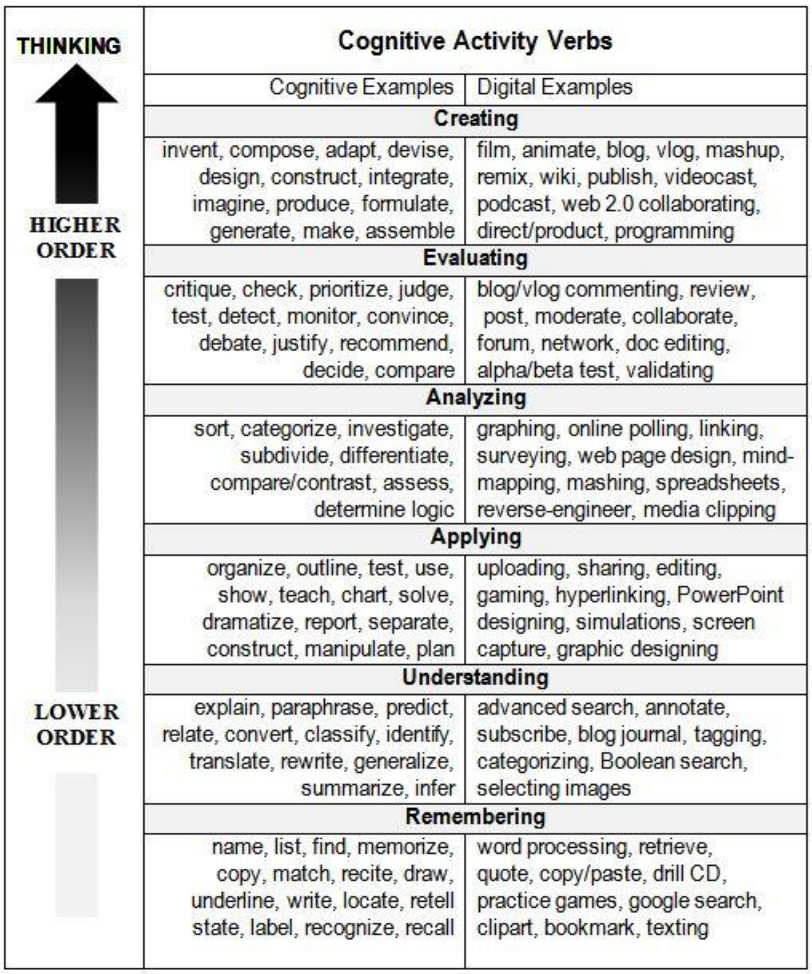
Student product innovation levels	RBT cognitive process verbs					
	Remember	Understand	Apply	Analyze	Evaluate	Create
4. Innovate						
3. Transform						
2. Enhance						
1. Reproduce						

Note. RBT knowledge levels are embedded in the student product innovation levels.

Due to the alignment of Anderson and Krathwohl's (2001) taxonomy table with the two dimensions of PB-LIFTS, I was able to make use of the word lists provided by Anderson and Krathwohl as support tools for determining levels of thinking. Additionally, using this approach to understand levels of thinking fostered in PBL units may yield far more meaningful results than using the six cognitive verbs alone. However, when the teachers' learning designs and student products involve technology to develop and produce projects, shortcomings of the verb lists developed by Anderson and Krathwohl at the turn of the 21st century became apparent. For evaluating projects that included technology use, another revision of Bloom's (1956) Taxonomy was needed.

The Digital Taxonomy

The RBT (Anderson & Krathwohl, 2001) was first published when educational technology was still in its infancy; therefore, the connection between learning and technology was not widely acknowledged, but this soon changed. As early pioneers of technology in education, Jonassen, Carr, and Yueh, (1998) referred to computer technology as *mindtools*. Jonassen et al. made a clear connection between student use of tools for learning and complex thinking when they referred to construction tools such as visualization, systems modeling, and hypermedia as well as data storage and retrieval systems as mindtools. Jonassen and colleagues argued, "Students cannot use 'Mindtools' without thinking deeply about the content they are learning, and if they choose to use these tools to help them learn, the tools will facilitate the learning and meaning-making processes" (Jonassen, Howland, Marra, & Crismond, 2008, p.83). Anderson and Krathwohl's (2001) RBT with action verbs and activities associated with cognitive levels provided an avenue to expand and apply the taxonomy to learning with technology (Cochran & Conklin, 2007). Churches (2007) took up this charge and developed a digital taxonomy. The centerpiece of Churches' work was the provision of action verbs and activities specific to technology use associated with levels of thinking. Churches' digital taxonomy (2007) may be critical to identifying levels of thinking in projects that were developed and produced using technology. Bower, Hedberg, and Kuswara (2010) provided an early attempt to sort action verbs used with and without technology. This inspired me to develop a cognitive activity chart of action verbs based upon Anderson and Krathwohl's (2001) RBT in one column and Churches (2007) digital terms in another (Figure 7).



THINKING	Cognitive Activity Verbs	
	Cognitive Examples	Digital Examples
	Creating	
HIGHER ORDER	invent, compose, adapt, devise, design, construct, integrate, imagine, produce, formulate, generate, make, assemble	film, animate, blog, vlog, mashup, remix, wiki, publish, videocast, podcast, web 2.0 collaborating, direct/product, programming
	Evaluating	
	critique, check, prioritize, judge, test, detect, monitor, convince, debate, justify, recommend, decide, compare	blog/vlog commenting, review, post, moderate, collaborate, forum, network, doc editing, alpha/beta test, validating
	Analyzing	
	sort, categorize, investigate, subdivide, differentiate, compare/contrast, assess, determine logic	graphing, online polling, linking, surveying, web page design, mind-mapping, mashing, spreadsheets, reverse-engineer, media clipping
	Applying	
	organize, outline, test, use, show, teach, chart, solve, dramatize, report, separate, construct, manipulate, plan	uploading, sharing, editing, gaming, hyperlinking, PowerPoint designing, simulations, screen capture, graphic designing
	Understanding	
LOWER ORDER	explain, paraphrase, predict, relate, convert, classify, identify, translate, rewrite, generalize, summarize, infer	advanced search, annotate, subscribe, blog journal, tagging, categorizing, Boolean search, selecting images
	Remembering	
	name, list, find, memorize, copy, match, recite, draw, underline, write, locate, retell state, label, recognize, recall	word processing, retrieve, quote, copy/paste, drill CD, practice games, google search, clipart, bookmark, texting

Figure 7. Cognitive activity verbs chart with and without technology.

The cognitive activity verb chart is intended as an aid for identifying levels of thinking in conjunction with PB-LIFTS and can be used with the cognitive process

Tables 3 and 4 as a support tool for interpreting levels of thinking in the teacher instructional pedagogy and student product innovation dimensions of PB-LIFTS. The results can be applied in a cell within the matrix on the PB-LIFTS framework as a preliminary assessment of HOTS in a PBL unit.

In addition to using the RBT to assess levels of thinking, the PB-LIFTS conceptual framework includes another layer of assessment using keywords as indicators of HOTS that I applied in all three dimensions of the framework . These indicators were included in the level descriptions on the PB-LIFTS framework for pedagogy and products. I differentiated the pedagogy types by teacher role, student role, and learning design. Indicators used for the student product innovation dimension included originality, creativity, and content. For the third dimension of PB-LIFTS, I incorporated indicators to identify HOTS in the 4Ts, task, thinking, teamwork, and tools. What follows in the next three sections are detailed descriptions of how I applied learning theories in the three dimensions of PB-LIFTS to assess HOTS and how I selected indicators for data collection and analysis.

Teacher Instructional Pedagogy Dimension

The horizontal dimension of the PB-LIFTS is a continuum of four constructivist pedagogies that progress from teacher-centered to student-centered instructional practices. Moving from left to right on the PB-LIFTS (Figure 2), the first three columns are labeled: *active*, *constructive*, and *social* constructive instructional strategies. These are derived from educational psychology and correspond to overlapping theoretical eras in the United States (de Corte, 2010; Schallert & Martin, 2003). The fourth column labeled connected learning was based upon the digital era (Battro & Fischer, 2012;

Beetham & Sharpe, 2013; Clarà & Barberà, 2013; Ravitz & Blazevski, 2014; Siemens, 2004). A teacher's described pedagogic strategy may or may not include technology integration; however, the use of the internet is typically involved in connected learning as students traverse networks and may use Web 2.0 technologies.

The pedagogy continuum is the horizontal dimension of PB-LIFTS and was used to identify a teacher's instructional approach based upon descriptions of how PBL units were planned and implemented. This understanding could illuminate levels of thinking; as the pedagogical approach becomes increasingly student-centered and student-directed, HOTS also increases. At one end of the continuum, learning is controlled by the instructor, and students perform structured activities to remember facts requiring lower ordered thinking skills. At the other end of the pedagogy continuum, learning is interactive, open-ended, and student-directed while instructors become guides and co-learners; this type of learning is complex and requires HOTS.

Traditional instruction is a widely used teacher-centered pedagogy associated with behaviorist philosophy rather than constructivism; therefore, it was not included on the PB-LIFTS pedagogy continuum. This study focused on PBL, which is based upon constructivist philosophy, where students are active in the learning process and produce a product. The least rigorous of the constructive pedagogy types is *active learning,* which could be confused with traditional instruction due to both being heavily controlled by the teacher. For example, it could be possible that teachers believe they use constructive learning because students work with manipulatives and engage in hands-on activities. Traditionalists also use activities to aid in retaining facts through routine drills. According to Kivunja (2014a), students cognitively process content in constructivist approaches. Experts caution that special education was founded on behaviorist learning theory, and the traditional approach is still prevalent in 21st century classrooms (Brownell et al., 2010; Ware, 2013). Zhao (2016) posited that education practices tend to focus upon children's deficits rather than building strengths, and this model of service provision perpetuates a system of lost talent. For this study, it was important to gain a deep understanding of each teacher's instructional approach; therefore, to distinguish pedagogy types that would illuminate HOTS, I used indicators and RBT assessment strategies.

The four pedagogy types included on the PB-LIFTS continuum are active, constructed, social, and connected learning. Each type can be identified using three indicators, including teacher role, student role, and learning design. In this study, the PB-LIFTS and indicators guided the development of semistructured interview questions and journal prompts to gather rich descriptions of teachers' experiences. Because learning context influences teachers' pedagogical decisions, as part of this study during interviews, I included opportunities for teachers to share aspects of their learning context that influenced their instructional design choices. What follows are descriptions of the four pedagogy types on the PB-LIFTS continuum, including active, constructed, social, and connected learning. The pedagogy types can be differentiated by examining the role of the teacher, the role of the students, and the learning design.

Active. The first approach on the PB-LIFTS pedagogy continuum is active learning corresponding to the cognitive theory era, which was popular from the 1960s into the 1980s (de Corte, 2010; Schallert & Martin, 2003). This era was influenced by Gestalt psychology, where the whole is understood as a configuration or arrangement of the parts. This marked an educational shift toward active rather than passive instructional strategies where students participate in teacher-directed information processing. In behaviorist pedagogy, teachers focus upon the environment and student behaviors, and in cognitivist pedagogy, teachers focus upon individual thinking processes as students engage actively in the environment (Kivunja, 2014a).

Teachers whose instructional experiences can be characterized as active learning on the PB-LIFTS framework would describe learning activities they prepared for discovering facts and associated worksheets for learners to organize and process information to aid retention. For example, after participation in activities, students would be expected to complete graphic organizers, fill-in-the-blank worksheets, or concept maps. In active learning contexts, the content and activities are controlled and mechanized such as carefully structured centers or lab activities. In these learning environments, students have opportunities to demonstrate their understanding of content by reworking it to show conceptual understanding rather than simply memorizing facts as in traditional pedagogy. The computer processing model of learning where students process inputs is a hallmark of cognitivism. Cognitive psychologists focused upon memory processes, not learning (Schallert & Martin, 2003).

At the active level, students demonstrate comprehension of the content controlled by the teacher. Opportunities to demonstrate the transfer of learning or higher order cognition are restricted, and the emphasis is upon content acquisition, cognitive processing, and the organization of knowledge (de Corte, 2010; Mayer, 2004). Critical indicators of active learning pedagogy are that the teacher directs the learning process, students are to complete specific tasks following the structure and sequence provided, and students' PBL products in active learning are typically predetermined.

Constructed. The second PB-LIFTS pedagogical approach is constructed learning, corresponding to the constructivist era that emerged in the 1970s and continued into the 1990s. Constructivism marked a departure from the behaviorist and cognitivist view that learning is mechanistic to the perspective that learning is a sensemaking process (Schallert & Martin, 2003; Scheer et al., 2012). In constructivist pedagogy, meaning making and building upon the individual learner's prior knowledge through interaction with the environment is critical to the learning process (Smart, Witt, & Scott, 2012). Although there are several varieties of constructivism (Baviskar, Hartle, & Whitney, 2009; de Corte, 2010; Doolittle & Hicks, 2003), the constructivist approach is generally learner centered. In this context, the teacher's role shifts from a transmitter of knowledge to a cognitive guide who facilitates the learning process. The student's role shifts from one who memorizes, records, restates or reorganizes knowledge to one who interprets and makes sense of it (de Corte, 2010; Ultanir, 2012). In constructivist pedagogy, learners actively attempt to create knowledge from their experiences, which requires more complex thinking than in the behaviorist or cognitivist approaches (Doolittle, 2014; Siemens, 2004). Constructivist strategies such as discovery learning and problem-solving require students to analyze, synthesize, and evaluate content with higher level cognitive skills (Slavich & Zimbardo, 2012).

Teachers whose instructional experiences can be characterized as constructed learning on the PB-LIFTS framework will describe how they activate and build upon students' prior knowledge. They promote students' development of knowledge and skills through interaction with the environment investigating authentic topics of interest. By working individually or in small groups, students in these classrooms typically produce a product such as a presentation or research report demonstrating an interpretation of the learning given project guidelines (Doolittle, 2014; Khan, 2013; Shaikh & Khoja, 2012). Teachers often assign authentic learning activities that pique students' curiosity and focus on real-world problem-solving through inquiry (Greenstein, 2012). Teachers may describe learning structures students follow, such as Osborne Parnes creative problem-solving (Treffinger & Isaksen, 2005) or the 5E model (Kivunja, 2014b). At this pedagogical level, the learning process, student products, and reflection can be used as a window to understand the complexity of a learner's cognitive engagement (Alexander, Schallert, & Reynolds, 2009).

Many constructivist instructional strategies have been developed and are widely used in classrooms in addition to PBL, such as problem-based learning, collaborative learning, and inquiry-based learning (Doolittle, 2014; Kang, Choi, & Chang, 2007; Slavich & Zimbardo, 2012; Wurdinger, 2016). In the present study, I used PBL as an umbrella term that includes several strategies under the constructivist paradigm. On the PB-LIFTS framework, constructed learning marks a pedagogical shift to student-centered learning, and to the right of this point, cognitive demands increase progressively on the continuum. Key indicators of constructed pedagogy are that teachers take the role of the facilitator; students manipulate materials and discover knowledge, and products are produced through hands-on construction, and are usually predictable.

Social. The third approach on the PB-LIFTS pedagogy continuum is social learning which, according to Schallert and Martin (2003), emerged in the 1990s during the socio-constructivist era with the discovery and translation of a Russian psychologist's work from the 1920s. Social constructivism was inspired by Lev Vygotsky, a specialist in "defectology," who emphasized the importance of language, culture, and social interaction in the learning process (Smagorinsky, 2012). To understand the impact of socialization and language on learning, Vygotsky believed that if he studied human anomalies, he could discover general laws of educational psychology. To this end, he visited a few institutions for the deaf, which he perceived as "natural laboratories." He argued that the secondary social effects of a handicap "are most important, and it is essential to engage the children in meaningful social activities" (van der Veer & Zavershneva, 2011 p. 459). Vygotsky advocated that learning is a social process and given a responsive context such as scaffolding from adults, children can perform at higher levels. Vygotsky connected social constructivism to HOTS fostered through engagement in socially meaningful activities (Gindis,1999).

Teachers whose instructional experiences can be characterized as socially constructed learning on the PB-LIFTS will describe students as socially engaging in dynamic learning. While the emphasis in constructed learning on the PB-LIFTS is placed upon knowledge construction through interaction with the environment, in social constructivist learning, the emphasis shifts to interdependent co-construction of knowledge by individuals socially interacting in the learning process (Palincsar, 1998). Hence, critical components of knowledge generation in socially constructed learning are dialog and interaction fostered by teacher guided engagement in real world contexts (Doolittle, 2014; Mercer, Hennessy, & Warwick, 2019; Webb et al., 2019). Knowledge generation becomes a cultural artifact of group interaction in social constructivist learning, and "the whole is greater than the sum of the parts" (Bell, 2011, p. 101). In these environments, students take more responsibility for learning from one another, respecting personal and cultural differences, and driving learning through collaboration (Roessingh & Chambers, 2011; Scheer et al., 2012; Skinner et al., 2016). Structures for interaction and collaboration are often used to guide the learning process, such as cooperative learning (Kagan, 1989). Instructors assume a supportive role and may also be co-learners (Ahn & Class, 2011) while students take ownership for learning (Churcher, 2014). At this pedagogical level, students demonstrate more considerable self-direction. For example, students may select topics to pursue and negotiate their projects' scope and depth with the instructor.

Additionally, they may contribute to how learning is measured and assessed. Assessment practices may include peer and self-assessment, self-reflection, and product evaluation (Doolittle, 2014; Greenstein, 2012; Larmer et al., 2015). Learners become more aware of how they learn, and meta-cognition requires high-level cognitive processing (Reigeluth, Beatty, & Myers, 2017). Critical indicators of social learning pedagogy are that teachers assume a supportive role; students take leadership roles and collaborate; knowledge is co-constructed through social interaction and collaboration. Student products cannot be predicted in advance of social learning engagement.

Connected. The final pedagogy column on the far right of the PB-LIFTS continuum is connected learning which is based upon a learning theory advanced by George Siemens (2004) in an article posted on the internet entitled "Connectivism: A Learning Theory for the Digital Age." Near the turn of the millennium, technology use in education as a communication tool had become so ubiquitous, and Siemens proposed the theory of connectivism expanding upon constructivism for a digital age. Connectivism is a theory of learning that describes how internet technologies impact the learning process, including how learners access, share, and create new knowledge across networks. Siemens acknowledged that constructivism could contribute to preparing students as life-long learners but falls short in a digitally connected global society. According to Siemens, constructivist learning requires the learner to be physically present and addresses what occurs inside learners as they make sense of their experiences. He argued that constructivist theories fail to describe how learning can take place using digital networks and considers how knowledge can be accessed, modified, and stored using technology external to the learner. Siemens contended that connected learning as essential for preparing students for work and communication in the digital age and emphasized that connectivism allows students to experience how learning occurs within organizations and across networks. Connected learning provides opportunities for students to hone the essential skills needed in the 21st century (Lamb & Arisandy, 2020; Zhang, & Zou, 2020). Siemens closed his article stating, “Connectivism provides insight into learning skills and tasks needed for learners to flourish in a digital era” (Siemens, 2004, “Conclusion,” para. 2).

Through a series of blogs in 2005, George Siemens and Steven Downes discussed the concept of distributed learning and described the connectivist model as communities of learners connecting, sharing information, and building knowledge (Bell, 2011; Downes, 2006). Participants in these learning communities may physically reside anywhere in the world. Tethered by the internet and mutual interests, learning communities form networks and can use Web 2.0 to share diverse opinions and contribute to knowledge generation (Siemens, 2008). According to Kop and Hill (2008), Siemens and Downes did not limit connectivism to the online learning environment. Clarà and Barberà (2013) clarified that connectivism was not an invention of the digital era because knowledge development had always occurred due to sharing and building upon ideas across learning networks. However, Web 2.0 increased the complexity of information exchange and significantly accelerated the process of knowledge creation.

Further, Downes noted that knowledge content was gradually becoming decentralized because of social networking as it was not located in a place (2010). Downes posited that because knowledge was growing and changing so rapidly, to learn what was needed for tomorrow, students must be able to navigate networks skillfully. They must be able to access and evaluate content that may not be available today. Siemens (2004) summarized, “The pipe is more important than the content within the pipe” (“Conclusion,” para. 1) referring to the pipe as the networks where current knowledge can be stored and accessed.

Teachers whose instructional experiences can be characterized as connected learning on the PB-LIFTS will describe students who demonstrate significant maturity and autonomy as they navigate networks and are not limited to working within the classroom. Connected learning using technology will blur the lines between formal and informal learning (Greenhow & Lewin, 2016). Teachers in connected learning assume a mentor role, and students are consciously aware of the learning process as they drive learning and exercise self-regulation. Students will strive to include diverse opinions and information sources, seeking to discover connections between concepts and ideas.

Learners will nurture and maintain connections using Web 2.0 and Web 3.0 technology while valuing contemporary knowledge construction (Aljawarneh, 2020). Learners will need to apply metacognitive thinking to evaluate, adapt, and make informed decisions as knowledge creation evolves across networks. Starkey (2011) asserted that HOTS were required in connected learning and information and communication technology (ICT). Starkey clarified that in connected learning of the digital age, students must apply meta-skills to evaluate the worth of sites and content before learning takes place. The process of learning is shifting away from memorizing and storing 'prescribed' knowledge that already been discovered toward rigorous critical analysis of knowledge drawing from multiple sources and perspectives to build new understandings across networks (Starkey, 2011, p. 19). Through connected learning, students may generate knowledge and produce projects engaging others at any time or place (Foroughi, 2015). Key indicators of connected learning pedagogy are that teachers serve as mentors, students direct the learning process, and unique products are produced through networked construction. The progression in levels of complexity and cognitive demand across all four of the pedagogy types in the horizontal dimension of PB-LIFTS is shown in Table 5 with brief descriptions of teacher role, student role, and learning design indicators.

Table 5

Instructional Pedagogy Indicators

Pedagogy indicators	A. Active	B. Constructed	C. Social	D. Connected
Teacher role	teacher directed	teacher facilitated	teacher supported	teacher mentored
Student role	follow structure & sequence, process materials	manipulate materials, discover knowledge	student-led collaborative interactive learning	student directed learning
Learning design	structured task completion, predetermined product	construction activities, predictable product	social interactive co-construction, unpredictable product	networked construction, unique product

In summary, the pedagogy dimension of the PB-LIFTS is a continuum of four constructive instructional strategies ranging from teacher-centered practices associated with lower ordered thinking skills to student-centered practices associated with HOTS. These can be assessed using RBT analyzing teachers' descriptive language to identify the overall level of HOTS and associated pedagogy type (Table 3). Secondly, three key indicators for the four pedagogy types, including teacher role, student role, and instructional design, can be explored to gain a deeper understanding of the teacher's pedagogical approach (Table 5). Results from the two assessments could be combined to determine the placement of the unit on the PB-LIFTS pedagogy continuum. The data collection and analysis for the PB-LIFTS pedagogy dimension was designed to clarify each teacher's instructional plan for the PBL unit, including the levels of teacher control and student autonomy in the learning process, and how teachers envisioned the learning to take place. This dimension heavily influences student outcomes as instructional pedagogy sets the stage for student opportunities to learn (Lin-Siegler, Dweck, & Cohen, 2016).

In addition to instructional pedagogy, the first phase of data collection also focuses on the vertical dimension of PB-LIFTS, student product innovation. Hence the focus shifts from the teacher's PBL plan to the tangible outcome produced by student teams. As discussed earlier, teachers' product descriptions can be assessed for HOTS using RBT (Table 4). Product descriptions can also be assessed for HOTS using indicators which I discuss in the next section.

Student Product Innovation Dimension

The vertical dimension of PB-LIFTS is a continuum of four levels of product innovation. From lower order thinking to higher, I named the levels: *reproduce, enhance, transform, and innovate*. Short descriptions of the four levels of product innovation were included on the PB-LIFTS framework (Figure 2). The descriptions reflect three product indicators selected from the literature, including originality, creativity, and content.

Scholarly literature related to education and career preparation revealed that employers seek individuals who can effectively work in teams to develop and produce innovative products. Workers with these skills are vital to economic stability in the global marketplace (Chatterji, 2018; DiCicco, 2016). Successful productivity of this nature requires 21st century skills, also referred to as HOTS (Chatterji, 2018; Cobo, 2013; Wagner & Compton, 2015). Germaine et al. (2016) added that purposeful use of knowledge, interpersonal skills, and positive attitudes toward collaborative work also contributed to successful team product innovation. The development of these skills should begin in K-12 schooling. Wagner and Compton (2015) argued that time and effort are required to develop 21st century skills, and for success in the modern world, these skills were an educational imperative. Teachers could support content mastery and cultivate the development of HOTS through real-world learning experiences such as PBL (Boss & Kraus, 2014). Through engagement in PBL, students were afforded opportunities to develop HOTS and the mindset for creativity and knowledge building as they applied skills to innovate and produce artifacts (Darling-Hammond, 2017; Wagner, 2014).

Innovation was often associated with PBL products, but it was not easily defined. In the context of education, the production of a team created product was a defining aspect of PBL, and PB-LIFTS was designed to assess levels of student product innovation to identify levels of HOTS. Kirton (2004) explored definitions of innovation and concluded that there was no consensus, but the term was often synonymous with creative outcomes. Kirton also posited that across definitions, cognition, creative processes, and productivity were recurring elements.

Pavitt argued that in the business world, there were three key sub-processes of innovation including "the production of knowledge; the transformation of knowledge into products, systems, processes and services; and the continuous matching of the latter to market needs and demands" (2009, p. 87). Similarly, in education, PBL was an instructional strategy that ideally engaged students as innovators (Bell, 2010; Kafai, 2018) and required that they apply cognitive processes to gather and transform content knowledge to produce new and creative artifacts that were valued as satisfying authentic needs (Amabile, 1988; George, 2007; Shalley et al., 2015). Thus for the purpose of this study, to identify product innovation levels I consulted the literature as well as the creativity and innovation rubric for PBL developed by experts from the Buck Institute for Education (BIE, 2013); from this I selected three indicators of product levels, including originality, creativity, and content (Table 6).

Table 6

Product Innovation Indicators

Product indicators	Originality	Creativity	Content
4. Innovate	unique, inventive product	ingenious, visionary	complex, multifaceted
3. Transform	redesigned, novel product	clever, creative	synthesized knowledge
2. Enhance	improved product	embellished, decorated	conceptualized, reworked facts
1. Reproduce	replicated product	imitated, copied	basic facts duplicated

Thus, the level of product innovation can be assessed using RBT and secondly using the indicators. The results can be combined to determine tentative placement on the vertical dimension of PB-LIFTS. In the next section, I address the PBL process skills that students might use to produce a product. This perspective of the teacher's PBL experience may illuminate areas of HOTS that were not revealed simply by assessing descriptions of the product. In the following section, I provide the theories applied to create the third dimension of the PB-LIFTS framework and describe how the selected PBL processes called the 4Ts can be assessed. In the next section I also provide examples of each product innovation level and include descriptions of the processes that contributed to the final product.

Student Process Dimension

Processes students used to produce a PBL product was explored in the second phase of the study to gain a deeper understanding of the teacher's PBL experience and answer the third related research question. The process skills that contributed to the product could be conceptualized as the third dimension behind PB-LIFTS that was less tangible than the two dimensions on the face of the conceptual framework. The process dimension supported the development and production of the final PBL product.

Although there are many processes involved in collaborative work that may contribute to a final product, the study was limited to four of them using the PB-LIFTS conceptual framework, including task, thinking, teamwork, and tool use. Evaluation results of the 4Ts might suggest a shift in the placement of the PBL unit on the PB-LIFTS in the third phase of the study when the teacher and researcher engaged in co-interpretation of the results. Indicators for each of the 4Ts that I used to evaluate the PBL processes were drawn from several sources. These resources included Buck Institute PBL rubrics (BIE, 2013), theoretical frameworks from Webb (1997) on rigor and complexity of thinking, Tuckman's (1965) model of team development, and Puentedura's (2006) SAMR model for judging levels of technology use. I show the levels of process skills in Figure 8, followed by a description of each of the 4Ts.

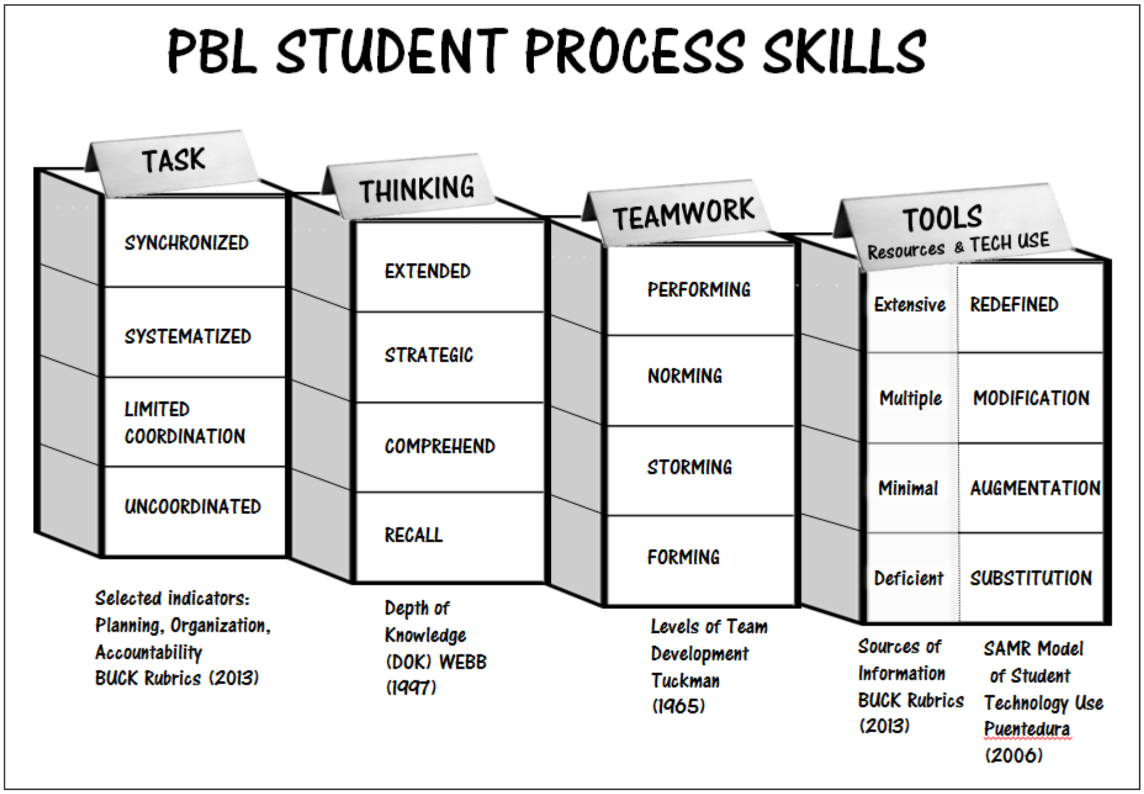


Figure 8. 4Ts student process skill levels.

Task is the first of the 4Ts with three indicators for judging the learning processes students used. Once a PBL project is decided upon, teams typically identify how they plan to accomplish it, and how they can track this progress. Thus, the three indicators selected for task processes are planning, organization, and accountability arranged in four levels. Often teams will produce a chart with a timeline and maintain a notebook or strategic plan showing project progress. Such planning, organization, and accountability processes require students to apply metacognition, and if done well, this involves HOTS.

Thinking is the second PBL process skill that can be examined via interviews with teachers to understand how thinking processes contributed to the innovation and productivity level of the final product. For this study, levels of thinking skills are based upon the four levels of Webb's (1997) DOK model. Webb's four levels were recall and reproduction, skills and concepts, strategic thinking, and extended thinking. Levels of student engagement in critical thinking and the use of content knowledge could be judged using this model, although Webb's DOK model was originally intended to judge the cognitive complexity and expectations of standards, associated instructional activities, and assessment tasks. Webb (2009) produced an expanded guide for using DOK and demonstrated that this could be applied to assessing student products as well as PBL processes. I incorporated Webb's DOK model in the PB-LIFTS to assess the complexity of thinking applied to the develop and produce a project. These levels range from a limited cognitive effort to reproduce an existing project involving simple recall and performing basic procedures, to complex thinking, collaboration, and problem-solving across content with multiple decisions involved to create and produce a unique product. Thus, the levels of thinking identified in the first phase of interviews using the cognitive activity chart of verbs with and without technology (Figure 7) and the cognitive process Tables 3 and 4 may be a superficial assessment of students' cognitive engagement. Webb's DOK model was designed to understand the complexity of learning processes to gain a deeper understanding of cognitive demands.

Teamwork is the third PBL process skill that can be examined via interviews with teachers to understand how teamwork skills may have contributed to the level of innovation and productivity of a final product. This aspect includes levels of communication and collaboration involved in sharing ideas with teammates and developing project plans. It involves intrapersonal skills for self-management and interpersonal skills to work effectively with teammates to build on one another's ideas and move forward productively. At the lowest level, the teacher is needed to guide group collaboration, and at the highest level, the group is autonomous and capable of generating group synergy (Amabile, 1993). The four levels of teamwork in PB-LIFTS align with Tuckman's (1965) levels of team development: forming, storming, norming, and performing.

Tools are the last of the four PBL process skill indicators explored to understand how student use of resources and technology tools may contribute to the level of innovation and productivity of final products. PBL projects require that students gather and select resources for knowledge generation, and technology tools can be used for research, collaboration, and production of a product. Rubrics from BIE (2013) identify levels of student resource use under the criteria labeled as identify sources of information. When students use technology tools for project development and production, the four tool levels of the PB-LIFTS align with Puentedura's (2006) SAMR model. SAMR is an acronym for substitution, augmentation, modification, and redefinition, and the levels are a method of classifying the complexity of tasks using technology. The SAMR model has become popular among teachers in K-12 and in higher education as a simple four-level tool for evaluating the functional aspects of technology use (Green, 2014).
Puentedura disseminates the SAMR technology integration model via social media using his website hippasus.com (Figure 9).

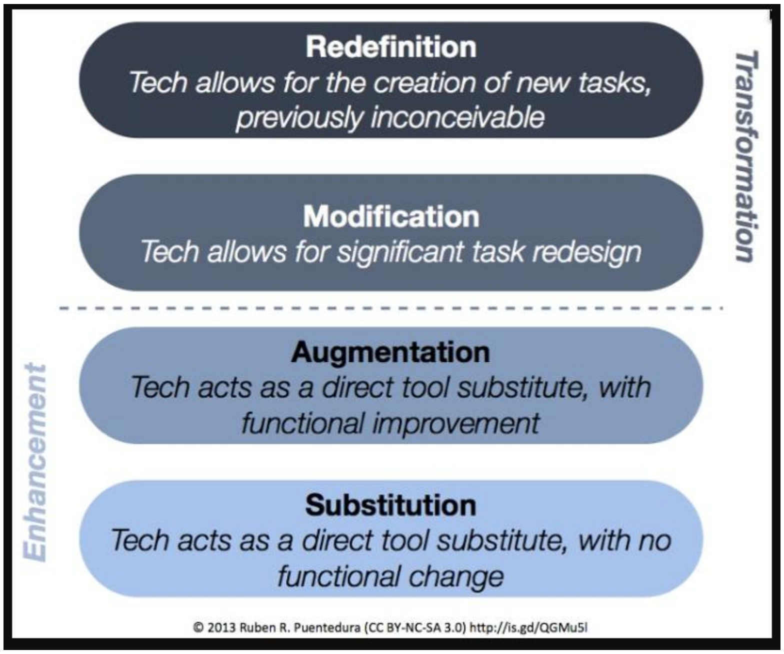


Figure 9. The SAMR Model. From "Transformation, technology, and education," by R. Puentedura (2006) (http://hippasus.com/resources/tte/). Copyright 2013 Creative Commons Attribution-Noncommercial-Share Alike 3.0 License.

Later in the literature review, I describe theories and research related to assessing the 4Ts in greater depth. To gain an understanding of the PB-LIFTS dimensions and how they interact in PBL units, I provide example instructional scenarios, products, and learning processes for each level of innovation regarding task, thinking, teamwork, and tools.

Reproduce. The lowest level of student product innovation on the vertical dimension of PB-LIFTS is *reproduce*. Students at this level produce products that are remakes or are models of content they learned previously. Projects are predictable and lack creativity. Teachers provide project expectations that are highly structured, focusing students' attention on remembering content, and meeting product requirements rather than the learning process. Accountability at this level may occur for a reward, but it is not consistent. Thinking at the reproduced level is low. Although projects at the reproduced level are hands-on, the project does not require critical thinking or problem-solving from students. By reproducing an existing artifact, students recall and practice facts remembering basic content. They may perform routine procedures and follow simple instructions in a controlled setting. This superficial level of cognitive demand is like the lowest level of Webb's (1997) DOK model of cognitive rigor named recall and restate.

If students engage in teamwork at the reproduce level, it is guided. Students will rely upon the teacher to mediate team interaction and negotiation. At this level, students typically lack confidence in their social skills and are reluctant to work in teams. They prefer to work individually or in pairs with teacher support. When the team meets to select a project, they may only consider one or two ideas rather than brainstorming additional suggestions to consider. At the reproduce level, teachers may provide a few project suggestions for the team to choose from that include simplified step by step instructions and require limited collaboration. This aligns with Tuckman's (1965) lowest of four levels of team development called forming. Last, the tools and resources that students use at the reproduce level are most likely provided in the classroom environment by the teacher. Although students might bring supplemental materials from home, the team relies on classroom resources and technology to gather information and to produce the product. When students integrate technology at this level it is simply a substitute or an alternative way to accomplish tasks that could be done manually. Student technology use at this level is basic and conventional such as typing rather than writing or finding and printing pictures rather than drawing. This aligns with the lowest level of Puentedura's (2006) SAMR model of technology use called substitution.

An example PBL project that would be categorized at the reproduce level might be students making a model of a volcano with a trifold poster backdrop demonstrating what they learned from a textbook chapter. The teacher's objective is for students working in small teams to show evidence that they learned required science concepts and vocabulary by producing a tangible project that will help them remember the content. At this level the teacher might provide structured project requirements such as each group will demonstrate an example of how Earth continues to change, provide four facts using a minimum of three-unit vocabulary words, two pictures, and a map.

Students might be assigned to a group of four and meet with the teacher serving as a facilitator to agree on a project. In this meeting, only one idea might be generated with the group unanimously voting to make a model volcano and poster using instructions they remember seeing in the textbook. The teacher guides the group to describe what the final artifact will include, breaks down the task in sequential steps, assigns member duties, sets up a timeline, and provides materials and equipment including a computer connected to the internet and printer. Using instructions from the science textbook students reconstruct the volcano model and select facts from the chapter for the poster. Following assigned duties, students work independently and bring their contributions to the project following the timeline. To produce this project, the class textbook is used along with the classroom computer, printer, and resources from the classroom cabinet. To produce the poster, some students copy facts from the book by hand, and others type them using the computer. Pictures and a map are copied from the internet, printed, and pasted on the trifold.

This project is at Level 1 reproduce for student product innovation because the task is structured by the teacher with the emphasis on satisfying requirements of the final artifact rather than the learning process. Student thinking is concrete requiring recall of facts and reproduction of simple procedures with limited critical thinking or problem-solving. Teamwork is guided by the teacher who mediates collaboration face-to-face in the classroom. Tools are used in a conventional manner and resources are limited in scope and provided by the teacher. Although the teacher may consider this design to be PBL, it has the hallmarks of traditional teacher-centered strategy (Ertmer & Newby, 2013).

Enhance. The second level of student product innovation is *enhance*. Tasks at this level are usually poorly planned by the students. Often the teacher will take control of the steps and remind students of their responsibilities; therefore, student accountability is not intrinsically motivated. At this level, students comprehend unit concepts and can demonstrate their understandings in a final product elaborating on basic content. Although the task may have students adding creative details that illuminate or extend concepts, the outcome is still a conventional project that has been enhanced. The teacher may define specific requirements for the final project and encourage students to demonstrate some of their own findings.

Thinking at the enhance level requires students to be able to use the information they have learned. Projects will demonstrate students' comprehension of concepts and vocabulary by making simple applications such as reorganizing facts and applying them in a graphic organizer. At this level, students can make applications in various ways, such as by showing relationships, interpreting information, or making predictions that indicate a deeper understanding of the content than simple rote memorization. Level 2 aligns with the second level of Webb's (1997) DOK model called skills and concepts. When students engage in teamwork at the enhanced level, they might attempt to manage group communication without teacher facilitation yet find collaboration difficult. Without a collaborative structure to follow, they may not have group norms or roles in place and struggle to clarify their purpose, share ideas, and make decisions. Members might independently decide how they will contribute to the project without team approval. As a result, the project development process may be disjointed, and this aligns with Tuckman's (1965) the second level of team development called storming. Regarding tools, at the enhanced level, students might gather some resources from the library or internet, accepting the first few without evaluating them. Technology tools at the enhance level are typically conventional with some improvements such as e-mailing to deliver material, use of spellcheck, copy, and paste word processing functions. In this way, technology functionally improves the production process, and this is like Puentedura's (2006) second level of technology use called augmentation.

An example PBL project that would be categorized at the enhance level might be students producing an elaborated version of the volcano project and poster from the textbook chapter. At this level, students may try to manage their own meetings with difficulty due to the lack of collaborative skills. Power struggles and the need for teacher intervention may occur. Students may try to develop a project plan, but participation may not be equal and individual accountability may be a problem. Some students might gather interesting facts on volcanos, and upon learning that there are active island volcanos; decide to show how islands are formed as the result of a volcanic eruption in the ocean.

They may elaborate on the baking soda and vinegar demonstration, adding colored lava and lights. Individual efforts may not come together well and must be re-engineered. For the trifold, students might arrange facts on a graphic organizer, such as comparing two active island volcanos. One student might volunteer to copy and paste facts into a word document to print if members will send them via e-mail. The typist might use spell check using classroom technology and receive help arranging printouts on the trifold for display.

This project is at Level 2 enhance for student product innovation because the product is essentially an enhancement of a Level 1 project with added visual details and facts. Members demonstrate an understanding of the basic content and extend this by applying knowledge to a related topic. Further, they can gather and organize additional facts to display in the product. Teamwork is attempted, although they may function more like an uncoordinated group of individuals than a team. Members gathered some resources, and technology was used to functionally improve the production process, although the final project was still a conventional demonstration and poster.

Transform. Level 3 for student product innovation is *transform*. At this level, students transform content from multiple sources and represent their learning in a creative product. Content is typically redesigned and represented using another medium for product presentation that contains some unique or original elements. The task at this level would be less defined by the teacher and encourage open-ended and self-directed learning. Projects at the transform level require students to collaboratively organize multiple-step processes that are more cognitively demanding than the two levels below it. The team will collectively analyze researched knowledge and craft a coordinated plan representative of their learning in a final product with accountability measures that are most often followed.

At this level, divergent thinking is critical to the creative process. Students generate ideas and state their reasoning with supportive evidence to arrive at a solution. Cognitive complexity at the transform level aligns with the third level of Webb's (1997) DOK model called strategic thinking, which requires short-term HOTS to coordinate knowledge from multiple sources, evaluate, prioritize, and devise plans to carry out processes in an organized, sequential manner.

Teamwork and tool elements are more sophisticated in Level 3 than the first two levels. Group members begin to function as interconnected parts with a common goal and develop an organized plan. Students engage in teamwork at the transform level and typically use a collaborative model in which group norms and roles are established, and the team moves through stages of project development and production in a coordinated fashion. Members are usually accountable to the process; decision making and problem-solving occur according to a collaborative structure. Although there may be times when students have difficulty agreeing, they will demonstrate some interpersonal awareness and skills to move forward and keep the project on track. This level aligns with Tuckman's (1965) third level of team development called norming.

Tools and resources that students use at the transform level are typically gathered from multiple sources and are analyzed and evaluated for quality and inclusion. Students will advocate for the use of selected resources and tools as appropriate to the development and presentation of a final product. Students use technology as a tool for learning and producing a product that represents their collective learning creatively.

Technology at this level allows for significant task redesign and aligns with Puentedura's (2006) third level of the SAMR model called modification.

A product at the transform level would show much more complex thinking, and the presentation mode would be significantly redesigned compared to levels one and two. For a project associated with the textbook chapter at the transform level, students might create a Prezi or PowerPoint to demonstrate the theory of plate tectonics and how large-scale motion has impacted the Earth's lithosphere. The product might demonstrate how the Earth's brittle upper mantle changes focusing on continental drift during the first three decades of the 20^{th}-century. The project might include an interactive timeline with visuals of the geographical changes over time. Students might gather content using a variety of access methods learning inside or outside of classroom walls.

This project is at Level 3 transform for student product innovation because the task results in redesigned content requiring some open-ended learning and demonstration of higher order complex and strategic reasoning. Students demonstrate some collaborative skills following a process for planning and accountability. Students research, evaluate, and advocate for resources to include in the product development process. Technology is used as a tool for transforming learning and product representation.

Innovate. Level 4 is the highest level for student products and I named it innovate. Students at this level create, plan, and produce a unique product representing deep self-directed learning. Team member accountability is valued. The task is purposely ill-defined by the teacher, who serves as a resource to students as they engage in the learning process. Students are responsible for developing the purpose and crafting the parameters of the project.

Thinking is extended at the innovate level and requires complex reasoning to gain new understandings from multiple sources of synthesized content. Students must use critical analysis and be able to support and communicate their ideas effectively to generate new and original representations of their learning. Engagement in complex strategic thinking for a sustained period requires significant use of HOTS to navigate and solve unexpected problems and stay on task to achieve project goals. This level of cognitive complexity aligns with Webb's (1997) highest level of the DOK model called extended thinking.

Team members at the innovate level demonstrate a level of trust and mutual support that promotes interdependence. Innovative teams recognize and respect the diversity of skills and knowledge among participants, and creativity is an outgrowth of team synergy. Teams at this level will use learning networks to share knowledge and reach out to experts in the field. They will demonstrate skills in effective collaboration, problem-solving, planning, self-regulation, and reflective thinking. This aligns with Tuckman's (1965) highest level of team development called performing.

Students at the innovate level are resourceful researchers who gather and critique multiple sources across disciplines and advocate for their inclusion in project content or final design. Technology is used as a communication tool for team members to collaborate among themselves and with outside sources. Technology at the innovate level allows for the creation of products that would be impossible without it. This level of technology use aligns with the highest level of Puentedura's (2006) SAMR model called redefinition.

An example product at the innovate level might be that students create a unique project demonstrating the team's learning about the relationship between theories of dinosaur extinction related to volcanic eruptions. This content would require an extensive understanding of the many theories and how they relate to volcanic activity. Students might choose to set up an animated debate using avatars portrayed as leading scientific theorists. The scientists could be projected on a screen to present and argue the two selected theories with a live audience. Next, to engage the audience creatively, the team may set up a question and answer session prior to voting for the debate winner using hidden interactors controlling the avatar's responses like puppeteers.

This project would be judged at Level 4 for student innovation and productivity because the task is open-ended, and student-directed learning reflects a deep and multidimensional understanding of the topic in a highly creative and original manner. To produce this project, team members would engage in extended thinking and complex reasoning throughout the processes of learning, design, and production. Teamwork reflects a high level of complex collaboration that may take place virtually as well as face-to-face. Resources used for research and synthesis would require careful evaluation and the technology tools implemented to allow for efficient communication and creativity that could not be accomplished without them.

In sum, the level of product innovation can be judged by examining a final product and determining where it fits in the PB-LIFTS innovation dimension; however, a product is the culmination of team member engagement in learning processes. Perhaps understanding individual and collective performance in learning processes may be a key to improving innovation skills. Table 7 shows the alignment of the four product innovation levels and the 4T processes.

Table 7

Levels of Product Innovation and Processes

PBL	Process skills			
	Task	Thinking	Teamwork	Tools
Level 4 Innovate	Synchronized: well planned logical organization high accountability	Extended: complex reasoning synthesize, design, critique, collaborate	Performing: networked collaboration regulated/interdependent constructive synergy	Extensive resources: credible & select Technology use: unique/innovative
Level 3 Transform	Systematized: adequate planning good organization usually accountable	Strategic: structured procedural analyze, support, generalize, initiate	Norming: collaborative model clarified roles/goals interpersonal skills	Multiple resources: vetted selection Technology use: task redesign
Level 2 Enhance	Limited coordination: marginal planning limited organization low accountability	Comprehend: manipulate content compare, organize, summarize, classify	Storming: power struggles norms/roles lacking teacher intervention	Minimal resources: conventional Technology use: functional change
Level 1 Reproduce	Uncoordinated: no shared plan disorganized process no accountability	Recall facts: superficial/routine recite, identify, define, list, rewrite	Forming: teacher guided limited idea sharing prefer independent work	Deficient resources: teacher provided Technology use: manual substitute

In the first phase of semistructured interviews, data can be gathered related to the teacher’s instructional pedagogy and the final product. In the second phase, data can be gathered focusing upon student PBL processes to gain a deeper understanding of the skills students applied to produce the PBL product. The PB-LIFTS conceptual framework includes the 4Ts processes as the third dimension of skills students use, including task, thinking, teamwork, and tools over the course of the PBL unit. These skills can be difficult for teachers to evaluate because of their overlapping nature. By applying the work of several scholars such as Webb and Tuckman, the 4Ts skills can be examined individually to identify HOTS. By assessing process skills using the PB-LIFTS conceptual framework, teachers and students may gain access to formative feedback highlighting the critical role these skills play in determining the quality of the final product. Perhaps this feedback can be used to set goals for improvement in future PBL units. It is important to emphasize that PB-LIFTS product levels are not intended for grading purposes, and the four process levels may differ from the assessed level of product innovation. For example, a PBL product that is identified as Level 3 transform may have process levels judged as level 3 for task, level 3 for thinking, level 2 for teamwork, and level 3 for tools. In this case, it is apparent that team members struggled in their roles, and perhaps project planning was not a cohesive process, yet they were able to achieve a level 3 product. This awareness could suggest to teachers that team training is needed or perhaps mastery goal setting for the improvement of teamwork skills is needed for individual members. The unit analysis results could be shared with teachers to engage in a joint interpretation of the data and place the unit on the PB-LIFTS, cognitive process table, and indicator tables for each dimension to reveal HOTS. Teachers could then be asked to share their views on the usefulness of the PB-LIFTS and support tools.

Using the PB-LIFTS conceptual framework for this study was beneficial in several ways. The framework provided avenues for identifying HOTS from a variety of data sources, which I describe in detail in Chapter 3. Using PB-LIFTS, HOTS can be explored in the teacher’s planning stage, in the final product, and in the processes in which students engaged throughout the unit. PB-LIFTS and associated tools can be flexibly adjusted to explore HOTS in any PBL unit. For example, in the case where students did not use technology, levels of HOTS can be identified by the teacher's description of resources students used and how they were used. The PB-LIFTS framework is based upon research models that are applied in phases to gain a deep understanding of HOTS in a teacher's described PBL unit. PB-LIFTS provides a lens to explore HOTS in three dimensions and includes the use of indicators to explore the teacher's pedagogical design, the student product, and student processes, including task, thinking, teamwork, and tools. In sum, the study benefited from using the PB-LIFTS conceptual framework to gain a comprehensive understanding of how teachers of the deaf used PBL to build HOTS with DHH students. This concludes the description of the PB-LIFTS conceptual framework for the study.

In the next section, I introduce the literature review and provide an overview of PBL as a constructivist strategy for developing 21st century skills and content for college and career readiness. This section provides background regarding how scholars have applied PBL across the continuum of constructivist pedagogies, which were included in the PB-LIFTS horizontal dimension. Further, this section differentiates PBL from other similar instructional strategies.

Introduction to the Literature Review

The international drive in education to engage students in rigorous learning that will prepare them for college and careers in a globalized society may have triggered a revival of PBL. PBL is an adaptable instructional strategy that can provide opportunities for students of all ages to learn content across disciplines while developing 21st century skills (Dole et al., 2017; Henshon, 2017; Wagner & Dintersmith, 2015; Wurdinger, 2018). Although there are many definitions of PBL, presently a number of scholars collectively described this constructivist approach as a comprehensive student-centered and student-driven learning strategy, in which participants collaboratively investigate a relevant topic or problem in depth over a sustained period of time, and the learning process culminates in students producing a product that is shared publicly (Hanney & Savin-Baden, 2013; Larmer et al., 2015; Roessingh & Chambers, 2011). This definition is broad, and in practice, implementation might vary significantly as teachers with a range of training and experience attempt to design and lead project-based units. Using the PB-LIFTs pedagogy continuum, it may be possible to identify which pedagogic approach and associated levels of rigor are embedded in unit designs based upon teachers' descriptions of their experiences implementing PBL.

Several researchers noted that teachers often confused problem-based and PBL strategies; therefore, the difference between the two should be clarified for this study. Roessingh and Chambers (2011) described problem-based learning as a constructivist process model that is rooted in critical theory and used to cultivate students' communication, critical thinking, and problem-solving skills. Galvan and Coronado (2014) elaborated that students focus upon a real-world problem or issue that is typically ill-defined and follow problem-solving steps using inductive and deductive reasoning to identify solutions to the problem. Hanney and Savin-Baden (2013) made the distinction that in problem-based learning, the process of knowledge acquisition is central to finding solutions to problems. In PBL, there is an interplay of processes involved in acquiring and applying knowledge, negotiating, planning, product production, and product presentation.

Roessingh and Chambers (2011) situated PBL as a social constructivist approach that expands problem-based learning and engages students in creative time-bound applications of learning that are motivational and require planning, organization, and self-regulation. When using technology as a learning tool in PBL, these processes could become quite complex and require significant higher order thinking. When technology was integrated to pursue PBL processes, the instructional design shifted from social constructivism to connectivism, as described by Siemens (2004). One explanation for the growing popularity of PBL is that this strategy can promote the development of observable skills that are transferrable to the workplace and are valued by employers in the modern age of innovation.

Galvan and Coronado (2014) argued that the most rigorous learning occurred when problem-based learning and PBL were combined and Dole et al. (2016) confirmed this. PBL requires students to work collaboratively over a period on a topic of interest and demonstrate their learning through the creation of a project for public presentation. In PBL, the processes of learning and final products could be assessed, and success would depend upon effective communication and collaboration which requires higher order thinking (Dole et al., 2016). Hanney and Savin-Baden (2013) found that merging problem-based and PBL approaches resulted in more rigorous learning and higher student engagement than when each approach was used separately. Galvan and Coronado (2014) added that when the two learning strategies were combined, the results were “amplified” (p. 40). Kafi and Motallebzadeh (2014) considered both approaches to be inquiry-based learning that was firmly rooted in constructivism and Stefanou, Stolk, Prince, Chen, and Lord (2013) asserted that the two had more similarities than differences, although PBL tended to be larger in scope than problem-based learning. For this study, PBL will be considered as an umbrella term that may include a few constructivist “cousins” such as inquiry-based, challenge-based, and discovery learning (Ravitz, 2009, p. 6). Henceforth, project learning will be referred to as PBL and may encompass any of these learning strategies that are cousins, and require students to produce a product representing their learning experience.

In sum, the 21st century skills movement has cast PBL into the limelight as a comprehensive strategy for developing skills, knowledge, and dispositions identified as critical for success in the modern world (Kereluik et al., 2013). According to Silva, (2009) quality constructivist learning provided motivational opportunities for students to engage in content acquisition while developing 21st century skills such as collaboration, communication, critical thinking, problem-solving, and creativity. The process of students applying 21st century skills in PBL, required higher order cognition and could lead to deeper, and more rigorous learning outcomes than traditional teacher-centered methods of instruction (Dole et al., 2016; Ichsan, Sigit, Miarsyah, Ali, & Suwandi, 2020; Larmer et al., 2015; Larson & Miller, 2011). Further, Silva (2008) asserted that the integration of technology in education expanded opportunities for complex thinking through applications of 21st century skills. The purpose of this qualitative study is to explore the lived experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the areas of PBL pedagogy, product, and process. To this end, it would be helpful to understand the history and evolution of PBL to situate current research related to PBL pedagogy, student product innovation, and higher order thinking. Having this background may also help me capture and interpret nuances that teachers express during interviews related to social and political circumstances that influenced their instructional choices.

History of Project-Based Learning

PBL is a student-centered instructional approach that is not new. Ancient educators such as Confucius and Socrates were known for their student-centered instructional strategies and John Dewey became famous in the United States as a progressive constructivist educator in the early 1900s. Dewey's colleague, William Kilpatrick, interpreted Dewey's work and was the first to refer to constructivist learning as the project method (Kilpatrick, 1918). Dewey was an outspoken pragmatist with strong convictions. He challenged traditional power structures and sparked national debate among educators, politicians, businessmen, and policymakers regarding his instructional philosophy and progressive views on education (Dewey, 1938).

Dewey believed that students learn best through experience and making meaning of content in natural settings while engaging socially in authentic problem-solving activities. He believed that teachers should serve as guides and that students can develop workplace skills and higher order thinking through carefully planned immersion in real-world content (Dewey, 1938). Dewey emphasized the act of thinking throughout all stages of a project, and this aligns with Larmer et al. (2015). They asserted that critical thinking and problem-solving are foundational to PBL as students are challenged to create and innovate when producing products that represent their learning. Dewey also described skills that experiential learning could foster, such as communication, collaboration, critical thinking, and creativity (4Cs). These skills are considered imperative to success in the higher education and the modern workplace today and are referred to as 21st century skills, super skills, career readiness skills, and the 4Cs across multiple knowledge frameworks (Dede, 2010; Jerald, 2009; Kereluik et al., 2013; Kivunja, 2015; Organization for Economic Cooperation and Development, 2005; Partnership for 21st Century Skills, 2004; Voogt & Roblin, 2012). Silva (2009) argued that 21st century skills are not new, but in the 21st century, these skills are "newly important" for success, particularly with the rapid growth of Web2.0 computer technology (p. 631).

Dewey was a visionary for more than his views on innovative pedagogy. As the leader of the progressive movement 1890 to 1920, Dewey was also the voice for the disadvantaged and underserved; he championed the concept of democracy in education and illuminated racial, socio-economic, and rural disparities. Dewey's campaign supporting constructivist pedagogy and equity in education led to the eclipse of the progressive movement. Tyack and Cuban (1995) described how powerful policy elites reacted against progressive ideologies; they systematically seized control of public education and invoked a business model that maintained control throughout the first half of the 20th century (p. 8). Wealthy politicians and business leaders restored an unjust system that favored the privileged and institutionalized traditional instruction methods. Teacher-centered instruction outmoded constructivist learning strategies and dominated classroom pedagogy for decades.

With the turbulent 1960s and the civil rights movement in the United States, demands for equity in schooling reemerged; however, individualized learning replaced constructivist pedagogy. During this time, PBL grew in popularity in Europe (de Graaff & Kolmos, 2007; Knoll, 1997), but in the United States, self-paced programmed learning became popular, and individual competition was encouraged rather than teamwork (Tyack & Cuban, 1995). During the 1970s, many new courses and programs were added to the curriculum to meet students' individual interests. Consequently, a plethora of electives emerged, and a variety of paths to high school completion became available such as work/study, continuation school, remedial instruction, and vocational courses. Tyack and Cuban posited that schools became a "marketplace" for salespersons and technocrats peddling new programs and equipment (1995, p. 114). The business community began to question the value of high school diplomas as employers complained that graduates were not prepared with essential skills for career readiness. To reinvent education during the 1960s and 1970s conservative outsiders including politicians and business leaders prescribed complex business models that were not well received by educators such as Management by Objective or Zero-Based Budgeting (pp. 114-115). Bell (1993) asserted that the early 1980s marked a pivotal time for U.S. education as a change would require strong leadership, yet the incoming President of the United States advocated for laissez-faire politics and promised to reduce government involvement and support for education.

According to Bell, the former Secretary of Education, President Reagan "was committed to abolishing the U.S. Department of Education" (Bell, 1993, para. 1); but education insiders successfully brought the dismal state of American education to the attention of the public and generated greater government involvement. In 1981 Terrell Bell, the Secretary of Education, established the National Commission on Excellence in Education to study the condition of education in the United States and *A Nation at Risk* was published (Gardner, 1983). The Commission harshly criticized American education describing a lax system that produced poor student outcomes and put the nation at risk. The authors reported a steady regression in academic test performance across generations and warned that losing the competitive edge in the global community put America's security and future prosperity in jeopardy. The commission report emphasized the need to increase higher order thinking for the development of essential skills such as analysis and problem-solving in addition to basic reading and math to meet the demand for highly skilled workers of the new millennium. The commissioners predicted that rapid developments in technology and science would dramatically impact the labor force and warned of the urgent need to reinvent the American education system to prepare students.

According to Blumenfeld et al. (1991), throughout the 1980s educators expressed concern that students were bored and unmotivated by traditional instruction approaches. Rather than igniting a drive to transform education from the inside through the implementation of innovative instructional strategies, *A Nation at Risk* (Gardner, 1983) was critical of teachers and their voice was essentially excluded from the reform planning process (Bell, 1993). The report sparked a back to basics movement driven by policy elites mandating minimum competency testing and "teacher-proof" curricula imposed by education outsiders touting traditional methods referred to as "real school" (Tyack & Cuban, 1995, p. 135). Hirschman (1991) rightly warned that such reactive public policies are often counterproductive to intended goals. Tyack and Cuban illustrated this point asserting that the use of tests as an accountability measure increases student engagement in lower level thinking. To prepare for tests teachers resorted to rote "drill-and-kill" instructional methods for memorization of facts (1995, p. 62) rather than implementing instructional practices that foster higher order thinking and problem-solving. Once again, a business model and traditional pedagogy were implemented to get American education back on track. Seven years after *A Nation at Risk*, employers still found high school graduates ill-prepared for the workforce. In response to the ongoing employment crisis Elizabeth Dole, the Secretary of Labor under President George H. Bush assembled a commission of experts in 1990 to identify and describe the skills required for the workforce. The Secretary's Commission on Achieving Necessary Skills (SCANS) may have contributed to the revival of constructivist learning strategies and PBL in the 1990s (Kane, Berryman, Goslin, & Meltzer, 1990).

As the Secretary of Labor, Dole charged the Commission to identify critical skills for successful employment in a high-performance knowledge-based economy that would illuminate the need for changes in education to meet modern workforce demands (Kane et al., 1990). The introduction of the SCANS report was a letter to parents, employers, and educators from the Secretary of Labor outlining the critical need to work together to prepare students for successful careers in the new millennium. Like Tyack and Cuban (1995), Kane et al. (1990) criticized traditional education as serving the elite and tracking the less fortunate into low-skill low-paying vocations. Kane et al. asserted that the future of the United States depends upon developing a highly skilled workforce that includes all learners and removes barriers to success such as race, gender, socio-economic status, and disabilities.

In the initial SCANS report, Kane et al. (1990) underscored the need for pedagogic innovation and stated that modern workplace skills cannot be developed using traditional instruction methods. Borrowing from Freire's (1970) critical pedagogy analogy they argued that teacher-centered instruction depicts students as "blank slates" and “passive receptacles into which knowledge may be poured” (Kane et al., 1990, p.7). Kane and colleagues emphasized the importance of applying findings from cognitive research on how learners learn most effectively and advocated for the implementation of constructivist strategies. They supported the need for teachers to immerse students in content through contextualized constructive learning in teams working on projects and engaging in sense-making, problem-solving, and meta-cognition. In essence, the pedagogic strategy recommended by Kane et al. in the SCANS report aligned conceptually with the key elements of “gold standard PBL” based upon research from the Buck Institute for Education published 25 years later (Larmer et al., 2015).

The Secretary of Labor’s Commission on Achieving Necessary Skills that began under Elizabeth Dole in 1990 concluded after several years under Secretary Lynn Martin. The commission produced a series of reports that progressively promoted a shift toward student-centered learning implementing constructivist pedagogy and performance-based assessments. SCANS research involved national experts in labor and education, employers from 50 fields, and schools representing every age level. The centerpiece of the SCANS project was a list of necessary skills and competencies for success in the workplace presented in the SCANS Report for America 2000 (SCANS Commission, 1991). The skills were divided into three areas of functional skills: basic content skills, thinking skills, and personal qualities; and five enabling competencies: resources, interpersonal, information, systems, and technology. Many of the SCAN skills are present in the 21st century skills frameworks mentioned earlier such as Partnership for 21st Century Skills (2004) and Kereluik et al. (2013) but each has its own method of organization. The America 2000 report highlighted the need for new strategies to prepare students for the knowledge economy and posited that teachers should begin early so students could start acquiring authentic workplace competencies in grade school. The need for instructional change in education implementing authentic constructivist learning strategies such as PBL to foster the development of these skills and competencies resonated across each report. Further, the expectation that SCANS would be widely integrated into the K-12 curriculum by the year 2000 was made clear. The SCANS Chairman, William Brock, declared that "the progressive forces of this country" must bring changes in public education so that every student would possess necessary workforce skills by age 16. Brock emphasized that "every school would be affected, every child would be affected, and every workplace would be affected" (Whetzel, 1992, p. 78).

The SCANS final report *Learning a Living: A Blueprint for High Performance* (SCANS, 1992) mirrored Dewey's (1938) philosophy and began with a message to teachers and employers imploring the two to work together to provide work-based experiences and accommodations for diverse learners with regard to English language skills, family income, and learning styles. The SCANS commission addressed specific pedagogic changes for realistic learning experiences and stated that "the enemy is rigid insistence on a factory model of schooling" and must be replaced with active learning in collaborative environments where students learn through interaction in groups, "teachers may not know all the answers" and "knowledge is related to real problems" (SCANS, 1992, p. xvii). Another important recommendation was for changes in assessment practices advocating for performance-based "assessment tied to learning goals" with SCANS skills and competencies integrated into national standards (SCANS, 1992, p.

xix). The rainbow graphic for the Partnership for 21st Century Skills (2004) framework clearly depicts this recommendation indicating that SCANS may have contributed to the development of 21st century learning frameworks.

Ten years after the final SCANS report, Arnold Packer, the former Executive Director of the SCANS project explored the impact of SCANS in terms of how the skills were being implemented and assessed (Packer & Brainard, 2003). Packer highlighted a variety of programs across the United States that had adopted the language of SCANS but lamented that the integration of SCANS in classroom curricula was slow and the goal for full implementation by the year 2000 was not yet realized. Packer and his colleague noted that some “first starters” showed some encouraging trends such as field study projects, teacher training in PBL and collaborative learning, course development activities for group work and mini-projects, a soft skills training pilot, and development of a computerized performance-based instrument to assess SCANS skills.

Packer and Brainard (2003) applauded the SCANS pioneers and commented that students in the pilot projects enjoyed the instructional strategies teachers implemented to develop SCANS skills. As an evolving student-centered learning strategy that cultivates student autonomy and self-regulation, a surge in PBL research investigating students’ opinions and attitudes toward learning designs emerged (Barron et al., 1998). Perhaps Packer’s perspective on the status of student involvement in education reform evolved as well. The 1990-1992 SCANS reports were addressed to parents, employers, and educators regarding the importance of their collaborative efforts to prepare students for the modern workplace. The documents did not directly address students; rather, they contained discussions *about* students and how their education needs should be met (Kane et al., 1990; SCANS, 1991; SCANS, 1992). Packer's reflection on the SCANS project a decade later indicated greater respect for student participation stating, "The SCANS report asked students, teachers, and employers to look beyond the classroom, the schoolhouse and the workplace and envision a system in which all participants are involved with learning a living" (Packer & Brainard, 2003, p. 3).

Despite the push-pull of education politics and pedagogy in the United States, de Graaff and Kolmos (2007) noted that PBL continuously thrived in Europe from the 1970s and began as problem-based learning first adopted as an instructional approach in medical fields. Both problem-based learning and PBL begin with an open-ended or ill-defined question to spark inquiry. PBL is time-bound and requires that students apply their learning and produce a product for presentation. Blumenfeld et al. (1991) clarified that a project is characterized as a complex task requiring several group members to contribute ideas and resources to produce a product. The project would be too much to expect one individual to deliver alone as the collaborative process incorporates the combined talents and resources of the group (Hans & Chakraverty, 2017). Socially constructed learning requires students to interact collaboratively, and social interdependence fuels higher order complex thinking (Chen, Wang, & Zhao, 2019). Students must attend to the content and product development processes while negotiating social interactions and such activities demand metacognition (Barnett, 1994; Hanney & Savin-Baden, 2013).

Blumenfeld et al. (1991) posited that traditional pedagogy was the main cause of students' general lack of motivation and disengagement in classrooms during the 1980s. Blumenfeld and colleagues argued that students were bored and given little opportunity to engage in higher order thinking and complex tasks due to the dominance of traditional instructional strategies in American classrooms. Students were expected to focus on rote memorization, worksheet completion, and tasks requiring low-level thinking. Blumenfeld et al. made a strong case for PBL based upon cognitive research.

Literature Reviews 1990 to 2000

Throughout the 1990s educators experimented with PBL in a variety of settings and developed PBL design strategies sharing case studies, class projects, observations, and anecdotal evidence. In the late 1990s, John W. Thomas was commissioned by the Autodesk Foundation, a philanthropic nonprofit, to conduct a literature review that has been widely cited synthesizing PBL studies from 1990 to 2000. Thomas (2000) found empirical research on PBL to be sparse and as a result, his study was not selective; Thomas included conference proceedings, white papers, education newsletters, and dissertation studies in his review and less than one-third of his references were from peer-reviewed journals. Thomas stated, "PBL research, for the most part, has not been presented or even referred to in popular periodicals or in books" (p. 35). Thomas asserted that PBL research and practice was disconnected and much work was needed. He noted that many of the PBL studies from the1990s used commercially packaged science projects that were not designed by teachers. Similarly, Krajcik et al. (1998) found that much of the PBL research was conducted in science classes taught by researchers at demonstration sites and asserted that more research in typical "rough and tumble" classrooms were needed (p. 315). Thomas (2000) concluded that his review indicated a tremendous potential for PBL to positively transform learning and highlighted important questions for future scholarly research. Thomas' study examined definitions and underpinnings of PBL research and practice, PBL and student characteristics, PBL implementation research, PBL obstacles for students and teachers, and research on improving the effectiveness of PBL.

Briefly, Thomas (2000) found that most of the research was conducted in science classes led by teachers with limited training and experience in PBL. He illuminated the need for studies on teacher designed projects, comparison studies across content subjects, and PBL assessment strategies. Overall, Thomas found that teachers needed professional development in PBL and administrative support and students as well as teachers, liked PBL better than traditional teacher-centered instruction. He summarized that for students to be successful in PBL they need teacher guidance and training in PBL procedures, structures for investigations, and guidance in productive use of technology. Finally, Thomas noted evidence that PBL could be an effective learning strategy with low performing students but illuminated a gap in PBL implementation research with diverse groups and highlighted this as an important focus for future studies.

Implementation Studies 2000-2010

During the first decade of the 21st century, there was a significant increase in PBL research published in scholarly journals. Holm (2011) conducted a highly selective review of research on PBL implementation in K-12 settings and cautioned that due to the nature of PBL, research is often descriptive using qualitative designs such as small case studies that cannot be generalized. Holm noted that much of the available PBL research was of poor quality and needed to be carefully scrutinized. One widely cited peer-reviewed article by Bell (2010), provided a comprehensive synthesis of PBL as an effective 21st century learning strategy. Bell, a doctoral student, essentially concurred with Thomas' (2000) findings. Upon closer examination, Bell's (2010) study was based upon a total of seven references and only three of them were peer-reviewed studies with the most recent being over five years old. The other four were not peer-reviewed resources; they consisted of commentary from Education Week (Boaler, 1999), books by John Dewey (1938) and Howard Gardner (2006), and Thomas' (2000) commissioned report. Scholars seeking to understand the nature and use of PBL should strive to use peer-reviewed studies as a dependable quality indicator; however, high-quality studies such as Holm's (2011) research cannot be verified as peer-reviewed using Ulrich's Periodicals Directory. Therefore, conscientious researchers should take care when selecting PBL research for inclusion in a literature review.

Despite variable quality in PBL studies, today a wide body of available scholarly research provides ample support for using PBL in the present study designed to explore how teachers may use this strategy to foster rigorous learning and higher order thinking. Aligned with the PB-LIFTS, the conceptual framework for this study, the literature review will focus upon PBL implementation research related to pedagogy and learning processes that foster rigorous learning and higher order thinking through student innovation and productivity.

To conclude, the history of student-centered instruction and constructivist pedagogy can be traced back to ancient times and PBL strategies have been in use in the United States since Dewey's time in the early 20th-century. Political swings have impacted its use in American education. The literature review revealed that even in the first decade of the 21st century the scholarly research base for PBL was weak; however, due to the global education imperative for graduates to enter the workforce with 21st century skill sets, the need for a pedagogical shift using innovative strategies to better prepare students sparked a surge in PBL research. The next section addresses the benefits of PBL found in recent research.

Benefits of Project-Based Learning

Numerous benefits of using PBL as an instructional strategy have been identified in the research literature. Recent experimental studies comparing PBL to traditional strategies with students from elementary to college levels have demonstrated that although PBL can be challenging, evaluations of this approach were generally positive as both teachers and students preferred PBL over the traditional teacher-directed approach (Bilgin et al., 2015; Catapano & Gray, 2015). PBL researchers have repeatedly documented motivational aspects of PBL when students exercise greater autonomy through engagement in real-world projects (Chiang & Lee, 2016; Ilter, 2014; Summers & Dickinson, 2012).

Benefits that are of interest for this study are related to PBL as constructivist pedagogy; however, it is important to mention that a host of other benefits have been reported in scholarly literature. Researchers found that students who participated in PBL demonstrated increased academic achievement (Han et al., 2015; Hung et al., 2012; Ilter, 2014; Karaçalli & Korur, 2014), long term knowledge retention (Karaçalli & Korur, 2014; Summers & Dickinson, 2012) higher attendance rates (Catapano & Gray, 2015; Creghan & Adair-Creghan, 2015; Shuptrine, 2013; Tamim & Grant, 2013), and improved learning behaviors (Chiang & Lee, 2016; Erdoğan & Dede, 2015; Hung et al., 2012; Ilter, 2014). Additionally, the benefits of PBL related to innovation, productivity and higher order thinking will be discussed in other areas of the literature review. The focus of this section is on benefits related to the constructivist nature of PBL.

From a pedagogical perspective, PBL is a comprehensive instructional approach that can be adapted for use in a variety of educational contexts and can foster the development of a range of skills and knowledge. Several recent studies concluded that when facilitated by skilled teachers PBL has the potential to increase students' content knowledge across disciplines while simultaneously developing 21st century skills needed for college and careers (Cho & Brown, 2013; DeWaters et al., 2014; Summers & Dickinson, 2012). In a case study weighing the strengths and weaknesses of using PBL at a Midwestern STEM high school, Cho and Brown (2013) summarized that although this strategy may not for everyone and not all content can be easily applied in projects "PBL surfaced as the best for developing twenty-first century skills for the new economy" (p. 756). Additionally, the results of a longitudinal study comparing two high schools within a rural school district revealed that students from the PBL high school outperformed students from the traditional high school in the achievement of social studies content and college and career readiness standards (Summers & Dickinson, 2012). In a study implementing PBL in middle and high school science classes, DeWaters et al. (2014) argued that when PBL is implemented by talented teachers, students can explore topics in depth and show growth in cognitive and affective domains without jeopardizing gains in content knowledge. In sum, current research has demonstrated that although PBL may be challenging for novice teachers it can be viewed as a comprehensive and versatile 21st century instructional pedagogy that has been successfully implemented across a variety of educational contexts and disciplines.

Researchers have identified several aspects of PBL that are motivational and promote the learning process, such as active learning and social engagement. Eighth-grade science students stated that PBL was difficult but motivational for them because they liked the challenge, having choices, using technology, and working with peers (Martelli & Watson, 2016). Ahonen and Kinnunen (2015) studied perspectives of 21st century skills education among 718 Finnish students aged 11 to 15 and found that social and collaborative skills were most valued by students as critical for their future success. Collaboration is a hallmark of the PBL process and may contribute to student motivation and the development of 21st century skills. Typically, students interact in small teams to acquire, evaluate, and apply content knowledge through the process of negotiation and *meaning making*. When students engage in such project processes they are afforded opportunities to develop skills that are valued in the modern labor force such as problem-solving, communication, collaboration, critical thinking, and creativity (Ainsworth, 2016; Cho & Brown, 2013; Moalosi et al., 2012). Studies also demonstrated that PBL designs can flexibly engage students in using a variety of technology and this supports the development of digital literacy, another highly valued 21st century skill in the workplace (Hao et al., 2016; Moalosi et al., 2012; Shuptrine, 2013). Although projects require time, Martelli and Watson (2016) concluded that PBL is an integrated and motivational approach that is more efficient than teaching skills in isolation.

The authentic nature of PBL engages students in learning about topics that are relevant to their lives and this can also be motivational for students (Martelli & Watson, 2016; Shin, 2018). DeWaters et al. (2014) found that students demonstrated greater self-efficacy for learning about real-world issues and were motivated to initiate connections with their communities for project support. Student engagement in authentic and personally relevant projects has also been found to increase ownership for learning and metacognitive processing (Ahonen & Kinnunen, 2015; Stolk & Harari, 2014; Tamim & Grant, 2013). For example, students studying global warming and how climate change can impact communities demonstrated greater awareness of group interactions and attention to decision-making processes (DeWaters et al., 2014) and engineering students demonstrated greater task value and elaboration strategies when engaged in PBL groups studying topics of personal interest (Stolk & Harari, 2014). PBL is a student-centered learning strategy that has been found to contribute positively to students' cognitive-affective and behavioral attributes (Ahonen & Kinnunen, 2015; Ilter, 2014; Moalosi et al., 2012; Wurdinger & Qureshi, 2015). Stolk and Harari (2014) found that PBL processes motivate learners as they promote autonomy, intrinsic goals, self-efficacy, and task value. Students can receive a variety of consistent feedback from peers, teachers, and self-reflection that drives learning over the life of a learning unit; thus, PBL strategies can help students focus upon the process of learning, not just the product (Tamim & Grant, 2013). Stolk and Harari argued that there is a direct relationship between student motivation and cognitive processing when learning is relevant and advocated that educators should seize the motivational benefits of PBL as a student-centered approach and shift away from traditional teacher-centered pedagogy.

Researchers identified the collaborative nature of PBL pedagogy as the key for developing teamwork, social, and communication skills needed for problem-solving and group productivity (Hung et al., 2012; Tamim, & Grant, 2013). Additionally, Han et al. (2015) and Karaçalli and Korur (2014) asserted that collaboration in PBL promotes self-regulation skills and according to Ahonen and Kinnunen (2015) these are critical to effective planning and cohesive teamwork. DeWaters et al. (2014) demonstrated that the complexity of group collaboration can be related to demonstrations of deeper learning and higher order thinking. Hsu et al. (2015) and Smith (2016) found that incorporating graphing technology to track PBL progress contributed to the development of organizational skills and deeper thinking.

Several studies demonstrated that PBL is effective for improving language skills due to the emphasis on social interaction and dialog among students in teachers. Martelli and Watson (2016) implemented PBL units from the Buck Institute for Education with 153 language arts students in the 8th grade and described significant progress in reading, writing, and oral skills. Studies have also shown PBL to be an effective strategy in classes with students acquiring English as a second language although teachers may have cultural barriers to overcome with students who expect to be passive learners receiving traditional teacher-centered instruction (Du & Han, 2016; Kim, 2015).

Studies in the scholarly literature have highlighted the benefits of implementing PBL with a variety of special populations. Tan et al. (2018) stressed that opportunities to engage underserved and historically marginalized students in STEM projects are critical to building identities as scientists and reducing the equity gap. Lambert (2015) argued that PBL can be a highly effective teaching strategy with students who have learning disabilities and described one student who rose to the top of his PBL math class from being among the least competent in a traditional math class. Hovey and Ferguson (2014) found that PBL can be an effective learning strategy with exceptional and diverse students. Martelli and Watson (2016) described teachers' experiences differentiating PBL with struggling students in inclusive classrooms and emphasized that scaffolding and attending to individual needs is a key to success. Moreover, scaffolding is fundamental to fostering the development of HOTS (Damsa & Muukkonen, 2020; Kadir, Abdullah, & Alias, 2019). The role of teachers in PBL classrooms shifts to serving as a guide and this allows educators to develop caring relationships and cultivate a culture of support which can increase student efficacy to overcome resistance to engagement (Kim, 2015; Martelli & Watson, 2016; Tamim, & Grant, 2013). Du and Han (2016) maintained that PBL could be implemented in varying degrees of rigor, and this allows teachers to make design decisions that can help all students experience success. The review of recent studies revealed that PBL has been successfully implemented with a variety of culturally diverse and underserved students such as inner-city children attending Saturday school (Catapano & Gray, 2015); Hispanic college students who developed career connections with local businesses (West & Simmons, 2012), and vocational high school students in Taiwan labeled as low achievers showed exceptional gains in problem-solving (Chiang & Lee, 2016).

In sum, the literature review revealed that studies had illuminated many benefits of implementing PBL pedagogy in a wide variety of contexts from elementary to adult education across all subject areas. Clearly, PBL is a comprehensive and versatile learning strategy that can be successfully implemented by experienced teachers to foster content achievement while developing 21st century skills through engagement in rigorous learning processes and higher order thinking. Although the recent literature showed that PBL could be implemented successfully in a plethora of learning environments with a variety of student populations, an empirical study with DHH students was not found. This gap is important because all students need to develop skillsets for success in the 21st century workplace and the literature shows that PBL is a strategy that can promote this development. My study will expand PBL research to the experiences of teachers of the deaf and extend the body of research on PBL to DHH students. What follows is an examination of the challenges of PBL. Despite the reported benefits, studies also describe a plethora of challenges to PBL implementation that teachers must overcome.

Challenges of Project-Based Learning

A variety of challenges to PBL implementation have been documented in scholarly literature. In this section, I organize the discussion of challenges of PBL using Bronfenbrenner's (1976) educational ecosystems model. Using this model, challenges can be conceptualized as situated in three nested spheres of social influence. At the center is the individual learner surrounded by the microsystem that may include challenges at the classroom level involving factors that impact learning such as time, place, learning activities, roles of teachers and students, and interactions among participants and facilitators. The middle sphere surrounding the microsystem is the exosystem. This level encompasses formal and informal social structures that govern or influence activities in schools and may present challenges to PBL implementation. At the exosystem level local communities, school districts, and legislative actions regulate processes within the schools such as teacher evaluation, curriculum, standards, and assessment. The outermost sphere is the macrosystem where national and international mechanisms shaped by cultural values, attitudes, and beliefs can influence instructional practices (Shuptrine, 2013; Tamim & Grant, 2013). As the 21st century unfolds and globalization rapidly evolves, educators who promote innovative learning strategies to prepare students for a changing world will face barriers when belief systems collide (Fullan, 2011). I will first discuss the PBL challenges on the macro, exo, and microsystem levels. Then I will address challenges to PBL related to planning, initiation, process, and evaluation.

Macrosystem Challenges

Several recent studies illuminated challenges to PBL adoption and implementation that can be broadly conceptualized as stemming from conflicting cultural values and belief at the macrosystem level. Such conflicts can be manifested by teachers and or students resisting new instructional strategies. For example, Stolk and Harari (2014) posited that traditional teacher-centered practices are deeply rooted in the culture of higher education and can influence instructors to reject constructivist pedagogy despite awareness of international scholars collectively calling for a pedagogical shift to better prepare students with practical skills needed for the 21st century marketplace. Lee et al. (2014) found that students from all academic levels and disciplines expect traditional "sit and get" instruction (p. 26). Qualitative data revealed that these college students rejected the introduction to PBL for a variety of reasons, but one reason was that they believed that PBL requires more work than the traditional approach. Other studies suggested that deep-rooted cultural beliefs regarding the roles of teachers and students may trigger resistance to PBL implementation (Pham & Renshaw, 2015; Yin, 2013).

In parts of the world where teacher-centered instruction has reigned for centuries and sustained passive learning pedagogy, both teachers, as well as students, have resisted student-centered learning (Chiang & Lee, 2016; Lee et al., 2014; Zhang & Liu, 2014). In a Korean study implementing PBL in an English class with 47 college freshmen, PBL conflicted with students' course expectations; consequently, instructors struggled for the first month with low attendance and students' refusal to engage productively in PBL groups (Kim, 2015). Other researchers found that Chinese teachers typically resist the notion of student-centered learning as this approach conflicts with the dominant Confucian belief system supporting obedience and teacher-centered instruction (Liu & Feng, 2015; Poole, 2016; Yin, 2013).

Zhang and Liu (2014) conducted a large mixed methods study of 733 Chinese secondary teachers and concluded that mandated high stakes testing may pose a greater barrier to the adoption of student-centered practices than Confucian cultural heritage. Zhang and Lui discovered that teachers are multidimensional and open to implementing student-centered learning approaches, but they are also concerned with preparing students for high stakes testing. Zhang and Lui concluded that teachers are finding a middle ground blending constructivist pedagogy and traditional approaches to prepare for tests. According to Bronfenbrenner's (1976) model, this is a challenge to PBL implementation imposed at the exosystem level where social mechanisms regulate schools.

Ecosystem Challenges

Researchers have found that high stakes testing is a challenge to PBL implementation in the United States as well as in regions where Confucian culture is dominant. Teachers are caught in a push and pull effect of education reform being encouraged to adopt student-centered practices and to meet accountability requirements mandated through standardized testing (Cho & Brown, 2013; Dole et al., 2016). Teachers are required to cover significant amounts of content with time constraints; thus, to prepare for tests students are often required to memorize facts which is a teacher-directed strategy. On the other hand, constructivist strategies require time for students to explore fewer topics in depth and produce creative applications (Summers & Dickinson, 2012; Tamim & Grant, 2013). Dole et al. (2016) referred to these challenges as conflicting visions and described the difficulties teachers face when trying to balance district pacing guides and scripted lessons with authentic project learning. Considering such pedagogical conflicts, researchers advocate that systemic change is needed to support the adoption and implementation of PBL in practice (Cho & Brown, 2013; Lee et al., 2014; Vega & Brown, 2013).

Aside from accountability mandates hindering PBL efforts, recent studies revealed that the lack of training was a major challenge to PBL implementation at the exosystem level. Polly and Hannafin (2010) examined national initiatives for education reform and noted curricular shifts toward constructivist learning; however, without organizational support for professional development, teachers struggled to implement student-centered teaching strategies. Another study by Polly and Hannafin (2011) detected misalignment between teachers espoused and enacted practices indicating that teachers hybridized PBL to suit their comfort zone adopting hands-on teacher-directed strategies rather than student-directed learning. Quantitative results of an explorative study including 134 preservice and in-service K-12 teachers from the Southwest United States indicated misconceptions regarding the methodology and purpose of PBL (Hovey & Ferguson, 2014). A number of researchers studying PBL concluded that teachers have a steep PBL learning curve and this requires ongoing professional development and systemic support (Cho & Brown, 2013; Hovey & Ferguson, 2014; Kim, 2015; Summers & Dickinson, 2012; Tamim & Grant, 2013).

Other challenges of PBL relate to professional development and building-level issues. A study by Vega and Brown (2013) illuminated the need for school level organizational support for PBL. Staff from three middle schools received a 5-day training in PBL from the Buck Institute during the summer with the expectation that teachers would be prepared to design and engage students in constructivist learning in the fall. Vega and Brown concluded that learning to implement PBL is challenging, requires time to master, and teachers need autonomy as well as administrative support for issues such as block scheduling and building a common planning time for teachers in the master schedule. Dole et al. (2016) categorized logistic challenges to PBL implementation related to finding resources, funding materials, designing PBL units, and having access to technology. Vega and Brown recommended that a building administrator is assigned to provide PBL support and oversight. Perhaps logistical challenges described by Dole et al. could be alleviated by building level administrative support as Vega and Brown suggested.

Other studies highlighted PBL challenges at the school and community level. Cho and Brown (2013) used SWOT analysis (strengths, weaknesses, opportunities, and threats) to study PBL in a midwestern STEM high school and asserted that whole school adoption and support for PBL is beneficial for creating a supportive “family-like” culture; however, they asserted that such a culture is vulnerable and must be constantly monitored. Examples of internal threats to PBL school culture were negative student attitudes and disengagement. Cho and Brown cited the “lack of public recognition of PBL” as a potential external threat to the internal culture of a small PBL school. In this study, the supportive atmosphere critical to PBL culture can be vulnerable for a small school nested in a community with a “big school mentality” (p. 758). Lee et al. (2014) described the importance of public recognition as a means of developing community partners to provide resources and support to students and their projects. Building community partnerships require time and human resources which can be a budget challenge. Lee et al. added that coordinating schedules for visits with the community can also be challenging as businesses do not operate on a semester schedule.

In sum, at the exosystem level internal and external school influences and can pose challenges to PBL. These challenges can involve conflicting visions, lack of professional development and ongoing training, systemic and administrative supports, school culture, public perceptions, and community partnerships. Collectively challenges at the exosystem level can influence PBL implementation nested in the microsystem where challenges can occur in classrooms among students and teachers.

Microsystem Challenges

The scholarly literature on PBL raises several challenges at the microsystem level. Tamim and Grant (2013) posited that a formidable challenge to implementing PBL is the teacher’s lack of experience in designing and facilitating rigorous learning. Inexperienced teachers struggle with the selection of a meaningful topic and creating essential questions that will drive learning. Students may also choose to develop a project that is outside of the teacher’s area of expertise (Lee et al., 2014). Hence, serving as a guide, providing coaching, and modeling critical thinking may be fraught with uncertainties and potential barriers to success when teachers feel insecure. Dole et al. (2016) noted that the shift to student-centered learning precipitates changes in classrooms that can be difficult for both teachers and students who are inexperienced with PBL. These challenges can be organized as impacting four stages of PBL implementation: planning for PBL, initiating PBL, PBL processes and procedures, and PBL evaluation.

PBL planning. Planning and preparation for PBL pose many challenges for teachers. Choosing the topic and creating good driving questions is time-consuming but critical to engaging students (Blumenfeld et al., 1991). Vega and Brown (2013) found that when planning PBL units teachers first struggle to align unit content with district benchmarks as well as scope and sequence timelines. Other recent studies report that the PBL planning process is labor intensive and requires significant time, energy, and resources (Dole et al., 2016; Summers & Dickinson, 2012). Although many PBL units can be readily downloaded from the internet, teachers tend to borrow and adapt ideas to create their own PBL units designed to meet the learning needs specific to the instructional context. For example, in a study by Martelli and Watson (2016), the teacher selected a PBL unit from the Buck Institute for Education (BIE) to implement in eighth-grade language arts classes. The teacher generally followed the unit plans but made revisions specific for her classes considering the students' needs for appropriate differentiation. Tamim and Grant (2013) asserted that there are many aspects of the planning process that are challenging for teachers such as finding and organizing resources, planning for multiple groups in large classes, managing several simultaneous projects, and keeping track of student processes. Hung et al. (2012) added that planning for technology integration can be another challenge; further, there are many strategies for fostering innovative processes that can complicate teacher planning (Seidel, Marion, & Fixson, 2020).

PBL initiation. The process of initiating PBL is complex and can be challenging as teachers must keep in mind immediate and long-term unit goals and flexibly respond to student needs while keeping students motivated and on track (Tamim & Grant, 2013). Several studies revealed that inexperienced teachers struggle with how to introduce PBL units in a way that will be motivational and sustain students' interest (Kim, 2015; Lee et al., 2014; Martelli & Watson, 2016). PBL experts encourage designing units with the end in mind; therefore, teachers need to consider what students should know and be able to do in addition to how they will be assessed (Boss & Kraus, 2014). Hence, designing and initiating PBL units with many layers to consider can be challenging for novice teachers who may be accustomed to following a linear curriculum using a textbook (Dole et al., 2016).

Another PBL challenge is that students who are inexperienced with constructivist strategies find it difficult to engage. Vega and Brown (2013) argued that middle school students are used to having content "spoon fed" to them or expect to do as little work as possible to "get by" (p.23). Similarly, Shuptrine (2013) found that high school students resisted exploring their topic because they were used to being told what to do. Dole et al. (2016) asserted that students with a fixed mindset are difficult to engage in a new learning approach and building confidence to takes time.

The changing roles of teachers and students are another challenge in the early stages of PBL. Teachers have difficulty "letting go" of classroom control and students have difficulty taking an active role in the learning process (Dole et al., 2016; Kim, 2015; Vega & Brown, 2013). Teachers should serve as guides and facilitate the learning process, yet this is challenging when classes are large (Tamim & Grant, 2013). Lee et al.

(2014) maintained that college instructors struggled with redefined roles like the experiences of faculty members in K-12 studies.

PBL processes. Beyond project initiation difficulties, an abundance of other PBL challenges surfaces when teachers encourage students to work in teams. Multiple studies reported that students at every age level are unprepared to engage in PBL groups productively and lack training. Without PBL processes and procedures in place, accountability, self-regulation, and team productivity are at risk (Ainsworth, 2016; Cho & Brown, 2013; Dole et al., 2016; Lee et al., 2014; Shuptrine, 2013; Wilson et al., 2017). Vega and Brown (2013) summarized that teachers must find time to train students in prerequisite skills including "teamwork, collaboration, time management, and public speaking" for students to engage effectively in PBL (p. 26). Ainsworth (2016) studied the behaviors of high and low performing teams. This study illuminated the need for training students in self-regulatory as well as coregulatory strategies to plan and monitor task completion and interpersonal dynamics. Such training can prevent social loafing or free riding which causes problems among team members regarding equity of workload. Problems regarding accountability among team members are a common challenge to successful PBL engagement (Ainsworth, 2016; Martelli & Watson, 2016; Trilling & Fadel, 2009).

Shuptrine (2013) illuminated the need for skills training that will help students engage in the process of PBL and increase regulatory skills. Shuptrine described high school students in a career tech education class avoiding teamwork at first but when they realized the topic was too challenging to tackle independently, they did not know how to come together and collaborate. Tamim and Grant (2013) added that getting students to collaborate is the most challenging aspect of PBL. Couros (2015) posited that innovative thinking grows from disagreements and effective teams share diverse ideas and merge them to create better ideas collaboratively. However, Cho and Brown (2013) reported that high school students did not have strategies for resolving conflicts and this hindered their ability to work in teams. Moreover Lee et al. (2014) added that students of all ages need training to work in PBL groups more effectively. Undergraduate and graduate students in this study experienced initial difficulties with team engagement which led to the conclusion that “the struggles of older more experienced students mirror those of K-12 students as they encounter PBL for the first time” (p. 28). Cho and Brown (2013) argued that having agreed processes and procedures in place can be an asset to increasing team accountability while serving as the basis for formative assessment at any stage of a project. Thus, in PBL pedagogy the learning process is valued and can be formatively assessed at every stage from project initiation to project presentation and reflection.

PBL evaluation. Experts in assessing 21st century learning advocate for multidimensional student-centered evaluation practices that can drive the learning process and cultivate lifelong learners whether learning takes place online on face-to-face (Boss & Kraus, 2014; Greenstein, 2012; Larmer et al., 2015; Marzano & Heflebower, 2012). The use of rubrics and peer assessment are common PBL evaluation strategies and can be a source of conflict when the individual being assessed and assessor disagree (Tamim & Grant, 2013). PBL assessment practices are in sharp contrast to traditional assessment methods where individual grades are heavily based upon final exams that have right and wrong answers. Lee et al. (2014) summarized that instructors in K-12 and college level struggle with “how to evaluate deeper content understanding, group processes, alternative products and soft skills" and prefer familiar assessment strategies such as term papers, quizzes and exams (p.28). Challenges to PBL assessment strategies can arise when students resist formative assessment practices focusing upon the end and not the means of the learning process. PBL evaluation should be ongoing providing feedback on the learning process, product, presentation, and reflection (Cho & Brown, 2013).

In sum, many PBL challenges have been documented in the scholarly literature along with suggestions for how they can be addressed. Challenges to PBL can be understood using the ecosystems model to understand sources of dissonance with PBL pedagogy. Challenges to PBL implementation can also be understood using a temporal framework identifying at what stage of PBL difficulties arises. Regardless of how challenges are organized, most often they are attributed to lack of experience with constructivist strategies on the part of teachers and students alike. The current literature on teachers' perspectives will provide further insight regarding PBL implementation that can be applied in this study.

Teacher Perceptions of Project-based Learning

Reviewing current research to develop a comprehensive understanding of teachers' PBL perceptions could support the process of interpreting data from teacher interviews in the study. Recent empirical studies that focused solely upon teacher perceptions of PBL are somewhat limited; however, by combining associated terms, several applicable findings can be gleaned from the literature. These findings can be organized as related to PBL impact on preparation, instructional practices, learning environments, and outcomes.

Preparation to Teach Project-Based Learning

In the previous sections PBL was described as a challenging yet innovative instructional approach and when implemented by skilled teachers can be an effective strategy to promote the development of students' 21st century skills and content knowledge. Two recurring themes regarding preparation for PBL are addressed in the literature from the perspectives of teachers; one concerns how teachers receive PBL training and the other relates to issues surrounding the preparation of PBL units. Regarding teacher preparation, studies revealed that training teachers to implement PBL is not a simple endeavor as there are many components to master. In a mixed methods study Zhu and Wang (2014) surveyed 325 award-winning teachers in China and identified a complex set of critical competencies and characteristics of innovative teachers. Briefly, the findings were arranged in four broad groups including learning competence, social competence, educational competence, and technical competence. Follow up interviews with 21 of these teachers confirmed that as a group they believed the development of innovative competencies requires time and dedication coupled with continuous learning opportunities. Studies showed that teachers believed ongoing PBL training and support was essential (Ertmer et al., 2014; Kim, 2015; Vega & Brown, 2013). Hovey and Ferguson (2014) studied teachers' perceptions from their experiences using PBL with English language learners, gifted students, and students with disabilities. They concluded that continuous support is particularly important for teachers implementing PBL with diverse populations. Further, since the practice of including students with diverse needs in general education is a growing trend in classrooms all over the world, teacher support is critical to PBL adoption and implementation.

Recent studies revealed that as a group, preservice and in-service teachers do not feel confident that their PBL training experiences adequately prepared them to implement PBL. In several studies, teachers expressed that learning about PBL through lectures and workshops alone was insufficient without supported hands-on experience applying this instructional strategy (Cook & Weaver, 2015; Lee et al., 2014; Vega & Brown, 2013). Baysura, Altun, and Yucel-Toy (2015) conducted a qualitative phenomenological study of 58 teacher candidates and noted that upon graduation and entrance into the field, they may not even be aware of their deficiencies. Participants in this study stated that they planned to use PBL due to the perceived benefits of this approach; however, the researchers learned that this view was based upon a 1 hour lecture covering PBL theory and nearly half of the candidates indicated they did not have an opportunity to apply PBL in their practicum experiences prior to completing teacher training.

Although these future teachers indicated their willingness and intent to implement PBL, many predicted that time management would pose the greatest barrier to success and that opportunities to apply theoretical principles in guided practice were needed. Despite this concern, they believed that PBL instructional strategies could facilitate the development of important 21st century skills that students need for college and career readiness such as conducting research, working in teams, and being productive. Although these teachers did not receive satisfactory training, according to Kim, Kim, Lee, Spector, and DeMeester (2013) teachers' beliefs about learning and effective ways of teaching often predict the instructional strategies teachers will employ. Because PBL is gaining popularity in schools, inexperienced teachers may find avenues for support within their buildings when they attempt to initiate PBL units. Habók and Nagy (2016) confirmed that having guidance and support when learning to implement PBL is important but cautioned that teachers must have adequate PBL methods training first.

A review of the scholarly literature revealed that in-service teachers often receive PBL training via short term professional development opportunities. PBL training is sponsored in a variety of ways such as through universities, education conferences, grants, state education agencies, and for-profit enterprises, as well as district or school-based training that may be voluntary, paid, or required. Several recent studies focused on teachers' perspectives of their PBL training experiences in an effort to discover effective strategies that prepare teachers to adopt and implement PBL across a range of teaching contexts (Cook & Weaver, 2015; Dole et al., 2016; Ertmer et al., 2014; Nariman & Chrispeels, 2016; Vega & Brown, 2013).

The literature revealed that PBL is frequently provided to practicing teachers via summer workshops. By comparing two professional development studies, promising elements of PBL summer training, as well as some of the pitfalls, come to light. A qualitative collective case study by Cook and Weaver (2015) examined a program funded by a National Science Foundation (2001) grant that was designed to explore the effects of a 2-week summer workshop on PBL and STEM with seven high school science teachers from rural public schools. Teachers were trained using PBL materials from the BUCK Institute for Education (BIE) and each teacher designed a PBL unit to use during the upcoming school year. When the researchers observed teachers implementing their units, it appeared that the training had minimal impact upon pedagogy as the teachers were not able to fully implement critical features of PBL. Overall, the teachers had difficulty in the role of the facilitator, the activities lacked rigor and did not demonstrate authentic meaning-making for students. Other problems were that students had difficulty working in teams and were simply told to cooperate. Another serious shortcoming realized in this study was that students' final products showed little connection to the essential question. Although teachers were unable to incorporate several of the basic theoretical principles of PBL that were emphasized during the training, during interviews teachers indicated that they felt PBL training should focus less on theory and pedagogy and more on *how* to apply PBL in content subjects. The teachers in this study did not have expert support available or access to fellow teachers implementing PBL in their buildings with whom they could collaborate.

In the second qualitative study teachers also received summer training and BIE PBL materials were used but the outcome of this training was quite different from the Cook and Weaver (2015) study. Dole et al. (2016) included 36 teachers from elementary, middle, and high schools who participated in a 4-week online PBL class followed by a 1-week field experience in which they cotaught a PBL unit with groups of children ages 6-14. Teachers received credit through a southeastern United States university for participation. The field component of this summer course provided researchers an observable means to study the impact of the training on teachers' instructional approach in action. Teachers were able to successfully implement principles of PBL during the field experience; however, it is important to understand that they had support. Dole et al. found that trainees who worked together as coteachers with guidance and oversight from PBL experts were able to navigate obstacles in a supportive environment and this promoted a sense of confidence. Training that includes opportunities to practice implementing this instructional method may be a key component of successful PBL training.

Learning to implement PBL takes time and teachers frequently comment that the role shift from teacher-centered pedagogy to student-centered learning is difficult and causes feelings of vulnerability. Dole et al. (2016) described the adoption of PBL instructional methods as *risky* for teachers who are new to student-directed learning with unpredictable outcomes. A professor from a mid-sized Canadian university implementing student-directed experiential learning in elective courses with 214 students expressed similar feelings (Breunig, 2017). In this self-study, Breunig commented that it was a struggle to give up control over the learning process. According to Breunig letting go of control at times felt risky and learning to step back to let students work through the learning process was a challenge. Dole et al. (2016) also commented that teachers found it difficult to let go of control at the K-12 level. Lee et al. (2014) raised another potential risk that may accompany the implementation of PBL; students may choose to pursue projects on topics that are outside of the teacher's area of expertise and this may cause discomfort for teachers who are new to functioning as a guide and colearner beside students. In environments where teachers are colearners with students the *process* of learning is valued over knowing the right answers. Hence, when the role of the teacher shifts away from being the authoritarian who controls the content and learning plan, it may not be easy for teachers who grew up with this traditional model and have used it in their own practice as well.

Several researchers highlighted the importance of teachers having time together to develop networks of collegial support to facilitate PBL adoption. A study by Le Fevre

(2014) shed light on issues related to teachers' perceptions of risk and acknowledged the importance of collegial support in schools adopting a new pedagogy. As part of a larger two-year study on pedagogical change related to a literacy initiative in a United States school district, Le Febre selected one of the elementary schools for a case study. Le Fevre investigated teachers' perceptions of risk and the findings of this study can be applied to pedagogical change and PBL. Le Febre found that deprivatization of practice, reducing dependency on textbooks, and increasing student voice were the three main triggers that caused teachers to feel threatened by pedagogical change; all three of these are present in schools implementing PBL. In PBL learning environments teachers typically do not work in isolation and projects are shared publicly, textbooks and scripted curricula are not the class content staple, and students are encouraged to exercise greater autonomy and self-directed learning (DeWaters et al., 2014; English & Kitsantas, 2013). Le Fevre (2014) elaborated that when the perception of risk is high, teachers will resist the pedagogical change but when teachers can collectively support a new pedagogy and commit to implementing it in a supportive environment where they are given planning time together, perceptions of risk are reduced. C. Kim et al. (2013) confirmed that networking helps teachers shift to new beliefs as a collective group and reduces stress.

Designing and preparing to initiate PBL units is challenging as well as labor intensive and the need for teachers to have time together for PBL development and preparation was a recurring theme in the recent literature. Although Breunig (2017) agreed that planning for PBL is important this professor also cautioned that over planning can also be counterproductive and stifle student autonomy; therefore, teachers must find a balance in their planning that will allow for flexibility to encourage student self-direction as appropriate. Researchers in Spain conducted a correlational descriptive design study to investigate the views of 310 teachers representing programs from nursery through post high school and vocational education (Gómez-Pablos et al., 2017). Questionnaire results revealed that teacher collaboration time supports the development of rigorous PBL designs, preparation of materials, and finding appropriate resources. Several studies noted that teachers struggled to develop essential questions (Ertmer et al., 2014; Lee et al., 2014; Nariman & Chrispeels, 2016). This is a critical planning piece as every PBL should begin with an essential question that serves as a unit springboard and drives the level of learning and rigor through to the conclusion of the experience and project evaluation. Creating quality essential questions is one of the more challenging aspects of PBL preparation and perhaps this is one area where teachers should collaborate to support one another. The value of teacher collaboration and dialog for increasing lesson rigor was demonstrated in a large-scale multiphase project by Vrikki et al. (2017) that involved 59 primary, secondary, and special schools over two years. In one part of this study, the researchers used video-based analysis of 13 teachers engaged in lesson study from four primary schools in the UK. The results demonstrated the positive effect of teacher interactions as they built upon one another ideas that promoted rigorous lesson planning and evaluation processes. Preparing rigorous PBL units is challenging and research evidence suggests that teacher collaboration is an important component of the planning process.

In addition to planning and colleague support, studies of teachers' perceptions regarding preparation for PBL highlighted needs and concerns related to resources and technology. In a case study of two social studies units with sixth graders who had to research and produce products, Rudnitsky (2013) found teachers believe that to be successful students must have access to a variety of high-quality resources and this was an area of need. Scholl (2014) asserted that to facilitate and sustain pedagogical change the availability of resources to teachers and students is critical. One example of teachers needing resources was shown in the Cook and Weaver (2015) study of rural science teachers who indicated that they needed a way to increase their own content knowledge so they could better implement PBL. In a grant study of a low performing elementary school that received new classroom technology, teachers asserted that they need resources for appropriate websites students with limited language skills could use for projects (Nariman & Chrispeels, 2016).

Teachers who strive to empower students using technology as a learning tool may find context-specific issues that must be resolved. For example, in a study by Rahimi et al. (2015) a teacher of middle school age students in the Netherlands found barriers that prevented him from engaging students in constructivist learning using Web 2.0 technology. The school technology system blocked students from accessing websites that had to be resolved before the teacher could launch technology-based learning. The teacher valued increasing digital learning and responsible use of the internet but to guide students and promote the development of these 21st century skills, the students had to have internet access to the web. In another quasi-experimental study at a two-year Canadian college, Lasry et al. (2014) identified an extra layer of planning teachers in technology-rich environments must address. In classrooms that are designed for collaborative learning via technology, instructors must consider the scaffolding needs of students who are technically inexperienced to avoid cognitive overload. Not all students come prepared to use technology to collaborate and produce artifacts; thus, preparing these students adds another layer of preparation for these instructors.

PBL preparation has been addressed in this section from the perspectives of how teachers described their preparation and training to implement PBL as well as issues related to preparing for PBL units. In respect to teacher preparation, studies have shown that preservice teachers may believe in the benefits of PBL, but they may not have had opportunities to apply it prior to entering the workforce and having their own class. In-service teachers often receive PBL training via a short-term workshop and this has been shown to be insufficient for developing a sense of readiness to implement PBL independently. Researchers have found evidence that PBL mentor support increases the confidence of inexperienced teachers attempting to implement PBL. Secondly, teachers are often responsible for designing their own PBL units and this can be challenging as well as time consuming. Studies suggest that teacher collaboration time is needed to support planning for PBL, and this dialog has been shown to increase lesson rigor.

Impact on Instructional Practices

PBL has been implemented across a continuum of constructivist pedagogies ranging from teacher-controlled activity learning on one end to student-driven connected learning on the other. For this reason, it is important to understand the teacher's purpose for PBL implementation to understand the ways in which PBL may impact instructional practices. Tamim and Grant (2013) found that teachers implement PBL with three main purposes in mind: to reinforce, to extend, and to initiate content. These three purposes be a sequential progression from controlling content to open-ended learning. Teachers who use PBL to reinforce learning engage students in supplemental activities designed to practice content previously learned. Teachers who use PBL to extend learning increase the cognitive complexity of content introduced previously to promote deeper critical thinking. Teachers who use PBL to initiate learning will use it to introduce new content by posing an essential question that will pique students' curiosity and motivate them to discover more. In the case of the latter, students exercise greater autonomy and self-direction; further, the content students discover and incorporate in their projects is unknown when the unit is first launched. Tamim and Grant also noted that some experienced teachers are comfortable implementing PBL for all three purposes depending upon learner needs and called these teachers navigators. This implies that PBL purposes may not depend upon who the teacher is, but rather on students' needs and abilities. Despite which purpose teachers choose to implement PBL, recent studies have found that PBL impacts teachers' instructional approach in a variety of ways. Recurring themes in the literature can be grouped as teacher and student roles, training needs for students, technology integration, and assessment strategies.

Roles. One foundational principle of PBL is that it is a student-centered approach in which teachers become facilitators in the learning process and students take an active role by working in small teams focused on an essential question. Students research and evaluate information then collaboratively craft a project plan that will result in the production of a creative product representative of their learning. This requires students to exercise some degree of self-direction and autonomy while the teacher serves as a guide supporting the process (Larmer et al., 2015). Thus, both teachers and students who are new to PBL experience a role shift from the traditional approach where teachers exercise complete control over the learning process using a prescribed curriculum and students passively absorb information that they will memorize and reproduce on exams. Regarding students accepting their role as active learners in PBL, some studies showed that students were initially resistant. Teachers expressed that student resistance was difficult to overcome but with time, students learned to appreciate PBL as they enjoyed their new sense of autonomy (Kim, 2015; Martelli & Watson, 2016; Vega & Brown, 2013).

Researchers in several recent qualitative studies explored the experiences of teachers who are new to implementing PBL and documented that learning to serve as a facilitator and to manage PBL teams takes practice and patience. For example, teachers are often accustomed to controlling the learning process; therefore, knowing when to stay back and let students work through difficulties or when it is time to intervene and provide scaffolding requires keen attention to the learning process and consistent situational assessment (Dole et al., 2016; English & Kitsantas, 2013; Nariman & Chrispeels, 2016). Teacher PBL perception studies frequently acknowledged that learning the role of the facilitator in PBL is challenging whether this approach is implemented in college (Breunig, 2017), adult education (Scott, 2016) high school (Cook & Weaver, 2015) middle school (Martelli & Watson, 2016) elementary (Nariman & Chrispeels, 2016) or with special populations such as ELL, gifted, or students with disabilities (Hovey & Ferguson, 2014). English and Kitsantas (2013) recognized the difficulty students and teachers experience when there is a transfer of ownership for learning. These researchers conducted a systemic review of empirical evidence to discover practices that have been shown to develop students' self-regulation skills for PBL and support their ability to assume an active role in the learning process. A key finding from the English and

Kitsantas study was that a significant role shift such as the transition from traditional to the PBL student role needs to be introduced gradually and methodically for a smooth transition.

When the role of the teacher shifts in PBL to support constructivist learning, studies showed that this impacted instructional practice in multiple ways. A case study by Tamim and Grant (2013) provided a comprehensive description of this impact. Tamim and Grant identified six accomplished PBL teachers of students in grades 4-12 who were asked to describe perceptions of their role and associated instructional strategies in PBL. These teachers stated they viewed themselves as facilitators, guides, and colearners who flexibly manage teamwork, and carefully scaffold learning as needed. They highlighted the importance of clarifying goals and expectations with students and providing rubrics to make learning targets explicit while generating ownership. They advocated for differentiating PBL activities so that all students can participate productively and work toward personal mastery goals. These experienced teachers viewed PBL instructional strategies as positively impacting classroom climate.

Recent studies also revealed that teachers implementing PBL for the first time noticed a positive impact on the learning environment. Teachers of every age level commented that the role shift to student-centered practice was trying at times but PBL allowed them to develop closer relationships with students (Breunig, 2017; Dole et al., 2016; Martelli & Watson, 2016). Dole et al. (2016) reported teachers remarked 32 times that they developed a greater rapport with students and a new sense of trust. Eight teachers made references to PBL strategies helping them become better listeners and communicators in their new role. Martelli and Watson (2016) provided an unusual account of a middle school language arts teacher who adapted BIE materials by reading a book and implementing two six-week PBL units with 153 students. In this study, the teacher described personal experiences using mastery goals and differentiating for struggling learners in general education classes. Although teachers often report that assuming the role of the facilitator and learning to implement PBL with all students is challenging, most often they conclude that it is a worthwhile endeavor.

Teachers reported that the PBL role shift for students can be particularly challenging. Teacher perception studies at every academic level from elementary school through college found students ill-prepared as active self-regulated learners ready to assume their PBL role and fulfill the tasks expected of them. For example, similarities were found between college and middle school teacher beliefs regarding student abilities to engage actively in PBL. Vega and Brown (2013) found that teachers believed middle school students were not prepared to collaborate, organize the learning process, manage time, or use technology effectively for learning as they had always depended upon their teachers to tell them what to do. Interviews with faculty members representing eight departments at a college in Indiana revealed similar concerns regarding students being unprepared for self-directed learning. Lee et al. (2014) summarized that the instructors believed their students struggled with problems like K-12 students due to teachers maintaining authority and control over the learning process throughout their educational experience. Faculty in this study did not think their students were prepared to find information to supplement their current knowledge or to make decisions. Additionally, they expressed concerns that students were not prepared to engage in collaborative learning. The findings of both Vega and Brown (2013) and Lee et al. (2014) suggest that students may be conditioned as passive learners due to teachers using traditional instructional strategies throughout their educational experience. In this case, students may not have had opportunities to develop the skills or mindset needed for PBL. English and Kitsantas (2013) addressed this problem and warned teachers that transiting to new roles in PBL must be done gradually and methodically to succeed.

Collaboration and teamwork are critical components of PBL and in the recent scholarly literature, teachers perceived two common barriers to collaborative teamwork: conflicts among team members and accountability issues. D. Lee, Huh, and Reigeluth (2015) posited that intra team conflicts were a major challenge for teachers and that available research on this topic is sparse. D. Lee et al. did an exploratory case study with 111 high school social studies students using PBL to examine sources of conflict based upon a three-prong framework. They studied team conflicts categorized as task related, process or procedure related, and relationship or personality related conflicts. They found that usually, more than one type of conflict occurred simultaneously among teams. From the results of this study D. Lee et al. recommended strategies teachers could use for grouping students to reduce the likelihood of conflict; however, they strongly advocated for training students to consciously develop collaborative skills. They found that students with training not only collaborated more effectively, but they also scored higher on performance tests as well.

Taken as a whole, recent studies of teacher perceptions underscored the significant role shift teachers and students experienced when engaging in PBL. The impact of this shift upon instructional practices revealed obstacles to PBL implementation that suggest the need for additional scholarly research. Numerous studies illuminated the difficulties teachers experienced when attempting the role of the facilitator in PBL who scaffolds learning when support is needed and serves as a guide to students who are to engage collaboratively in student-driven learning. Research revealed that teachers struggled to step back and allow students to take greater control over the learning process. Although it was theorized that this was due to a force of habit, recent studies in a variety of contexts found that teachers had difficulty turning over control to students because they did not believe students possessed the skills needed to assume their role as autonomous learners. Hence, teachers from elementary through college levels expressed that for students to engage productively in collaborative learning they need PBL training.

Training needs for students. The literature review for this study revealed widespread agreement among teachers that students need training in collaborative skills as a prerequisite to PBL engagement. Moliner et al. (2015) confirmed that collaborative training was beneficial to constructivist learning processes in a study of 54 students taught by five science and engineering instructors at four universities in Spain. Qualitative data were collected via an online survey that contained multiple choice and some open-ended questions. The instructors stated that students were trained in how to interact in teams and claimed this promoted creative and productive team collaboration and enhanced students' soft skill development. Similarly, in a qualitative case study following a semester long PBL experience in engineering education at a university in Portugal, Alves et al. (2016) studied the perspectives of eight instructors from different schools and departments. The researchers found that the instructors described the student teams as dynamic and engaged. Their ability to work together collaboratively was attributed to training in teamwork and communication skills prior to beginning the PBL.

Team conflicts were often described as a barrier to PBL collaboration in recent studies and accountability issues were identified as causing friction. In several studies teachers referred to the issue of “social loafing” or “free riding” which is a common problem within teams when one member is not productive and the others do the project work (Ainsworth, 2016; Dole et al., 2016; Lee et al., 2014; Moliner et al., 2015; Tamim & Grant, 2013; Vega & Brown, 2013). Ainsworth (2016) theorized that team disparity can be caused by specialization of labor. For example, a free rider may choose a task perceived as requiring the least amount of effort and rush through it or simply fail to honor timelines. Lee et al. (2014) and Vega and Brown (2013) noted that students who do not value the process of learning often focus more on *finishing* without concern for producing a quality final product. This causes accountability problems due to conflicting goals or unequal contributions. D. Lee et al. (2015) posited that when students do not participate equally this can trigger process conflicts and relationship conflicts within the group which can also cause task conflicts. This analysis provided by D. Lee et al. illuminated how conflicts can snowball and if not resolved can jeopardize an entire project.

In contrast, Breunig (2017) noted that students were invested in real-world projects they cared about in the community and this caused a "heightened sense of accountability" (p. 12). Moliner et al. (2015) found that with PBL practice, the development of communication and group processes or transversal skills promoted creative team productivity. Similarly, Lee et al. (2014) and D. Lee et al. (2015) noted that the longer students work on different projects together, team management skills develop; they begin to coordinate tasks, work through problems, become more efficient, and curb social loafing. This point was also mentioned by K-12 PBL teachers who noted that given multiple opportunities to work together on projects team management skills begin to develop (Dole et al., 2016). Further, D. Lee et al. (2015) posited that as group processes become "habitualized" conflicts diminish (p. 583). Because studies of teachers PBL perceptions document team management and collaboration concerns, it is important to explore PBL strategies teachers report as beneficial to PBL team development.

Several studies documented PBL instructional strategies teachers perceived as supportive of collaborative teamwork. Alves et al. (2016) noted that productive teams of engineering students claimed a common area where they gathered to interact. The teacher narrative stated that teams "personalized" their work area. It can be inferred that having a group space may increase productivity; perhaps displaying project artifacts such as timelines increase peer oversight and accountability. Hao et al. (2016) surveyed the effects of precommitment on PBL among 41 students from a southeastern United States university and found that establishing written commitments significantly improved goal attainment and project performance. Lee et al. (2014) supported this finding stating that students generally perform better when they have a contract. D. Lee et al. (2015) suggested that the use of team management technology could reduce social loafing and increase productivity. Lee et al. (2014) clarified this point stating that teachers observed the positive impact of contracts involving peers as members of a learning team. Tamim and Grant (2013) acknowledged this point with the assertion that peer engagement in regulating team productivity improves student behaviors. Overall, teachers agreed that peer oversight improves productivity, but multiple studies emphasized that above all, training students via direct instruction to function in teams is highly recommended (Gómez-Pablos et al., 2017; Nariman & Chrispeels, 2016; Tamim & Grant, 2013). Teacher perceptions of issues that occur in student groups and how team development occurs are important to explore since it likely impacts their facilitation and willingness to continue implementing PBL.

Although the voices of teachers in recent studies showed strong agreement that students need direct instruction in team processes and collaboration prior to PBL engagement, only two of the teacher perceptions studies in this review reported successful training of this nature. Science and engineering college students in Spain and Portugal received formal instruction in collaborative skills that were integrated into their course of studies (Alves et al., 2016; Moliner et al., 2015). Instructors reported that this training supported successful teamwork; however, insights regarding curricular specifics or course syllabi were not shared. Teacher perception studies related to PBL documented widespread agreement that students must receive training in group work yet awareness of curriculum materials for this purpose were not mentioned. There appears to be a gap in the body of scholarly research on PBL instructional strategies recommended by teachers for training students in group engagement and collaborative learning processes that should not be discounted. An overarching goal of PBL is to promote rigorous learning that supports innovative thinking and productivity yet integral to this constructivist model is effective team collaboration. One point of synthesis from this literature review is that teachers collectively declared that training for students in collaboration as an area of critical need which indicates a gap between theory and practice.

Technology integration. The impact of technology integration on instructional practice is addressed frequently in scholarly literature related to PBL and constructivist pedagogies. Overall, studies indicate that teachers' beliefs determine the degree to which technology is integrated into the learning process. In a PBL study of a low performing elementary school that received a federal grant as a Turnaround School, technology was placed in every classroom and teachers were given technology support (Nariman & Chrispeels, 2016). By the second year of the grant, researchers found that teachers used document cameras to present content and laptops to show videos and PowerPoint presentations to students. Teachers also commented that technology was a valuable resource for engaging students in lessons; however, there was no mention of students using technology as a learning tool for their projects. Technology appeared to be used as an alternative means to present content. The study also revealed that 28% of the teaching staff reported that they were uncomfortable integrating technology in PBL. Similarly, Habók and Nagy (2016) found that secondary level teachers believed the use of information communications technology (ICT) in PBL was not vital and did not incorporate the use of available ICT in PBL learning designs. In the Habók and Nagy study, the researchers found that the teachers who did not make use of ICT tools preferred to lecture which is a traditional approach. In contrast, leaders in the field of ICT and PBL argue that the incorporation of Web 2.0 tools for students' PBL projects is not only transformational but indispensable for innovative learning and the development of 21st century skills (Boss & Kraus, 2014; Ertmer & Ottenbreit-Leftwich, 2013; Gómez-Pablos et al., 2017; Thamarasseri, 2014; Voogt et al., 2013). The literature shows that the types of technology, how technology is used by the instructor, and student use of Web 2.0

technology in PBL can be influenced by the pedagogical preferences of the teacher and may impact the quality of PBL projects.

Other researchers noted a relationship between teacher pedagogical orientations and technology integration. Koh, Chai, and Tsai (2014) surveyed 354 Singaporean teachers from primary to junior college in a quantitative study to discover teachers' perceptions of constructivist learning regarding technology, pedagogy, and content knowledge (TPACK). The researchers found that teachers were least comfortable integrating technology in constructivist learning. C. Kim et al. (2013) conducted a four-year exploratory mixed method study of 22 teachers from elementary through middle schools in the southwestern United States and found that teachers' beliefs can be a second-order barrier to integrating technology in learning and that teacher networking is critical to technology integration. Further, they found that there is a strong correlation between teachers who integrate technology and student-centered learning. This was supported in a study by Lasry et al. (2014) who found that even when teachers are placed in high tech classrooms, they will not integrate technology in learning if they have a traditional teacher-centered belief system.

The findings of recent PBL studies also revealed ways that technology use can positively impact instructional practice. Boss and Kraus (2014) described the results of integrating technology as opening new windows for student collaborative productivity, thinking, creativity and communication. Boss and Kraus posited, "When teachers thoughtfully integrate these tools, the result is like a "turbo boost" that can take PBL into a new orbit" (p. 16-17). Lin et al. (2015) found that ICT positively impacted learning processes for teachers and high school students as colearners in online PBL. Interacting in global learning networks promoted the development of 21st century skills, self-direction, and deeper learning. Allison and Goldston (2016) studied the use of technology in two elementary science classrooms and the impact on instructional practices. In this study, Google Drive was used for group projects and teachers commented that students were able to seamlessly communicate ideas and share information inside and outside of the classroom. One teacher appreciated the collaborative affordances of this technology in the learning process yet confessed she was trying to figure out how to manage and evaluate this type of learning while projects were already in progress.

Assessment strategies. Scholarly studies that examined teacher perspectives of PBL assessment exclusively were not found; however, studies that included teacher perceptions of PBL assessment as part of a larger research effort and addressed tensions between old and new assessment strategies. The seminal work of Blumenfeld et al. (1991) on PBL shed light on the differences between traditional and PBL assessment practices and can be summarized as follows. Traditional education assessments are typically administered at the end of a content unit and consist of a series of questions such as multiple choice that have right or wrong answers. Teachers score the exams and use raw scores to assign letter grades based on a curve. PBL assessment practices include formative evaluation measures that provide authentic feedback to students throughout the learning process. Assessment strategies can impact social opportunities to learn from and with others in learning environments. Traditional assessment practices generate a competitive culture and do not promote social learning; in contrast, PBL assessments drive learning processes and foster a climate of interdependence for knowledge building through collaborative engagement.

PBL philosophy supports students receiving feedback from multiple performance measures throughout a unit cycle and may include a variety of measurements such as observation tools, contracts, checklists, reflection logs, and rubrics. Generally, there are two types of rubrics, holistic and analytic (Brookhart, 2013). Holistic rubrics can give an overall judgment of skill, such as collaboration, or a final product rated on a scale with all the evaluation criteria considered together. Analytic rubrics give more specific feedback as component criteria are broken down and described in detail. For example, a collaboration rubric may include the following criteria with described levels of proficiency for each: task focus and participation; research and information sharing; team communication; time management; and dependability and shared responsibility. Rubrics can be used by the teacher to give feedback to whole teams or individuals; they can be used for peer and self-evaluation as well. Rubrics should provide clear descriptions of performance targets and can be used to set individual mastery goals and to evaluate soft skills such as communication, critical thinking, or creativity (Greenstein, 2012). In addition to learning processes, rubrics can also be used to evaluate final projects and presentations (BIE, 2013). Providing students with consistent measures of performance can drive the learning process with meaningful feedback as opposed to receiving a letter grade that indicates how well facts were memorized for a test (Larmer et al., 2015).

As mentioned in the section on PBL challenges, experts encourage teachers to design PBL units with the end in mind which includes how they plan to assess learning (Boss & Kraus, 2014). Larmer, Mergendoller, and Boss, well-known PBL experts from the Buck Institute for Education, encourage teachers to use BIE PBL materials such as unit plans and rubrics for assessment that are available online free of charge. BIE materials align with the “The Gold Standard PBL”, a popular graphic of the essential elements of PBL (Larmer et al., 2015, p. 34). Teacher participants in many of the recent studies on PBL from every instructional level stated they used BIE teaching materials and rubrics (Cook, & Weaver, 2015; Dole et al., 2016; Ertmer et al., 2014; Habók & Nagy, 2016; Lee et al., 2014; Vega & Brown, 2013). One college instructor stated that he was comfortable with the BIE model and materials as they could be flexibly customized and applied across course content with a range of student populations (Lee et al., 2014).

Although rubrics provide clear descriptions of observable behaviors and may on the surface seem easy to use, recent studies may indicate that using rubrics effectively may require practice. For example, in Lee et al. (2014) data analysis revealed that three instructors who had access to BIE materials were uncomfortable evaluating creativity, group work, soft skills, production quality, and product innovation. In a study by Cook and Weaver (2015) high school science teachers received help from experts developing PBL units on biofuels during a summer workshop and were encouraged to use BIE rubrics for assessment when implementing the units with their classes. BIE provides several rubrics for assessing PBL including collaboration, critical thinking, and creativity and innovation. Each rubric has several components; the latter has separate component sections for process and product (BIE, 2013). Assessment difficulties and lack of rubric use were apparent in teacher interview narratives (Cook & Weaver, 2015). One teacher stated that five student teams in one class produced boring posters for their projects that were factual in nature and inferred that the projects lacked creativity. Collectively, the five instructors in this study used a mix of assessments but the components were frequently unclear. Regarding the products students created in one class Cook and

Weaver stated, "…there was no rubric to give students' guidance on the final product and students were observed to be unclear on what was expected of them" (p.13). Another teacher used an evaluation rubric for a final product that included teamwork; however, it was unclear how process and product were distinguished. From the Lee et al. (2014) and Cook and Weaver (2015) studies it appears that although these teachers had access to rubrics, they were not ready to use them well. Perhaps if they had used rubrics effectively, they could have clarified expectations and targets for collaboration, critical thinking, creativity, and process and product goals for final projects; additionally, they may have felt more confident assessing skills and products.

Recent scholarly studies revealed that teachers used a variety of strategies to assess PBL including personally created or commercially prepared rubrics, self-evaluation, peer evaluation, and reflective tasks. Teachers reported that when students reflect upon their performance this can increase self-regulation, metacognition, and influence them to revise and improve their work (Alves et al., 2016; Moliner et al., 2015; Rahimi et al., 2015). Peer evaluation was mentioned in several PBL studies of teacher perceptions. Instructors across departments reported that PBL assessment strategies were a significant change in practice that made both instructors and students uneasy. Instructors stated that they felt comfortable assessing content but that they were uncomfortable assessing soft skills and student products, so they relied on peer assessments for grading (Lee et al., 2014). Ainsworth (2016) explored team member regulation strategies among Canadian college students in communication classes and incorporated peer evaluations in the online course Moodle that allowed students to confidentially evaluate teammates. Ainsworth credited confidential peer evaluations as an effective way to reduce social loafing and increase accountability. Instructors at a southeastern United States university felt that peer assessment motivated students to work harder because they were aware of each other's learning goals and progress (Hao et al., 2016). Tamim and Grant (2013) confirmed that teachers from grades 4-12 also agreed peer assessment improved learning processes. Researchers reported that teachers believe peer assessment in PBL can increase motivation and self-regulation in learning processes. Alves et al. (2016) found that overall teachers felt positive about using rubrics and formative assessments in PBL but cautioned that students felt there were too many assessments, and this caused dissatisfaction. Alves et al. reported that students complained peer assessments were unfair; therefore, teachers remarked that peer assessment was an area in need of improvement.

Collectively, PBL studies that focused solely on teacher perspectives of assessment strategies were not found although several recent studies highlighted teacher's perceptions of the impact of PBL on assessment practices. As an overview, it is clear from the literature review that strategies for PBL assessment are different from traditional methods and therefore, PBL impacts instructional practice in this area. Studies of teacher perspectives showed that a variety of formative assessments conducted throughout PBL units were preferred over giving a summative test at the end of a unit for grading purposes. The studies indicated that teachers believed rubrics and other strategies of PBL assessment can be flexibly applied in a variety of learning contexts across a spectrum of subjects. Teachers reported using PBL assessments to provide feedback to individuals and groups of students. Overall, the studies revealed that some teachers are experimenting with PBL assessment but as a group, they do not feel proficient.

Studies related to teacher perceptions of PBL in this literature review were generally positive but highlighted several important implementation challenges and gaps in the research. Studies indicated that teachers believe engagement in PBL fosters the development of critical skills students need for success; however, data show that learning to use PBL strategies effectively involves a pedagogical shift that requires commitment, practice, and access to resources. Teacher perception studies illuminated the many ways that PBL impacts instructional practice regarding the roles of students and teachers, student training needs, technology integration, and assessment. Teacher perception study results from the last five years have led researchers to conclude that although teachers may believe students benefit from PBL, they are overwhelmed by time, resource, and assessment constraints. Although research shows that some teachers have been able to skillfully navigate the challenges of PBL implementation, the gap that remains is an understanding of how these teachers are able to successfully implement PBL when others have not. This gap is important because teacher perceptions of successful PBL implementation may illuminate how challenges related to time, resources, and assessment can be overcome. Several studies employed quantitative methods to investigate what teachers know about PBL, how they are using it, and key competencies in constructivist pedagogy, (Hovey & Ferguson, 2014; Koh et al., 2014; Zhu, & Wang, 2014). Qualitative methods were used to explore the effectiveness of PBL professional development approaches (Cook & Weaver, 2015; Ertmer et al., 2014; Nariman & Chrispeels, 2016; Vega & Brown, 2013) as well as teachers' perceptions of benefits, challenges, and influence of PBL on practice (Breunig, 2017; Dole et al., 2016; Lee et al., 2014; Martelli & Watson, 2016; Tamim & Grant, 2013). My study used a phenomenological approach to explore the experiences of teachers of the deaf in PBL implementation regarding HOTS in PBL instructional pedagogy, student innovation, and student processes. My study expanded on current research by using the PB-LIFTS as a research-based conceptual framework for the development of interview questions used to gather rich understandings of the in-depth experiences of teachers of the deaf who implement PBL. No other PBL research on teacher perspectives has included an analysis of interview data that identified HOTS in PBL pedagogical approach, student products, and student processes.

Project-Based Learning and Higher Order Thinking

PBL is a constructivist instructional strategy widely recognized as a comprehensive student-centered method that has been shown to promote cognitive engagement, the development of 21st century skills, and academic achievement when implemented by skilled teachers. The purpose of this qualitative study was to explore the experiences of teachers of the deaf in using PBL to build HOTS with DHH students in three dimensions of PBL including pedagogy, product, and process. Cognitive activity has been described by scholars since ancient times and one of the most well-known works in education is Bloom's (1956) taxonomy of cognitive objectives. Educators today often define lower order thinking and HOTS using Anderson and Krathwohl's RBT (2001) in which lower ordered thinking skills are categorized as factual and conceptual cognitive activities for the purpose of remembering, understanding, and applying content. In contrast, HOTS are procedural and metacognitive activities that include analyzing, evaluating, and creating content. All these cognitive processes can be demonstrated in PBL and can be flexibly applied in any learning environment across the continuum of constructivist pedagogies. The essential components of PBL described by Larmer et al. (2015) include an authentic issue and a driving question, collaboration and sustained inquiry, student voice and choice, reflection, critique, revision, and a public product. PBL has been applied in many contexts as an effective educational strategy that can foster the development of thinking skills for all students across the disciplines through engagement in problem-solving, communication, collaboration, critical thinking, and creativity following PBL processes (Cook & Weaver, 2015; Dole et al., 2017; Ertmer et al., 2014; Hovey, & Ferguson, 2014; Kivunja, 2015; Lin et al., 2015; Moliner et al., 2015; Petersen & Nassaji, 2016).

PBL processes actively engage learners cognitively and the relationship between PBL and HOTS is dependent upon the interaction of three key elements: the skills of the teacher, the pedagogical approach, and the learning context (DeWaters et al., 2014; Häkkinen et al., 2017; Kwan & Wong, 2015; Schulz & FitzPatrick, 2016). These three elements impacting PBL outcomes are described as follows. First, teachers must make many decisions over the course of every PBL unit and the development of implementation skills requires practice (Dole et al., 2016; Martelli & Watson, 2016; Stefanou et al., 2013). Secondly, regarding pedagogy, a continuum of four constructivist approaches can be used as a focusing lens to identify teachers' PBL designs relative to intended complexity and cognitive demand. The first two pedagogies described by Schallert and Martin (2003) are active and constructed learning and are considered to be student-centered learning strategies although teachers maintain primary control over the learning process. The second two pedagogies are socially constructed and connected learning described by Doolittle (2014) and Kivunja (2014a) as complex constructivism;

these pedagogies are more cognitively demanding, and learner driven. Last, the learning context including the students, the environment, and resources also influence PBL outcomes (Hovey & Ferguson, 2014; Skinner et al., 2016; Smart et al., 2012). The interactions of these elements and mediating effects of variables such as student motivation and autonomy have been studied in the recent literature regarding how they influence thinking skills and how HOTS can be measured. I will review these studies following an overview of literature addressing cognitive skills for 21st century learners using constructivist pedagogies.

Cognition and 21st Century Skills

For students to prepare for living and working in the modern world, they need opportunities to learn content through active learning about real-world issues while developing 21st century skills. These skills are also referred to as 4Cs including communication, collaboration, critical thinking, and creativity (Kereluik et al., 2013; Kivunja, 2014a; National Education Association, 2012) and PBL processes can engage students in learning content while developing these skills (Holmes & Hwang, 2016; Lin et al., 2015). Cognitive strategies are embedded in each of the 4Cs although critical thinking is the only one that refers specifically to thought processes (Germaine et al., 2016; Soulé, & Warrick, 2015). A widely accepted definition of critical thinking was provided by Ennis (1985) who defined it as “reasonable and reflective thinking that is focused upon deciding what to believe or do” (p. 2). As a constructivist pedagogy, engagement in PBL requires stages of thought and action; therefore, the definition proposed by Ennis fits well with the essential elements of PBL described by Larmer et al. (2015). To gain an understanding of the relationship between PBL and HOTS it is important to explore cognitive processes that may occur through 4Cs engagement in PBL.

The point that thinking strategies are included in each of the 4Cs was clarified in the work of Germaine et al. (2016) and Kivunja (2015). These researchers provided expanded definitions of the 4Cs and examples of tasks that illuminate cognitive strategies for each skill. Selected examples are as follows: critical thinking includes problem-solving skills that involve effective reasoning and systems thinking; communication includes conscious expressive and receptive skills such as deciphering the meaning and intentions of others in a variety of contexts and responding constructively; collaboration requires skills such as negotiation, compromise, and self-regulation in order to work respectfully with diverse teams while valuing individual contributions; creativity and innovation include metacognitive skills that lead to the creation of new ideas of value and require elaboration, analysis, evaluation, and revision. Germaine et al. (2016) concluded that although the 4Cs may be described as discrete skills, in practice they are entwined, overlap, and are interdependent. The 4Cs expansions provided by Germaine et al. (2016) and Kivunja (2015) clearly show the variety of thinking embedded within each of the 4Cs and illuminates how one activity such as working with team members can engage learners in all 4Cs. Moreover, when students engage in PBL they are afforded opportunities to develop a variety of 21st century skills and HOTS which can be fostered in social learning PBL designs (Przybysz-Zaremba et al., 2017; Wurdinger, 2018).

Complex Project-Based Learning Pedagogies and Higher Order Thinking Skills

When teachers design PBL units using complex pedagogies such as social constructive and connected learning, student engagement in the 4Cs is more demanding and requires students to use HOTS. For example, Lin et al. (2015) conducted an international mixed method study to explore student and teacher perceptions regarding the efficacy of PBL for the development of 21st century skills through engagement in online learning communities. They included 117 high school participants and 10 teachers from four countries and summarized that student and teacher participants perceived an increase in communication, collaboration, creativity, and critical thinking through PBL processes. The researchers found that technology use in connectivist pedagogy transformed learning as students used 4Cs in connected communities that led to deeper learning through student engagement and self-direction. Theoretically, connected learning is the most challenging of the four pedagogies on the constructivist continuum, most likely because connected learning requires effective use of technology and ICT skills (Darling-Aduana, & Heinrich, 2018; Lasry et al., 2014). Learning and working constructively with others virtually adds complexity to communication and collaboration processes.

Soulé and Warrick (2015) argued that in order to prepare students for the realities of the 21st century, technology use can and should be infused in the 4Cs. Lasry et al. (2014) found that when social learning and technology were combined in socio-technological classrooms with student-centered pedagogy, students demonstrated higher conceptual knowledge and engaged in more rigorous cognitive activities than in the conventional classroom setting. A systemic review of 48 studies on PBL in science and technology with K-12 students by Hasni et al. (2016) confirmed that using PBL learning strategies promoted more rigorous learning and justified the use of this approach in science and technology classes with students of all ages including low-achievers. Hasni et al. (2016) found that PBL in social learning was motivational; Kivunja (2013) supported this finding and extended it to connected learning stating that "multiplier effects" of collaborative learning through peer networks were observed indicating that when students engaged as a community of learners via technology, the motivation to participate in learning greatly increased (p.139).

Motivated engagement in PBL using technology is not always an indication of rigorous learning. Rahimi et al. (2015) found that technology tools and personal learning environments (PLE) were motivational for students as they can engaged in group work and accessed information anywhere and anytime; however, they also found that engagement in technology does not necessarily mean students engaged in HOTS. Using a model for constructing Web 2.0 PLEs, Rahimi et al. (2015) studied how 29 secondary students chose tools, worked with people, and produced content for a digital geography project using connected learning pedagogy. Although the PBL was well designed, included essential PBL elements, and the researchers noted positive outcomes such as students being highly motivated to use technology, the final products lacked rigor. Students spent much of their time focused on the appearance of their websites rather than engaging in deeper thinking about the content of their projects. Rahimi et al. noted that students were preoccupied with *finishing* the task using technology for short term benefits rather than as a learning tool.

As a result of the study by Rahimi et al. (2015), the researchers warned that teachers should not assume all PBL products are a demonstration of HOTS. This finding was corroborated in other studies (Cook & Weaver, 2015; Rudnitsky, 2013). Rudnitsky found that students tended to focus on finishing projects rather than learning processes.

Rudnitsky studied teams of students in the sixth grade who engaged in social constructivist learning for history projects. Using discourse analysis, Rudnitsky found that students were primarily focused on final products and presentations without thoughtful content exploration and synthesis. This was a similar problem that arose in a study by Cook and Weaver (2015) with high school science teachers implementing PBL after receiving summer training. The final projects lacked rigor and showed minimal linkage to the driving question.

Experts from the Buck Institute for Learning cautioned that engaging students in "projects" that are really assignments or activities result in superficial outcomes causing teachers to experience frustration (Larmer et al., 2015). Rudnitsky (2013) concluded that "…teachers can change the trajectory of group thinking in significant ways" by shifting the emphasis from finishing and showing a product to valuing learning processes that contribute to the development of meaningful final products (p. 17). Rudnitsky referred to the later as "minds on" learning processes and pointed out that this requires understanding how students think as they work. Listening to how students negotiate, share viewpoints, and draw out ideas as they develop projects is one way to discover thinking processes. Rudnitsky found that a powerful motivating factor for minds -on learning in one project was students having product-oriented goals; perhaps these goals helped students stay focused on the process and development of a tangible product. In summary, as the complexity of PBL pedagogy increases in social and connected learning designs, opportunities to use the 4Cs and embedded thinking skills also increase. While there is much research available on PBL studies that reported positive outcomes, when researchers look more closely at the amount and duration of HOTS engagement, the findings can be disappointing. For this reason, it is important for teachers to be aware that using a complex PBL pedagogy to engage students in motivational activities may not necessarily indicate engagement in HOTS.

Project-Based Learning General Claims of Higher Order Thinking Skills

Studies on teachers' PBL perceptions cited earlier in this review revealed that implementing PBL can be demanding, but overall teachers believed there were numerous educational benefits of PBL. Taken together, the benefits of PBL outweighed the challenges and findings showed that engagement in 21st century skills precipitates HOTS. To illustrate this point, many studies concluded with general claims supporting PBL as an effective teaching strategy for learning content and developing 21st century skills or 4Cs which encompass cognitive processes (Alves et al., 2016; Dole et al., 2016; Hao et al., 2016; Lee et al., 2014; Moliner et al., 2015; Tamim & Grant, 2013).

Some studies referred to the development of transversal skills which is an expansion of the 4Cs. For example, Alves et al. (2016) asserted that teachers identified the main strengths of PBL as developing students' technical skills and important "transversal competencies such as communication, teamwork, time management, and problem-solving" (p. 133). Similarly, Moliner et al. (2015) concluded that PBL promoted the development of transversal skills such as communication and group processes that are critical to team productivity and creativity.

Other studies connected student motivation and engagement in PBL processes as evidence of cognition. For example, Habók and Nagy (2016) reported the opinions of Hungarian teachers from lower elementary through secondary levels who had experience in implementing PBL. From a total of 109 returned questionnaires, Habók and Nagy reported that overall, the benefits of PBL were “indisputable” (p. 9) and elaborated that PBL teachers characterized successful projects as motivational for students; they promoted a high degree of activity which was associated with lifelong learning and learning-to-learn through cognitive engagement. One of the research interests in the Dole et al. (2016) study was to learn how teachers assessed PBL to gain an understanding of how PBL models promoted deeper learning. The results did not lead to definitive answers as the assessment data were limited; however, the researchers reported that students self-assessed their progress; they were challenged and motivated; students developed skills in organization, collaboration, and research; students created their products and “their presentations in the end reflected critical thinking and problem-solving” (p. 9). Similarly, Kim (2015) concluded that PBL final presentations promoted critical thinking and problem-solving. This suggested a connection between PBL products and HOTS.

From this collection of studies, it is difficult to ascertain how projects were evidence of deeper learning without more explicit assessment data. While researchers (Alves et al., 2016; Habók & Nagy, 2016; Kim, 2015; Moliner et al., 2015) clearly suggested that PBL and HOTS are related, it is unclear how this was determined. In the case of Moliner et al. (2015) rubrics were used to evaluate transversal skills and projects but the criteria used, and the results were not shared. Despite the positive claims regarding the development of transversal skills, Alves et al. (2016) also concluded that assessment methods were an area of need. Habók and Nagy (2016) found that teachers had many positive perceptions of PBL, and evaluations were used; however, it was also found that teachers did not perceive they had a significant role in evaluation. In this study most PBL assessments occurred during projects via oral feedback from students;

therefore, it remains unknown if teachers assessed projects or processes and how evidence of HOTS was determined. Difficulties with PBL assessment were brought out in other studies. For example, Lee et al. (2014) summarized assessment problems stating teachers relied upon peer assessments and instructors felt uncomfortable assessing soft skills, collaboration, and group interactions as well as how to assess products. Perhaps teachers were uneasy about how to be objective when the skills seemed so intertwined and interdependent. Although the results of many studies on PBL report positive outcomes, if the assessment was also found to be an area of weakness it is difficult to say with certainty that these studies demonstrated a solid relationship between PBL and HOTS.

Because many studies made references to high levels of student engagement in PBL and concluded with general claims regarding the benefits of this instructional method, teachers may have associated student activity with HOTS. Mistaking student activity as an indication of HOTS could be a function of teachers' experiences with two contrasting pedagogies: traditional instruction, a teacher-centered method associated with passive learning and PBL, a student-centered method associated with active learning. Freire's (1970) critical pedagogy brought attention to traditional instruction methods which he claimed were oppressive for students as passive learning has been associated with student boredom in classrooms. More recently, Sharp, Hemmings, Kay, Murphy, and Elliott (2017) used mixed methods to identify what contributed to boredom among 235 undergraduates in the UK and confirmed that traditional lecture methods were demotivational. Sharp et al. warned educators to work collaboratively with students and to draw back from "an increasingly consumerist and utilitarian model of students as passive recipients motivated only by extrinsic reward" (p. 674). Thus, teachers who are accustomed to using traditional methods and are impressed when they see the motivational effects of PBL, may be mistaken if they assume that active engagement indicates HOTS. If teachers had practical methods for assessing PBL, the relationship between PBL and HOTS could be shown using evidence rather than perceptions. To explore the relationship between PBL and HOTS, it may be useful to examine studies on PBL processes and factors associated with cognitive outcomes.

Processes and Factors Associated With Higher Order Thinking Skills

Studies that indicate a relationship between PBL and HOTS have evolved significantly in scholarly literature since the first major literature review of PBL in the 21st century by Thomas (2000). Thomas found that scholarly studies on constructivist learning were scarce but identified common features of PBL that imply cognitive processes which are still used to define PBL in the current literature (Chowdhury, 2015; Condliffe et al., 2016). Close examination of these PBL features reveal the types of thinking that are prompted in PBL processes and bring to light the potential for students to engage in HOTS using this constructivist pedagogy. A summary of five key PBL features are as follows: (1) learning is complex and aligned with curriculum content and standards; (2) PBL begins with a driving question centered on an authentic issue that is revisited throughout the learning process over an extended period of time; (3) learning is constructed by small teams of students through inquiry and collaborative knowledge building; (4) students are given the responsibility to research, design, organize, and manage their project while exercising autonomy and collaborative decision making; (5) PBL culminates in the production of a real product that is a tangible representation of their learning for public presentation. The PBL review by Thomas (2000) was expanded by Condliffe et al. (2016) to include a PBL literature review of studies from 2000 – 2015. Condliffe et al. found that PBL research had grown significantly during this period. Current research on PBL revealed factors associated with HOTS and student engagement in PBL processes that often overlap. These factors can be broadly categorized as student motivation, self-regulation, and student technology use.

PBL can be implemented in an unlimited number of contexts and include all five key process elements; however, PBL outcomes will differ depending upon the unique chemistry of the learning design, teacher's skills, student characteristics, and the learning environment. Ravitz (2010) proclaimed that "no two teachers implement PBL in the same way" (p. 293) although all of the variants of PBL are intended to promote rigor and develop students' 21st century skills. In reviewing the evidence of PBL as an effective strategy for promoting rigorous learning and HOTS, Ravitz noted that student motivation seemed to be a critical factor for successful implementation. Going deeper, Stolk and Harari (2014) connected student motivation to learn with PBL processes and asserted that such active learning can foster the development of HOTS.

The social nature of PBL processes has been found to promote students' intrinsic motivation to engage in self-directed learning and HOTS. Bagheri, Ali, Abdullah, and Daud (2013) compared the effects of PBL and conventional instruction on self-direction with 78 students studying educational technology over a semester at a university in Iran. In this study, an experimental design was used incorporating pre and posttests randomly assigned to control and experimental groups. Bagheri et al. found that students in the PBL classes performed significantly better than students in the conventional setting regarding self-directed learning skills, learner attitudes, and learner dispositions. Specific skills PBL students demonstrated were time management, goal orientations, taking personal responsibility for learning, self-assessment, and evidence-based decision making. It was noted that PBL was intrinsically motivational for students because they had some control over project objectives and could socially interact. Hence autonomy and social learning opportunities may motivate students to engage in rigorous learning.

Kwan and Wong (2015) surveyed 967 ninth grade students in seven Hong Kong schools to quantitatively study the mediating effects of motivation on critical thinking in constructivist learning environments. They identified motivational factors that contribute to the development of HOTS such as goal orientations. Borrowing from Ennis (1985), the researchers defined critical thinking as “reasonable and reflective thinking that is focused upon deciding what to believe or do” (p. 2). They summarized that as the constructivist environment increases so do goal orientations and cognitive strategies. Goal orientations included both intrinsic and extrinsic goals and cognitive strategies included metacognition and elaboration. Kwan and Wong also found that when goal orientations increase so do critical thinking abilities. Kwan and Wong summarized that “the influence of the constructivist nature of the learning environment on critical thinking ability was achieved through students’ internal cognitive variables (i.e., goal orientations and cognitive strategies)” (2015, p.77). Based upon the results of this study Kwan and Wong suggested that teachers should increase critical thinking by offering choices and emphasizing the value of tasks to promote intrinsic goal orientations. They also posited that students who received training in cognitive and meta-cognitive strategies perform at higher levels of thinking and therefore, these skills should be taught beginning when children are young.

Recent studies also examined the motivational effects of PBL and HOTS with diverse learners. Dole et al., (2017) studied the effects of PBL on student learning and motivation using a qualitative exploratory case design to collect and analyze three types of data from 36 teachers of elementary and middle school students with diverse backgrounds including giftedness. When teachers reflected on the differences, they experienced implementing traditional and PBL instructional methods, the researchers found that PBL promoted higher levels of motivation and engagement across all learner groups. Further, students demonstrated greater creativity, perseverance, and divergent thinking skills. Chiang and Lee (2016) conducted a quasi-experimental study in Taiwan to study the motivational effects of implementing PBL with 88 lower functioning high school students in two vocational schools. Chiang and Lee found that PBL was highly motivational for the students in the experimental groups who demonstrated higher level problem-solving skills and creativity through collaborative teamwork. In both studies, motivation in PBL was directly connected to student engagement in collaboration, sense of autonomy, and HOTS.

Researchers also studied the relationship between motivation, PBL, and HOTS in math education with students who had learning challenges. Holmes and Hwang (2016) investigated the effects of PBL among diverse groups regarding mathematical skill development and strategies for learning including cognitive, social, and motivational variables. Using an exploratory framework for a mixed-method longitudinal study, Holmes and Hwang studied the effects of PBL on Latino and low socio-economic status

(SES) students in a small Midwestern U.S. school district. Participants included 532 students in eighth and ninth grade. The first year involved a control group of 444 high school students taught using conventional methods and 88 students in the experimental group attended a PBL high school. Quantitative data included standardized test scores and online surveys. Qualitative data included classroom observations and student interviews. The findings indicated that although a pre and post academic performance gap continued to exist; the gap reduced significantly for struggling math students in the PBL group. Students in the PBL group increased organizational skills by 34% and internal cognitive skills also increased as evidenced by students being autonomously motivated to use effective study strategies. Evidence of critical thinking was noted in students “constructing their own understanding” of math which was not possible in the conventional setting (p. 457). Remijan (2017) implemented engineering procedures for project design to engage reluctant secondary math students in five design-focused projects. Samples of student constructions using math and postproject reflections showed high levels of motivation and mathematical reasoning as well as collaborative and creative skills. Observational data demonstrated the motivational influence of these community-based projects. Students commented that having the freedom to be creative was motivational as well as empowering for them which highlighted the important role autonomy played in promoting HOTS.

Similar relationships between motivation, PBL, and HOTS have been found with primary age students who showed delays in science concepts. Can, Yıldız-Demirtaş, and Altun (2017) pursued a mixed-method quasi-experimental study on the effect of using PBL with 26 kindergarteners identified as delayed in their understanding of science. The study was designed to examine the development of science process skills and scientific thinking. Pretest and posttest data revealed the students in the PBL class showed significant growth. Qualitative findings were strongly in favor of teachers using active learning and PBL together as these strategies positively supported young children's scientific thinking skills and conceptual understandings. Han et al. (2015) also found that the collaborative element of PBL had a significant impact on struggling learners in a longitudinal study including 836 students. The group was diverse in that it included high, middle, and low achievers as well as students of different ethnicities and socioeconomic levels. Han et al. found that the low achievers and Hispanic students from lower-income homes showed a significantly higher growth rate in math skills through STEM PBL. Further, the low performing group showed the greatest positive impact of collaborative learning. Further, García-Merino, Urionabarrenetxea, and Fernández-Sainz (2020) confirmed that the use of PBL was most effective in improving performance levels of low performing students who had limited prior knowledge.

Studies also connected PBL with self-regulation and HOTS. Stolk and Harari (2014) found a critical connection between self-regulated PBL learning and HOTS. They found that when students took control of learning via PBL processes they exercisde self-regulation and demonstrated cognitive skills. Thus, self-regulated learning was a defining characteristic of PBL, and HOTS were embedded in PBL processes. The five key features of PBL stated earlier included descriptions of responsibilities students were expected to assume such as organizing, managing, designing, and collaborative planning. All these responsibilities required students to participate mindfully in PBL learning processes to self-regulate and practice HOTS. In the recent literature researchers focused upon self-regulated learning as it related to PBL and HOTS using a variety of approaches and illuminated an array of factors that influenced PBL and HOTS (Ainsworth, 2016; Bagheri et al., 2013; English & Kitsantas, 2013; Hao et al., 2016; Holmes & Hwang, 2016; Rahimi et al., 2015; Stefanou et al., 2013). Summarizing the findings of a mixed-method study on the development of students' self-regulation skills, Lord, Prince, Stefanou, Stolk, and Chen (2012) stated that the results suggested "students' development as self-regulated learners involved a complex interplay between many factors" and these were influenced by instructors' pedagogical design (p. 606). This statement implied that instructors' interpretations of active learning and methods of implementation could affect the many variables that come into play in the development of self-regulated learners. English and Kitsantas (2013) provided further support that emphasized the role of pedagogical design as it influenced self-regulated and socially regulated learning. Hence, PBL and HOTS outcomes cannot be separated from the teacher's pedagogical approach and learning design.

PBL processes promoted the development of self-regulation skills that were critical to deeper thinking and learning engagement. According to English and Kitsantas (2013), HOTS was integral to self-regulated learning and teachers should design learning environments and instructional strategies to intentionally cultivate goal orientations and dispositions that promoted self-regulated learning. Lord et al. (2012) provided evidence of specific skills related to self-regulation strategies in successful PBL in a study that included 176 engineering students from four colleges. They found that PBL promoted HOTS as an outcome of learner interactions and self-regulation which included meta-cognitive processing, help-seeking, elaboration, and peer learning through critical thinking and problem-solving. Lord et al. posited that all these skills contributed to students' ability to take control of learning and this aligned with their definition of self-regulation and characteristics of lifelong learners who engaged in critical thinking and HOTS. Ainsworth (2016) conducted a qualitative study aimed at identifying self-regulation strategies and interpersonal skills used in high and low performing teams of multilingual college students in Canada. Ainsworth analyzed peer evaluations and post project surveys from 39 undergraduates ages 19-24 and found that self-regulation strategies were critical to HOTS and high team performance in PBL particularly when members were not native speakers of the language used in team interaction. Ainsworth also found that interpersonal relations or social regulatory strategies were strong in high performing teams such as encouraging all members to participate and be heard, meeting deadlines, contributing sources, and guiding team members. Ainsworth emphasized that these skills should be taught, and team member expectations should be clarified prior to engagement in PBL for optimal outcomes.

Student technology use was yet another factor addressed in the literature that showed a relationship between PBL and HOTS. In a qualitative study, Rahimi et al. (2015) found that the use of Web 2.0 tools for communication and collaboration promoted greater ownership for learning, digital responsibility, technical skills, and self-regulation as well as social regulation among 29 students ages 11-13 in the Netherlands. Using tools such as wikis and Google Docs for coproducing, students were motivated to participate and experienced greater autonomy and creativity. Similarly, Al-Chibani (2016) found that using Google Docs in a remedial English class at the college level improved students' attitude and writing skills as the collaborative writing process was motivational while promoting creative thinking and higher levels of communication. Rahimi et al. (2015) noted high levels of thinking through metacognitive activities related to the process of developing digital artifacts through self-regulated learning. Further, it was noted that by using connectivist pedagogy in PBL, “a dynamic balance of power, support, and independence” evolved among teacher and students (p. 236). Hao et al. (2016) used a quantitative approach to study self-regulation from the perspective of students setting goals and making precommitments prior to PBL engagement in technology-rich learning at the college level. Hao et al. concluded that precommitments shared digitally improved the quality of goals students set and academic performance. They suggested that students may have worked harder because of the added social awareness of one another’s learning objectives highlighted another motivational aspect of technology for students.

To summarize, there exists overwhelming evidence in the recent scholarly literature indicating a strong relationship between PBL processes and HOTS. PBL processes can motivate students to engage in learning demonstrating a variety of behaviors associated with HOTS such as self-regulation, goal orientations, and collaborative communication. This has been demonstrated with a variety of student populations in multiple contexts across a range of disciplines; however, these studies do not provide guidance addressing how teachers can measure HOTS in PBL.

Measuring Higher Order Thinking Skills

PBL is a multidimensional instructional strategy designed to engage students in rigorous constructivist learning coupled with consistent feedback mechanisms for evaluating and guiding the development of HOTS through PBL processes and final product creation. PBL experts encouraged formative assessments throughout PBL unit stages targeting specific skills as well as summative assessments for evaluating final products and overall performance for reflection, goal setting, and continuous improvement (Boss & Kraus, 2014; Greenstein, 2012; Larmer et al., 2015; Williams, 2017). Assessments such as rubrics and rating scales can provide feedback from multiple perspectives as they can be completed by instructors, peers, or individual learners for self-assessment (Bender, 2012; Greenstein, 2012; Guerriero, 2017). As a systemic feedback process PBL assessment can drive deeper learning (Bedir Erişti, 2016; Panadero & Jonsson, 2013; Pantiwati & Husamah, 2017; Sáiz-Manzanares, Segura, Calderon, & Antona, 2017), promote student self-regulation and autonomy (English & Kitsantas, 2013; Hao et al., 2016; Rahimi et al., 2015), and allow for differentiation which can enable teachers to track the development of HOTS for all students (Bender, 2012; Hovey & Ferguson, 2014; Martelli & Watson, 2016).

My study focused upon evidence of HOTS in PBL processes and production of a final product as described by teachers who reflected upon their PBL experiences implementing a favorite unit. Despite the availability of PBL evaluation instruments such as rubrics from the Buck Institute for Education (www.bie.org) that can be flexibly adapted for a variety of learning environments, recent studies revealed that teachers frequently struggled with assessing PBL products and the skills students applied in PBL processes to produce them (Alves et al., 2016; Cook & Weaver, 2015; Habók & Nagy, 2016; Lee et al., 2014). This difficulty may be justified because every PBL unit is implemented in a unique context with several phases and learning processes that require students to apply intertwined skills such as collaboration and communication that are not easily differentiated. The global imperative to integrate PBL in instructional practice is well established in the literature. Hence PBL curriculum and assessment are popular topics in recent studies; yet deciding upon *what* to assess as well as *how* to assess is challenging for teachers (Simmons, Wagner, & Reeves, 2016). Scholars from around the world have published resounding pleas for additional research on methods and instruments for assessing levels of engagement and outcomes in constructivist learning environments (Hamilton et al., 2016; Smith, 2016; Voogt et al., 2013; Zhao et al., 2017). In this section I reviewed the literature on PBL processes and factors associated with HOTS. For the next section, I reviewed scholarly literature on PBL assessment and HOTS, assessment of PBL products for innovation and creativity, and assessment of PBL processes including levels of task, thinking, teamwork, and tools.

PBL assessment practices and HOTS. In recent literature, a variety of strategies have been used in PBL assessment such as checklists, portfolios, and rating scales, but rubrics were a key tool for facilitating and assessing HOTS. Brookhart (2013), a recognized expert in formative assessment and rubric construction affirmed that the main purpose of rubrics is to assess performance and they can be used effectively to give performance feedback to learners for both processes and products. According to Brookhart (2013) holistic and analytic rubrics were two common types of rubrics and both were used in recent PBL studies. Holistic rubrics typically listed general categories of competencies or several skills were grouped together. The rubric provided a method for evaluators to indicate levels of performance or proficiency for each category. Holistic rubrics were often used to assign grades quickly. Analytic rubrics gave a breakdown of skills and competencies that were described in detail at each level of proficiency. In practice, teachers can highlight where students are currently performing on analytic rubrics and students can see how they might improve by reading the performance description at the next level. Baines, DeBarger, De Vivo, and Warner (2017) asserted that well designed performance-based rubrics motivated students to produce products that were tangible evidence of higher-level thinking. In a quantitative study on rubric use in higher education Menéndez-Varela and Gregori-Giralt (2016) found that rubrics were much more than rating scales; they have evolved as valid assessment tools that can guide learning and therefore, should be considered as a first-order teaching resource. Hattie (2013) clarified that well-constructed rubrics can be motivational as they provided learning maps that students used to calibrate where they were functioning to determine how they could move to the next level. Hattie posited that rubrics should provide clear statements of performance levels for selected criteria to serve as a guide for students; thus, analytic rubrics can generate a sense of confidence when expectations and learning objectives are transparent. Building upon the principles of rubric use provided by Hattie, numerous studies confirmed that the use of rubrics in PBL promoted deeper learning and revealed the development of HOTS and metacognition through observable PBL processes and tangible products (Panadero & Jonsson, 2013; Peng, Wang, & Sampson, 2017; Sáiz-Manzanares et al., 2017; Smith, 2016).

Recent studies explored how rubrics can be designed and used effectively to promote HOTS. Cuenca et al. (2016) found that when levels of generic competencies were delineated in rubrics, teachers were able to objectively assess student performance and this facilitated the acquisition of transferrable skills through an impartial and systemic evaluation method. Wollenschläger, Hattie, Machts, Möller, and Harms (2016) argued that clear expectations stated in rubrics alone are not sufficient to motivate students to achieve higher levels of learning; specific types of feedback were also needed. Using a pre and post experimental design, Wollenschläger et al. studied three rubric feedback conditions with 120 randomly selected eighth grade students from six classes in Hamburg, Germany. Participants were assigned to receive three types of feedback. The first was feedback at the task performance level that described correct responses and transparent learning goals. The second type of feedback was at the process level that included transparent goals and descriptions of individual performance. The third type of feedback at the self-regulation level included transparent goals, individual performance descriptions, and guidance information with suggestions for how the student could improve performance. The researchers found the third feedback condition that included suggestions regarding next steps for improvement positively affected performance outcomes through metacognition. Thus, the researchers concluded that self-regulatory feedback such as the use of analytic rubrics can have a mediating effect on learner performance and thereby promote HOTS.

Assessment Feedback and HOTS. Other researchers studied the effects of feedback on learners that were grade-oriented rather than process-oriented. Sáiz-Manzanares et al. (2017) compared the effects of two types of rubrics on learning outcomes in a quasi-experimental study with 171 engineering and social science students at a university in northern Spain. One provided grade-oriented feedback on task completion and the other provided process-oriented feedback that supported self-regulation and metacognition. Sáiz-Manzanares et al. found that process-oriented rubrics provided motivational feedback that produced higher outcomes through a culture of continuous improvement rather than the mindset that learning concludes with a test and a grade assigned. Analytic process rubrics helped clarify tasks and expectations and facilitated project planning while supporting learning goals. This type of formative feedback also promoted metacognitive activity as students could identify and correct errors as the learning experience progressed and through a cycle of reflection set improvement goals. The researchers concluded that to produce the greatest benefit, instruction in self-regulation strategies should accompany the use of process-oriented rubrics. This was a similar finding in a longitudinal study by Zhao et al. (2017) who found that the use of process-oriented rubrics increased Chinese business students' engagement and learning outcomes when used for peer assessment; however, the researchers emphasized that students need training in how to use rubrics effectively.

While the scholarly literature indicated that analytic rubrics can provide feedback known to promote HOTS, they can also be text heavy and reportedly labor intensive for teachers to create. Further investigation revealed that single-point rubrics are emerging in practitioner conference proceedings (Estell, Sapp, & Reeping, 2016) and blogs (Burns, 2015; Druffel, 2015; Gonzalez, 2015) as a favorable alternative to analytic rubrics; however, peer-reviewed studies on single-point rubrics are scarce. Fluckiger (2010) wrote an article published in the Delta Kappa Gamma Bulletin describing the construction of single-point rubrics as well as pros and cons of their use based upon a collective case study of 10 purposefully selected action research reports. Briefly, Fluckiger described the development of single-point rubrics as a joint endeavor between students and teachers creating a written description of the level of proficiency for predetermined criteria that appeared in only one vertical column. Single-point rubrics have three main columns:

proficiency descriptions for each criterion or standard are in the center column and the columns on either side provide space for evaluators to write their observations or reflections. The column on the left is for noting areas needing improvement and the column on the right is for describing how the student went beyond proficient. In addition, Fluckiger provided example single-point rubrics that included a column adjacent to the proficiency description where evaluators write in evidence of how the level of proficiency or standard was met. The single-point rubrics can be used to engage students in self-assessment; however, these rubrics can also be filled out by the instructor or used for peer assessment. From the available literature, it appeared that the single-point rubric was fairly new and the format may be an effective method of assessing PBL products and processes while engaging students in transparent evaluation procedures that can promote HOTS via self-regulation strategies. For these reasons single-point rubrics used to assess PBL may be an upcoming research topic in peer-reviewed education journals.

Aside from the analytic rubrics described by Hattie (2013), other PBL assessment strategies have been used in recent studies that appeared to shift the focus from feedback mechanisms that promoted learner self-improvement through metacognitive awareness to assigning a grade. This type of feedback draws attention to *finishing* a product, not the processes and skills applied to accomplish it. An example of a grade-oriented assessment was used in a mixed method PBL study by Jacques, Bissey, and Martin (2016) in which drone projects produced by French engineering students were evaluated by instructors. The assessment listed four project competencies aligned with 13 learning outcome statements or standards. A column was provided for student performance ratings for each outcome to be judged by instructors as one of three levels of mastery which were then aggregated for assigning a grade. Although the competencies targeted project tasks, tools, and process standards, without descriptions of the three levels of mastery, students may not be aware of how they could improve. In this example, rating competencies provided a method of grading students but did not provide feedback on individual performance or suggestions for improvement that have been found to promote metacognitive processes, self-regulation, and continuous improvement in many recent studies (Hattie, 2013; Perry-Smith & Mannucci, 2017; Sáiz-Manzanares et al., 2017; Smith, 2016; Wollenschläger et al., 2016).

Another example of a grade-based assessment in the recent PBL literature was a qualitative study by Baser et al. (2017) that focused upon collaborative projects using technology. Turkish seventh graders collaboratively developed website projects in blended face-to-face and virtual learning environments. To evaluate the projects, a rubric was provided listing 20 criteria items that were rated as good (5 points), moderate (3 points), or undeveloped (1 point). Two of the items aligned with judgments of innovative qualities of the websites including originality and usefulness to a target population but the other 18 items essentially listed content requirements such as consistent text formatting, contrasting background, and text colors, functional links, and citations provided. Hence this type of feedback on student products may help them see what they failed to include and supports the grade they received but it does not provide a method of guiding students to produce more innovative products by focusing on next steps that would improve learning processes and outcomes. Further, Liu, Wu, Chen, Tsai, and Lin, (2014) cautioned that when project requirements are too explicit, student creativity can be negatively impacted. In sum, it can be seen from the project scoring methods used in these example studies that failure to provide students with a balance of information related to how innovation and creativity were judged as well as process oriented feedback may be a lost opportunity to generate metacognitive processes and HOTS.

Traditional versus PBL assessment. The paradigm shift to student-centered assessment is slowly evolving as this approach imposes extensive changes in long-standing teacher-centered education practices such as testing and grading methods. Juxtaposing traditional and constructivist assessment practices illuminates significant differences in education philosophies and beliefs about learning processes. From an assessment perspective traditional education promoted learning via individual competition as students typically took summative exams to conclude learning at key intervals of the prescribed curriculum and instructors awarded grades based on a curve; in contrast, PBL is a constructive learning pedagogy that engages small groups of students in collaborative learning and culminates with teams presenting their creative artifacts and reflecting upon the learning experience. In PBL both formative and summative assessments provide feedback to students on products as well as the processes used to develop and produce them. Constructivist pedagogies shift the assessment focus to learning processes and according to Kivunja (2013, 2015) formative feedback to students on PBL processes can drive learning and promote HOTS. Despite the global imperative to develop students’ 21st century skills through active student-centered learning (Pellegrino, 2017; Perry-Smith & Mannucci, 2017; Wagner & Compton, 2015), studies indicated that teachers found constructivist assessment practices challenging to adopt (Alves et al., 2016; Cook & Weaver, 2015; Habók & Nagy, 2016; Scholtz, 2016; Schulz & FitzPatrick, 2016).

A recent study published in a practitioner journal was an example that traditional assessment practices can persist even when the required curriculum is designed with the expectation that teachers will implement authentic assessment and students will demonstrate higher levels of cognition. Using a qualitative design Pantiwati et al. (2017) studied assessment practices of 16 junior high science instructors teaching in urban schools in Indonesia. The aim of the study was to examine to what extent teachers were using authentic assessment and promoting high levels of cognition using the approved science curriculum based upon six levels of cognition from Bloom's Taxonomy (1956). The researchers found that projects were implemented frequently but teachers assessed student learning using paper and pencil multiple choice tests with right and wrong answers targeting the lowest three levels of cognition. This indicated a continued reliance on traditional assessment practices and a mismatch between the curriculum design and evaluation strategies. Teacher reliance on familiar traditional methods is just one of the many challenges related to PBL assessment.

Peer and self-assessment. Other PBL practices that can be used to assess learning processes but may be difficult for traditionalists to adopt were peer and self-assessment. A study by McClure, Webber, and Clark (2015) revealed a sharp contrast between the opinions of college instructors and business students regarding peer evaluation. The researchers designed a questionnaire to gather data on peer assessment for the purpose of comparing the views of 417 business students at a university in Michigan to the views of a national sample of 1,429 business education instructors. The study revealed that students valued peer evaluations and felt that this process improved their critical thinking skills. However, the instructors overall did not feel that students have the skills to effectively evaluate peers and did not support peer assessment.

Contrary to the instructors' beliefs found by McClure et al. (2015), Pantiwati and Husamah (2017) conducted a quantitative study using a pretest and posttest design to discover the effects of peer and self-assessment on metacognition and HOTS with a sample of 59 students enrolled in a science course at an Indonesian university. Using path analysis, they found that peer and self-assessment in a semester-long active learning environment increased students' metacognitive awareness an average of 23.9%. Students became more aware of how they learned. Additionally, the assessment strategies motivated students to be more accountable and strive for higher levels of performance. These findings align with other studies that found peer and self-assessment promote metacognition and HOTS (Jaime et al., 2016; Liu, Lu, Wu, & Tsai, 2016; Strom, Thompson, & Strom, 2013).

Zhao et al. (2017) examined the impact of peer assessment on HOTS in social constructive learning. As part of a larger longitudinal study on education reform, Zhao et al. studied the impact of peer assessment feedback using PBL performance rubrics with 324 Chinese business students. They quantified multiple sources of qualitative data and found that rubrics provided an effective means for students to learn how teammates viewed their performance and this awareness motivated students to improve. Zhao et al. (2017) concluded that peer assessment also helped students attend to the learning objectives and promoted higher learning outcomes through self-calibration processes such as that suggested by Hattie (2013). Strom et al. (2013) found that orientation training for peer collaboration and evaluation helped middle school students learn the importance of giving and receiving honest feedback. They stressed that teachers need to be patient with this process as students will give “gratuitous feedback” to friends and fail to judge others fairly in the early stages (p. 95). Panadero, Romero, and Strijbos (2013) found similar results in a quasi-experimental study with a sample of 209 college students in Finland. When first learning to give peer feedback students gave friends higher ratings than they deserved but the researchers found that over time, peer assessments using rubrics were more reliable.

Williams (2017) used action research to study how peer and self-assessment can be used for group and individual grading in PBL with multicultural college students. Williams posited that assessment is by nature a subjective process and therefore, assessments using rubrics were not flawless; however, the researcher demonstrated how peer and self-assessment data could be used to assist the teacher in developing a transparent method of grading groups and individuals. In the second round of PBL Williams co-created assessments with students and found that by involving them as assessment partners using data from student self-assessments and group evaluation, individual grades could be accurately determined while reducing teacher subjectivity. Williams also concluded that co-constructing formative assessments clarified expectations and increased student motivation to perform collaboratively at higher levels and reduced incidences of free riding in group collaboration. While studies support involving students in PBL assessment as co-constructors and collecting multiple sources of data (Strom et al., 2013; Williams, 2017), determining which processes to assess is another challenge for teachers as 21st century skills are complex and overlapping as well as difficult to define (Scholtz, 2016; Schulz & FitzPatrick, 2016; Simmons et al., 2016; Voogt et al., 2013).

To summarize, rubrics are a key strategy for formative and summative PBL assessment that can drive learning and HOTS through effective feedback mechanisms. PBL assessment strategies are significantly different from traditional assessment practices and teachers often struggled with this shift. One prevalent form of PBL assessment that has been found to promote HOTS is peer and self-assessment as well as assessments that are co-constructed by teachers and students. Peer and self-assessments are often used in PBL and when given instruction and practice, students can give good feedback that has been found to promote metacognition and self-regulation. Peer and self-assessments can provide teachers with important understandings regarding student perceptions that they can use to inform the grading process and identify training needs.

Assessing PBL products for innovation and creativity. It is generally agreed that creativity and innovation are critical to economic prosperity in the modern world and a wide body of research supports the use of PBL as an instructional strategy for cultivating these skills in the schools. A final PBL product is the culmination of a unit in the form of a tangible creative artifact representing the knowledge building activities of a small team of learners and studies showed there are many ways to assess PBL products. Bloom's (1956) Taxonomy of cognitive processes was often referenced in PBL literature and according to RBT (Anderson & Krathwohl, 2001) creativity requires high-level thinking and in PBL, students must apply HOTS to research, collaborate, plan, produce, reflect, revise, and finalize creative projects (Baser et al., 2017; Ellis, 2016; Özer et al., 2015; Siew et al., 2017; Valgeirsdottir et al., 2015); therefore, to develop an understanding of PBL and HOTS an examination of how creativity and innovation in PBL products were assessed in recent studies as well as instructional strategies integrated in PBL that have been found to increase creativity may shed light on the relationship between PBL and HOTS.

Creativity and innovation are valued 21st century skills and there has been a recent surge in research on creativity in PBL. According to Henriksen and Mishra (2015) creativity studies in education lag behind other fields such as psychology where quantitative methods have been applied, for example, to study creative historical figures. Such research is of limited use to practitioners who are interested in developing students' creativity for problem-solving and project development. Henriksen and Mishra posited that educators often struggle to define creativity as the concept is perceived as "fuzzy or subjective in nature" and this may have contributed to a research gap (p. 126). Despite this difficulty, creativity research has shown that both novice and expert product assessors recognize creativity when they see it (Hennessey, 1994; Valgeirsdottir et al., 2015).

Recent PBL studies evaluated the originality and usefulness of products to assess levels of creativity and this approach can be traced to Amabile (1988). As an expert in creativity, Amabile supported using a product-oriented approach to assess creativity by evaluating the novelty and usefulness of a product that was collaboratively produced by a small group of individuals. Amabile further posited that "product measures are more straightforward" than assessing creative individuals or processes based upon complex observations (p. 126). Drawing from several definitions and creativity models Acar, Burnett, and Cabra (2017) studied four factors of creative products including originality, value, surprise, and aesthetics to determine which factor had the strongest correlation with creativity and innovation when products were judged by experts and novice evaluators. Acar et al. found that originality was the factor most strongly correlated to product creativity followed by the element of surprise which contradicted previous studies supporting product value as more important. Weisberg (2015) asserted that assessing the value or usefulness of a product was a highly subjective concept and argued that creativity judgments based upon the *intentionality* of a product would be a more objective choice. Despite this, recent studies continue to include measures of novelty and usefulness or associated cognates such as originality and value to judge levels of creativity in PBL products; however, there was little continuity regarding how product creativity was assessed across PBL studies. Assessment frameworks used to measure product creativity tended to be unique to each study context (Baser et al., 2017; Esjeholm, 2015; Henriksen, Mishra, & Mehta, 2015; Özer et al., 2015).

Major findings of recent PBL studies that included a method of assessing levels of creativity in student products often reported instructional strategies that researchers credited as contributing to creative outcomes and HOTS. For example, Esjeholm (2015) concluded that students age from 7 -15 years old engaged in using technology for PBL projects were more creative and demonstrated HOTS when teachers provided enough time for learning prior to engaging students in product development. Chua et al. (2014) reported a similar finding in a quasi-experimental study comparing two approaches to PBL implementation in which products produced by 60 engineering students working in 12 teams were assessed using Bloom's (1956) taxonomy. Chua et al. found that student products showed greater creativity and evidence of HOTS in the enhanced PBL condition where strategies for scaffolding, mind-mapping, and round table dialog were incorporated to immerse students in background knowledge and concepts prior to engagement in product development. Similarly, Kadir et al. (2019) found that when teachers provided scaffolding to develop concepts prior to engagement in PBL, this had a reinforcing effect on students' HOTS.

PBL studies in which student products were assessed for creativity also revealed the potential for cooperative and collaborative learning strategies to increase student product creativity and HOTS at all age levels. These learning strategies were incorporated in PBL studies with third-year chemical engineering students (Azizan et al., 2017), six-year-old science students (Siew et al., 2017), and seventh grade science and technology students (Baser et al., 2017). For example, learning strategies that foster scientific creativity with preschoolers were the focus of a quasi-experimental study that incorporated pretest posttest control group design conducted by Siew et al. (2017). The sample size was 216 six-year-olds randomly assigned to three learning environments: hands-on, problem-based learning, and problem-based learning with cooperative learning strategies. Five trait dimensions were used to measure creative outcomes including fluency, originality, elaboration, the abstractness of title, and resistance to premature closure. The results of this study showed that the students who received problem-based and cooperative learning instruction outperformed the other two groups. The researchers concluded that students exposed to cooperative learning strategies had social tools for collaborative problem-solving. They also asserted that having a clear learning structure for students to use was critical to producing creative products. Similarly, Hattie (2013) emphasized the importance of students being aware of the learning process as this generated self-confidence and readiness to pursue next steps. Azizan et al. (2017) studied the effect of cooperative learning on creativity with 105 chemical engineering students engaged in using multimedia to develop a board game project. Bloom's Taxonomy was used to judge the depth of learning and the researchers reported that students demonstrated HOTS at the highest levels of the taxonomy by effectively using 21st century skills referred to as the 4Cs including communication, collaboration, critical thinking, and creativity. They found that most students not only increased their skills in using technology creatively but working in teams using a structured learning process resulted in positive creative output. In sum, PBL products have been evaluated in recent studies using a variety of methods and have shed light on instructional strategies that can impact student creativity and HOTS. PBL products were tangible evidence of learning processes and supported the development of HOTS. In addition, it was critical to assess learning processes formatively and provide feedback that would promote self-regulation and student-driven learning.

Assessing PBL processes. It was often noted in the literature that student engagement in communication, collaboration, critical thinking, and creative learning processes through PBL strategies promoted deeper learning, workforce readiness, and 21st century skill development including digital literacy and technical skills. In order to benefit from metacognitive learning opportunities in PBL students must attend to PBL processes; however, Smith (2016) observed that students often rushed to finish tasks that they thought the teacher would grade and disregarded the learning process. Smith argued that the product was not the sole source of value in PBL and assessment practices could shift the focus to both learning processes and product. For this shift to be realized, teachers needed tools that could be flexibly applied to assess complex learning. Kivunja (2013, 2015) maintained that HOTS should be observed and assessed in PBL processes and asserted that feedback can drive learning; however, Voogt et al. (2013) concluded that new tools for assessing 21st century skills were needed. More recent studies in scholarly journals indicated there was a lack of researched methods for assessing learning processes in PBL that could be easily adapted and applied in practice (Schulz & FitzPatrick, 2016; Smith, 2016; Williams, 2017). Further, Zhao et al. (2017) confirmed that the need persisted for assessment strategies that would support social constructivist pedagogy including rubrics for engagement processes.

Thinking. Higher order thinking and critical thinking skills were often used interchangeably in this review, and critical thinking was a key 21st century process skill that should be assessed in PBL. When presented with the task of measuring higher order thinking as a learning process, educators often thought of Bloom’s (1956) Taxonomy of Cognitive Objectives. Since Bloom’s Taxonomy was first published, it has remained one of the most well-known works in education around the world and continues to influence how teachers conceptualize levels of thinking. My study explored how teachers fostered HOTS in PBL; therefore, I reviewed literature on the use of Bloom’s Taxonomy and revisions of that work that have been applied to assess HOTS. Although Bloom’s Taxonomy has been criticized for decades in the scholarly literature (Booker, 2007; Ennis, 1985; Soozandehfar & Adeli, 2016), researchers continue to use it. Soozandehfar and Adeli asserted that the taxonomy has been “expanded, elaborated, and interpreted in various ways and its breadth has been expounded on” but it continues to survive (p. 1). Bloom’s Taxonomy of six cognitive objectives and RBT by Anderson and Krathwohl

(2001) that proposed using a matrix of six cognitive process verbs and four knowledge levels to assess rigor have been cited many times in the recent literature related to HOTS and PBL but there is little consistency in how they were used and it appeared that there was widespread confusion and misrepresentation.

Some PBL studies mentioned Bloom's Taxonomy as a method for identifying critical thinking and loosely combined it with other strategies for judging rigor (Edmunds, Arshavsky, Glennie, Charles, & Rice, 2017; Heinrich, Habron, Johnson, & Goralnik, 2015). Other researchers synthesized concepts from Bloom's Taxonomy or RBT and incorporated new and old terminology in their frameworks (Chua et al., 2014; Ellis, 2016; Nkhoma et al., 2017). Most often studies that used the taxonomies did not use them to measure the rigor of PBL processes or products. For example, Chua et al., (2014) used four of the six levels from Bloom's original taxonomy to judge question levels for a written test to compare academic outcomes of two PBL learning conditions; Ganapathy et al. (2017) used Bloom's Taxonomy to judge levels of thinking in summative assessment questions to show the need for instructor training in HOTS versus lower ordered thinking skills; Scholtz (2016) found that instructors in a South African university misinterpreted how to use the taxonomy to assess critical thinking. For example, one department reported that their instruction and assessment practice targeted the lowest levels of the taxonomy with first year students and each successive year of the degree program targeted higher levels of the taxonomy. These studies are a sample of the various ways Bloom's Taxonomy and RBT have been applied to measure and assess thinking.

In a critical appraisal of Bloom's taxonomy and RBT, Soozandehfar and Adeli (2016) provided 17 criticisms with clarifying examples. Within each example, it appeared that the greater problem was not with either taxonomy per se, but how practitioners have misinterpreted, loosely applied, modified, and adapted Bloom's taxonomy and RBT to fit their purpose and called fidelity of implementation into question (Carroll et al., 2007). Sosniak (1994) reviewed the history of Bloom's taxonomy over 40 years and claimed that the taxonomy is sometimes "taken so for granted that a traditional reference seems quite unnecessary" (p. 111). Sosniak also stated that Bloom's Taxonomy is often included in curriculum work unreflectively "without serious thought about how or why it is to be used" and in many cases there was a "dogmatic insistence on the use" of the model from funding agencies (p. 112). Perhaps Sosniak's points explained some of the patterns noted in this literature review; however, some promising applications of Bloom's Taxonomy and RBT were also found.

Two PBL studies in the recent literature used RBT to measure levels of critical thinking in online communication. These studies expanded PBL research to connected learning pedagogy and demonstrated that researchers could capture implicit interactions and metacognitive processes that were complex and difficult to assess without technology. Shadiev, Hwang, and Huang (2015) conducted a qualitative case study to investigate how PBL might facilitate cross-cultural learning in a virtual learning environment. Shadiev et al. were interested in student communication within a collaborative cyber community (3C) learning environment. The six cognitive levels of RBT were used to code online communication among seven students from five different countries engaged in cross-cultural learning using PBL. Three raters were used to analyze data from asynchronous and synchronous communication as well as semistructured interviews. The results showed that students were able to communicate across cultures at least at a level of understanding on the taxonomy and using the PBL structure, cross-cultural learning was possible in the 3C environment.

In a second study Morueta, López, Gómez, and Harris (2016) explored critical thinking skills in a 3-year longitudinal study by assessing social and cognitive interactions among groups of college students engaged in complex online tasks using Moodle, a learning management system (LMS). The researchers designed three levels of tasks based upon the highest three levels of RBT including analyzing, evaluating, and creating to study students' social and cognitive interactions among team members. Morueta et al. used these levels to differentiate online learning tasks to understand correlations between complex tasks and students' social and cognitive learning processes. A total of 9878 units of meaning were collected from 96 discussion forums for analysis. Morueta et al. found that when teams were presented with a creative task which was the most rigorous of the three types, online cognitive engagement and social interaction increased. Morueta et al. claimed that this study demonstrated the importance of students using collaborative skills through online team engagement in cognitively demanding tasks. The authors recognized LMS as an ideal tool that can "catalyze high-level thinking" by supporting communication, knowledge construction, and problem-solving (p. 122). Observations of HOTS through online social participation involved affective, interactive, and cohesive interactions that created a respectful, cohesive, and emotionally supportive learning environment for task-focused work. Thus, Morueta et al. (2016) found that online socially connected project creation was the most cognitively rigorous of the three types of learning examined and these findings were supported in an online PBL study by Lin (2018).

Although the studies by Shadiev et al. (2015) and Morueta et al. (2016) contributed to the body of PBL research using the six cognitive process verbs of RBT (remembering, understanding, applying, analyzing, evaluating, and creating), neither study used the four knowledge levels (factual, conceptual, procedural, and meta-cognitive) which the authors of RBT (Anderson & Krathwohl, 2001) recommended be used together as a matrix to capture the depth of learning while reducing ambiguity. One reason Anderson and Krathwohl revised the original taxonomy was to emphasize that students needed to use all levels of learning and teachers should not focus only on HOTS but should ensure a balance of HOTS and lower ordered thinking skills. The authors plotted teaching objectives and activities across sample learning units for different subjects using the RBT matrix of six cognitive verbs and four knowledge levels to demonstrate how all levels of skills are needed at various stages of a unit of study. Using the matrix was helpful for situating activities in the context of learning and served to illuminate the complexity of thinking required when pursuing learning objectives and activities. This is critical because little can be understood about the rigor of learning by simply using RBT cognitive verbs alone. However, only one study in the literature was found that used both dimensions together. Y. J. Lee, Kim, and Yoon (2015) used RBT to compare levels of rigor in Korean and Singaporean curricula by analyzing elementary science objectives. They found that most of the objectives were at the lower levels of cognitive and knowledge process skills in both curricula. In the knowledge levels, metacognitive tasks were absent and, in the cognitive activity dimension, analyze and evaluate were absent. A small number of items at the creative level of RBT cognitive activity appeared in the Korean curriculum. Although Y. J. Lee et al. did not directly assess PBL products or processes, but they noted that many of the objectives were constructivist tasks.

This literature review of recent PBL studies using RBT to assess levels of rigor and thinking skills revealed that currently, most PBL researchers used the six levels of the RBT cognitive activity verbs alone although Anderson and Krathwohl (2001) advocated using a two-dimensional table including four knowledge levels to strengthen and support task analyses. Anderson and Krathwohl (2001) provided many example vignettes with detailed explanations of how to analyze objectives and associated activities using the RBT table which is a matrix of six cognitive activity verbs and four knowledge levels. Using this two-dimensional table, the level of rigor for project objectives and activities could be plotted. The RBT was designed to remediate two major criticisms of Bloom's (1956) original taxonomy. First, cognitive verbs could be applied at more than one level and were, therefore, ambiguous. Secondly, the taxonomy placed greater value on higher levels of cognitive activity and discounted the importance of students developing skills at all levels. The two-dimensional table of RBT cognitive activity verbs and knowledge levels to situate learning in context reduced the ambiguity of using cognitive verbs alone. The table also provided a means of evaluating the depth of learning that could be tracked to balance skill development at all levels appropriate to the task; however, most often the knowledge levels were disregarded in recent literature.

Currently, Webb's (1997) DOK is a popular method of judging rigor and has been mentioned in several PBL studies. Webb's four levels of rigor including *recall,* *skill/concept, strategic thinking, and extended thinking* conceptually align with the RBT knowledge levels *factual, conceptual, procedural, and meta-cognitive* although Webb (1997) intended to use the DOK for judging the rigor of standards and assessment questions with regard to cognitive complexity. Anderson and Krathwohl (2001) demonstrated how to use RBT matrix to evaluate cognitive levels of teachers' learning objectives and activities. A YouTube video of Webb (2014) highlighted why Webb might have developed the DOK which was like Anderson and Krathwohl's (2001) knowledge levels. In explaining his purpose, it was clear that he was likely unaware of Anderson and Krathwohl's (2001) knowledge levels but he was familiar with the RBT cognitive verbs because he commented that the verbs were insufficient for judging rigor. In the video, Webb (2014) stated that the six RBT verbs were developed by psychologists and focused upon action verbs that did not help him as a curriculum content specialist understand different levels of thought processes when working with content.

Several recent authors supported using Anderson and Krathwohl's (2001) six levels of cognitive processes with Webb's (1997) four levels of DOK to measure learning rigor (Branscome & Robinson, 2017; Darling-Hammond et al., 2013; Ellis, 2016; Harris & Patten, 2015; Hess et al., 2009; Sondergeld et al., 2016). In addition, researchers continued to modify, add example activities, and merge assessment models for example, Hess (2006) used Bloom's (1956) taxonomy and Webb's DOK to create a matrix to assess rigor similar to the RBT table proposed by Anderson and Krathwohl (2001) and named it Hess's cognitive rigor matrix. Later, Hess et al. (2009) replaced Bloom's (1956) cognitive objectives with Anderson and Krathwohl's RBT cognitive skills but kept Webb's (1997) DOK rather than using Anderson and Krathwohl's RBT knowledge levels. Churches (2007) expanded the cognitive verbs for the RBT to include technical terms and named this Bloom's Digital Taxonomy which he shared using social media blogs and infographics. With the rapid growth of technology use in education and practitioners sharing assessment strategies via social media, it can be challenging to track the theoretical and pedagogical development of assessments and understand how they came to appear in scholarly works. The literature review revealed that both of the four-level models DOK and RBT knowledge levels designed for assessing thinking, objectives, and learning activities have a common dividing line between higher order thinking (levels 3 and 4) and lower order thinking (levels 1 and 2) and the terms used in the four levels of DOK and RBT knowledge levels aligned semantically. In the literature, the use of two-dimensional tables for judging the rigor of learning has been consistently recommended for reducing ambiguity and increasing assessment consistency.

Communication and collaboration. Most of the recent studies found in this literature review of PBL process assessment methods involved the use of technology which may reveal a pedagogical shift from face-to-face social constructivism to connectivism as predicted by Siemens (2004). Varying degrees of blended and online learning activities using technology tools for communication and collaboration were incorporated in current PBL learning and assessment studies (Darling-Aduana & Heinrich, 2018; Eliyasni, Kenedi, & Sayer, 2019). Due to the growing and ubiquitous use of Web 2.0 applications for complex team communication and collaboration, researchers have used a combination of thinking and communication models to study networked learning. For example, Seifert (2016) studied connectivist pedagogy in a mixed method study applying RBT cognitive levels (Anderson & Krathwohl, 2001), the SAMR model that differentiated types of technology use and levels of complexity (Puentedura, 2010), and an adaptation of RBT called Bloom's Digital Taxonomy and Communication Spectrum (Churches, 2009). Churches provided a graphic that showed levels of cognition from RBT matched with communication activities via technology suggesting that levels of thinking and HOTS in online activities such as texting and blogging could be identified. In addition to using models, software used for online learning offered new tools to researchers for understanding cognitive demand in networked learning environments.

Due to the increasing use of LMS in PBL, researchers gained insights into social constructive engagement via learning analytics that illuminate high levels of complex team communication. According to Brown (2017), new technology was a constant driver of change in teaching and learning, and to prepare for the world of work students must be adept at using technology for a variety of purposes. A wide body of research has shown that PBL is an excellent conduit for developing communication and collaboration skills using technology. In addition to providing forums for team members to interact virtually, Peng et al. (2017) asserted that Web 2.0 technologies also enable researchers to capture and track complex interactions among learners that were previously inaccessible; hence Web 2.0 technology provides a window for studying learning dynamics and HOTS through PBL processes. A comprehensive review of the strategies that researchers could use to assess PBL learning processes in Web 2.0 applications was beyond the scope of this study; however, teachers in the study may described technology applications used for PBL assessment. Therefore, it is appropriate to provide a few examples of studies that included technology in the evaluation of PBL communication and collaboration skills.

Brown (2017) engaged teams of engineering students in developing websites to track and assess group and individual contributions to PBL projects for a 14-week creative solutions course at a university in New Zealand. The websites were used in place of a final project report and provided an avenue for peer, self, and product assessment which 76% of the 54 survey respondents stated they preferred. One requirement of the projects was that they had to demonstrate effective visual communication with a general audience which Brown asserted was a critical transferrable skill for engineering graduates entering the workforce and the websites provided a window for tracking this development. According to Conley and Darling-Hammond (2013) the evaluation of transferrable skills is a hallmark of quality assessment systems; in other words, higher order cognition could be identified when students demonstrated the ability to transfer skills to new learning contexts.

Several Web 2.0 applications such as wikis, websites, google docs, blogs, and digital storytelling used in PBL could support the development of communication and collaboration skills that were critical for working in teams. To contribute to best practices in learning to communicate using technology with elementary age students, Liu, Wang, and Tai (2016) explored engagement patterns and language learning using digital storytelling with 24 third grade students over 19 weeks in Taiwan. The participants were first time users of this Web 2.0 technology and Liu et al. found four phases of engagement that included two cycles of disengagement and re-engagement suggesting that teachers should provide guidance to support re-engagement in social learning processes. They also confirmed that using the online platform students' language skills increased. In a larger study, Lin et al. (2015) explored online cross-cultural collaboration and learning behaviors with 29 teams composed of 163 high school students from four countries. In a mixed method study on global learning, students engaged in PBL via a dedicated online website called APEC Cyber Academy (ACA) designed for networked learning. The researchers concluded that an analysis of student interaction showed improved communication, collaboration, creativity, critical thinking, engagement, technology skills, sense of responsibility, and time management.

In addition to using technology as a communication tool in recent research, technology was also used as a method of managing, accessing, and assessing online interaction in social constructive and connected learning. Roussinos and Jimoyiannis (2013) used learning analytics to explore PBL communication and collaboration in online learning. Students used wikis as a communication tool and the researchers investigated patterns of collaborative engagement and contributions to PBL projects. The study included 47 college students enrolled in an ICT course in Greece that employed the learning management system to oversee course progress. Students participated in 11 PBL wiki groups. Descriptive analysis was used to assess 423 student-generated wiki pages with a wealth of embedded data related to collaboration and communication such as 854 discussion posts, 2542 edits, 208 images as well as hyperlinks, videos, and tutor messages. The researchers confirmed that using ICT, students can contribute to PBL projects outside of the classroom at any time wherever they have internet connectivity. In this study, the collaborative interaction levels varied significantly from group to group highlighting that interpersonal dynamics were a pivotal element in constructive learning. The researchers identified four roles that students assumed based upon contributions to the wiki information flow among leaders, moderators, peripheral members, and lurkers.

These roles indicated high to low levels of engagement and cognitive presence, respectively. Noting that students with low levels of participation were focused upon the final product and project requirements, rather than learning processes, Roussinos and Jimoyiannis speculated that such poor learning habits may have been learned in high school.

Learning analytics was also used in the study described earlier by Morueta et al. (2016) to explore social and cognitive relationships among team members engaged in online PBL. Through content analysis of forum participation, Morueta and colleagues found that social interaction increased with higher level tasks. More complex forms of learning analytics were researched beyond simple online metrics. For example, Tempelaar, Rienties, and Nguyen (2017) combined eight social-cognitive learning theories, student demographic data, and LMS logs on 1,069 university students in the Netherlands to predict learning needs and recommended interventions teachers should consider that will support social learning needs. Tempelaar et al. claimed that using learning disposition analytics personalized interventions for at-risk students could be prescribed. Similarly, Conde, Colomo-Palacios, García-Peñalvo, and Larrucea (2017) gathered data from engineering training modules on student performance and applied learning analytics to generate a web of data capable of predicting individual student teamwork needs. PBL studies using learning analytics to identify personalized team member support needs were not found but because cohesive teamwork is critical to successful PBL and HOTS, this may be forthcoming.

Teamwork. Engagement in collaborative teamwork is a key requirement of PBL processes and these skills were challenging for teachers to assess although several approaches have appeared in the scholarly literature. Strom and Strom (2011) developed a 25-item teamwork skills inventory (TSI) for peer and self-assessment of cooperative learning performance. They tested the TSI with 303 high school students over 4 weeks of continuous collaboration tasks and collected 1,136 random responses. They found a high-level of agreement between self and peer responses indicating that the TSI could be used as a reliable tool for assessing collaboration skills. The TSI focused on five main categories of collaborative activities: attending to teamwork, seeking, and sharing information, communicating with teammates, getting along as a team member, and critical and creative thinking. The researchers found that individual accountability increased and deduced that the TSI made criteria for judging teamwork skills transparent and students are more likely to value skills that are assessed. The most challenging area of the inventory for students was bringing materials and seeking and sharing information with the team. Strom et al., (2013) designed a quantitative teamwork skills study with 297 middle school students that included 39 students with disabilities and drew attention to the importance of all students developing teamwork skills for success in the workplace. Using a pretest posttest design the TSI was used with students 10-14 years of age. Again, the results indicated that finding materials and sharing information were most challenging for students indicating that teachers needed to scaffold these activities. Strom et al. also found that special education students believed their teamwork skills were better than they were perceived by general education peers; however, both groups rated general education students as having better teamwork skills than the special education students.

Several other methods of teamwork assessment were found in recent studies but transfer to other contexts in the literature appears to be limited. For example, Loughry, Ohland, and Woehr (2014) used complex peer evaluation system used with college students called the comprehensive assessment of team member effectiveness Sheridan, Kinnear, Evans, and Reeve (2015) used discourse analysis to assess teamwork development and concluded that this method of assessment would be too time-consuming for teachers. Britton, Simper, Leger, and Stephenson (2017) used a two-phase assessment method with undergraduates called Team-Q and TeamUp that included a rubric but this assessment was also too long. Torrelles, Mañas, Bernadó, and Alsinet (2015) used a teamwork rubric with 55 teams of workers in a variety of settings to evaluate teamwork competence skills. Communication processes were found to be the weakest area showing the need for training in conflict resolution and team cohesion as well as planning, progress tracking, and informed decision making. Mozas-Calvache and Barba-Colmenero (2013) evaluated PBL teamwork using a peer and self-assessment method in a case study of 20 teams of engineering students studying surveying via PBL. Although the study was very context and task-specific, the teamwork evaluation system allowed the instructor to gather data on individual performance in the areas of global evaluation, leadership, communication, and team involvement. Data were entered into a web system referred to as the MySQL for analysis from peer and self-questionnaire responses, weblogs, and an evaluation form. The researchers claimed that this evaluation system could easily be adapted in other contexts requiring a significant amount of practice work. Individuals tended to rate their team involvement higher than was perceived by peers. The study also confirmed that team members who had previous experience together performed at higher levels which corroborated the findings of other PBL research studies (Conde et al., 2017; Lee et al., 2014; Rudnitsky, 2013). Peng et al. (2017) asserted that teamwork was always situated within a unique context and involved dynamic interactions that were complex and multileveled. Just as teachers must design PBL units with the learning needs and social skills of the students in mind, methods of assessment were also context dependent. This may help explain why assessment methods seemed to have a low incidence of transfer or adoption in the literature review. Ravitz (2010) claimed that no two teachers implement PBL in the same way and perhaps considering the interpersonal dynamics of PBL it could also be said that no two teams would experience a PBL unit the same way.

Riebe, Girardi, and Whitsed (2016) conducted a systemic literature review of 57 higher education studies on teamwork pedagogy to discover common issues and practices related to instruction and assessment. The researchers found that the studies in the review often used quantitative methods. Riebe et al. argued that this method alone is incapable of capturing nuanced interactions; therefore, to fully understand teamwork pedagogy, they recommended a mixed method design. Peer and self-assessment strategies were used constructively in many of the studies, but constraints related to assessment included artifact evaluation, team processes, and grading individual vs. group performance. The researchers stated that college instructors tended to assume that teamwork is taught in K-12; and according to the articles reviewed, instructors frequently placed students in teams without providing instruction in how to collaborate. Across the studies in this review, cooperative, collaborative, and experiential learning strategies were used for teaching teamwork pedagogy and to introduce students to developmental stages of teamwork, several studies reported using Tuckman's (1965) model. Overall Riebe et al. (2016) found "a proliferation of information available to educators on teamwork pedagogy" from the past two decades; however, the researchers concluded that "that the same types of practices are presented with no real discernible innovation or advancement in the teamwork pedagogy domain." (p. 633).

Bonebright (2010) reviewed the use of Tuckman's model of small group development over a 40-year period and concluded the Tuckman's model as a simple and informative way to promote the development of teamwork skills that has weathered the test of time in a variety of settings. For each of the four levels of team development, there were observable characteristics and behaviors that differentiate each stage. When teams first come together, they were at the forming stage. There was uncertainty about member roles, members were polite but experienced anxiety and asked for outside help to establish rules for how to work together. The second stage was storming that was marked by conflict, disagreements, tensions, and hostility. There were struggles for leadership in this stage as members worked toward organizing tasks. The third stage was norming marked by greater acceptance of one another, more sharing of ideas and members began to agree on procedures for accomplishing identified tasks. The last stage was performing where the team communicated more effectively and became goal oriented. Members become interdependent problem solvers focused on completing the tasks (Lin, 2018). Thus, over the four stages relationships among team members could be characterized as experiencing dependency, conflict, cohesion, and interdependence. Applications of Tuckman's model in K-12 settings were not found in the scholarly literature; however, this is a very simple way for team members at all instructional levels to understand team development, assess, current functioning, and identify goals for improvement.

In recent studies, researchers applied Tuckman's model in college settings and three examples that follow showed ways in which the model was useful in practice for promoting higher functioning teams in virtual and face-to-face learning environments. Haines (2014) applied Tuckman’s stages of team development to study the process of virtual team development with business education students from two southwestern universities. Haines posited that virtual teams were increasingly the norm in the modern workplace yet there was a widespread belief that virtual teams perform poorly due to communication barriers interfering with relationship formation. Haines studied team development over 10 trials and found that virtual and face-to-face teams evolved in much the same way following Tuckman’s stages. Haines found that developing a sense of belonging, trust, and goal commitment in the early stages of virtual team development were critical to future success and that team goals and communication requirements must be clear and specific. Kearney et al. (2015) devised a method to access and assess team interactions and conducted a qualitative case study over three years to explore engineering team characteristics and development processes in an academic computer lab of a central United States university. Kearney et al. gathered several forms of written and spoken language and applying linguistic analysis, they were able to identify and track team growth using Tuckman’s model of team development. Teamwork is a hallmark of the nursing profession and medical teams have contributed significantly to the development of PBL. When nursing programs from two uniquely different universities were forced to consolidate, faculty members were challenged to efficiently balance workloads and develop effective team processes. Realizing that such team development can be a complex process, Natvig and Stark (2016) seized this opportunity to study team development. The researchers chose to use Tuckman's (1965) model of team development because it was a well-known and widely used model for team research in the literature. The researchers found that the team progressed through the four phases of Tuckman's model and that having a team charter for guidance through processes, a strong leader was selected to oversee adherence to team structures and tasks. Tuckman's stages of small group development helped members understand the systematic and predictable stages of team development and supported member progress. From this overview, it appears that Tuckman’s model continues to serve as a simple starting place to understanding a variety of teams. For this study, through semistructured interviews with teachers, their descriptions of team interactions should reveal team developmental stages that may serve as a springboard for gaining deeper understandings of the PBL experience and student demonstrations of HOTS.

Tools. Sources of information were tools for learning and in PBL processes there were several critical skills related to resources that could be assessed and reveal HOTS. Darling-Hammond et al. (2013) asserted that learning to effectively search for information and evaluate sources requires critical thinking. In today’s world locating and synthesizing knowledge from a variety of credible sources and using them to create new ideas are highly valued skills. Perhaps it was Webb (2009) who drew attention to the importance of resource use as an indicator of deeper learning and complexity of thought. This point was clear in Webb’s (2009) published guidelines for using DOK to evaluate rigor across subject areas. For each of the four DOK levels, Webb included descriptions of teacher and student roles, possible products, and potential activities. Embedded within these descriptions Webb included levels of resource use. For example, at level 4 which was the highest DOK level of complex extended thinking, Webb elaborated that students analyze multiple sources of information, evaluate the quality and usefulness of resources, make applications, and create new knowledge. Darling-Hammond et al. (2013) reported that these were considered higher order skills that could be applied in transferrable learning and should be included in high-quality assessments. Thus, as a transferrable skill, expertise in using resources as learning tools could be applied across the disciplines or anywhere that reliable information would be used to guide decision making and to create new knowledge.

The assessment of student resource use often appeared in PBL studies in tandem with another skill. For example, using resources was prominent on the PBL critical thinking rubric from the Buck Institute for Education (BIE, 2013). The rubric included four phases of critical thinking opportunities and three of them involved resources as learning tools including gathering and evaluating information, using evidence and criteria, justifying choices, and making implications. In a quantitative PBL study focused upon levels of thinking with 204 Vietnamese business students, Nkhoma et al. (2017) found that knowledge application, sharing, and creation promoted higher order thinking. In a mixed method study on teamwork in PBL Haines (2014) reported that one of the most critical skills for effective virtual teams was the ability to use information resources and materials productively. Haines observed that teams commonly reached a stage where productivity was intense and “effective work depended on the group’s ability to use available resources such as information, expertise, and materials” (p. 214).

In the literature the abilities to identify, evaluate, and use quality information sources for a variety of purposes were high-level skills and in PBL engagement these were often challenging for students. In addressing the issue that the internet could supply students with an overwhelming abundance of information, Thamarasseri (2014) asserted that much of it is *disinformation*. When using the internet as a tool, students must learn to evaluate and select sources for specific purposes. These processes required critical thinking and teachers might need to provide scaffolding for students to master skills in resource use. Strom et al. (2013) found that bringing resources to PBL collaboration was an area that is particularly challenging for students and recommended that this skill be actively taught. Özer et al. (2015) evaluated secondary science projects submitted for regional competition and found that overall, the projects were weak in using resources to support learning. Resources were important learning tools in PBL that skilled self-regulated learners should access, assess, and apply seamlessly. In addition to finding, evaluating, and applying knowledge resources in PBL, technology was also a tool that students of all ages could learn from and with; thus, from this perspective, student use of technology for learning should also be assessed for HOTS when exploring student use of tools in PBL.

As a pioneer in learning technologies and educational psychology David Jonassen combined the principles of constructivism and the belief that students could learn through experiences with technology when used as “mindtools” (Jonassen et al., 1998). Jonassen championed the concept that students should learn *with* rather than *from* technology and posited that the use of technology as a mindtool engaged students in higher order thinking and built skills needed for success in the modern world (Jonassen, Howland, Moore, & Marra, 2003). Jonassen et al. encouraged educators to focus upon how purposeful technology use could ignite higher levels of cognition for all students including those with diverse abilities. He elaborated that students do not learn from technology; they learn from *thinking* and teachers should be mindful of how technology integration might impact the learning process. Over the life of a PBL unit, technology use might not be required; however, Larmer et al. (2015) emphasized that technology integration could "give projects the equivalent of a turbo boost taking learners places they couldn't otherwise go" (p. 128). Couros (2015) asserted that there were right and wrong ways teachers should encourage students to use technology. Couros created a chart contrasting purposes of student technology use to clarify his point that "technology is a tool, not a learning outcome" (p. 23). For example, Couros asserted that instead of having students use technology to make Prezis, produce videos, or create blogs, the goal should be to raise awareness, change minds, make a difference, take action, join partners, or drive change. Thus, regarding innovation and productivity, technology should not be integrated for the sake of demonstrating computer skills using various applications, but it should be used as a mindtool with a higher purpose.

In recent years, technology tools, access, and use in and out of the classroom have expanded significantly in education giving credence to Brown's (2017) assertion that as technology constantly evolved it was also a constant driver of change in education. Further, this impact could be seen in the findings from a two-year, mixed method study on digital technology use of children from birth to 5 years of age in four European countries (Palaiologou, 2016). Data suggested that the way children learn was changing and educators needed to re-examine instructional practices and learning environments. Palaiologou's study revealed that children were "heavy users of a number of digital technologies at home" and they were perceived to be "digitally fluent from a very young age" (p. 5). According to interview data, when parents became aware of their children's digital agility their perspective of what it means to be literate changed; they realized that literacy in today's world means much more than just the ability to read books and their very young children were already developing computer literacy on their own. Currently, in education settings around the world teachers are integrating technology as an instructional tool, and students are using technology in a variety of ways; yet assessing student technology use for HOTS may not be intuitive.

Due to the growing and ubiquitous presence of technology in education, it is important for teachers to guide its use for learning and be able to assess levels of rigor. Prior to the arrival of Web 2.0 interactive technology, Webb underscored the relationship between teachers' instructional pedagogy and learning outcomes. He also provided criteria for technology use, materials, and tools in his early DOK (Webb, 1997) work. When DOK was applied in a guide for careers and technology (Webb, 2009), use of Web 2.0 tools was articulated in the lists of possible products for each level such as Google search, social networking Wiki, blog, simulation, mashing, and podcast. Webb did not directly apply DOK to PBL; however, the possible products he suggested could be tangible outcomes of PBL units. Use of the internet in homes was already a global phenomenon by the end of the 20th century and technology in education was a growing trend as well. In their account of the history of knowledge sharing via technology, Paroutis and Al Saleh (2009) attributed the initial growth of research on technology use to business interests and recalled that the term *Web 2.0* first appeared around 2005 in a media company blog post. Apparently during this time educators were also engaged in monitoring technology trends as word of a simple model for assessing levels of technology use called SAMR spread rapidly across education networks (Puentedura, 2006). Perhaps the sudden popularity of SAMR indicated that educators were eager for a technology assessment tool that could be applied in a variety of contexts.

As an invited speaker Reuben Puentedura first proposed using the SAMR technology integration model while working as an education consultant in Maine (Puentedura, 2006). Using the internet and social media Puentedura (2013) disseminated SAMR via his educational consulting website http://hippasus.com, blogs, YouTube videos, and taped presentations posted on the internet. The overarching goal for using SAMR was to identify the *transformative* influence of technology applied in education. Puentedura did not define what he meant by transformative learning in his blog posts although he often referred to this topic. An internet search revealed that much has been written about transformative learning in scholarly journals. Illeris (2017) conducted a comprehensive study and concluded that Mezirow's transformative learning theory is the most widely accepted definition. Mezirow (1997) posited that transformative learning is a process in which learners are meaning makers who apply critical thinking skills and develop new perspectives that guide action. Metacognitive processes are applied in transformative learning to challenge previous assumptions, frames of reference, or habits of mind; through reflective thinking and discourse learners develop new insights that support the assimilation of knowledge for decision making.

SAMR is an acronym of four types of technology use that graduate in complexity: *substitution, augmentation, modification, and redefinition*. Puentedura generalized that the lower two levels functioned to simply enhance learning and the upper two levels transformed learning. As a versatile model, SAMR has been applied in K-12 and higher education as a simple four-level tool for evaluating the functional aspects of technology use for learning activities from basic to highly innovative endeavors (Green, 2014; Hunter, 2015; Phillips, 2015; Theisen, 2013). From this perspective, the role of critical thinking and transformative learning in innovation could be seen.

In education settings, the SAMR model was adaptable and could be used for a variety of purposes. Every level of the SAMR model could be demonstrated using a variety of applications across the entire spectrum of devices including hard wired or mobile technology such as laptops, tablets, iPads, and smartphones (Chou, Block, & Jesness, 2012; Jude et al., 2014; Oakley & Pegrum, 2014; Romrell et al., 2014). In classrooms where students work independently or collaboratively using technology, learning spaces may seem chaotic; therefore, having a straightforward technology integration model that could be used to balance pedagogy and technology could also help teachers organize and manage learning activities (Phillips, 2015; Romrell et al., 2014). Additionally, Mishra and Koehler posited that a technology integration model could be used as a lens to study learning processes bridging theory and practice (2006).

The levels of SAMR can be described as the following. According to Puentedura (2006) the lower two tiers of the SAMR model function to enhance learning. The first tier is called *substitution*. At this level students use technology to accomplish tasks that functionally can be accomplished without technology. For example, instead of writing an essay by hand, students may use computers and Microsoft Word or Google Docs to type it. In other words, the task is functionally the same but typing served as a substitute for pencil and paper writing. The typed product can be considered an enhancement to writing by hand. The second tier of the SAMR model is *augmentation*. At this level, the student is still using technology as a substitute, but the technology has additional functions such as spell and grammar check or cut and paste. In Google Docs, the student can use cloud sharing as an enhancement instead of manually saving the typed essay and attaching it to an e-mail or sharing a printed copy. Students may complete digital worksheets requiring online searches for information that are directed by the teacher and assignments may be submitted electronically.

Puentedura (2006) posited that the upper two tiers of SAMR are transformative learning. The third level of the SAMR model is modification. At this level, technology is used in ways that transform learning through the addition of technical features that significantly redesign a task. Students may gather information and create spreadsheets, charts, and graphs. They may use bookmarking and engage in online discussions. Students can use technology to share their voice and ideas. Technology may allow for the addition of visual, audio, or textual capabilities in projects. At the modification level projects may be collaborative endeavors where classmates or instructors are invited to comment and suggest changes to a product or presentation software may include interactive features and multimedia. For example, the comment function in Google Docs or Voice Thread allows students and teachers to share and receive feedback. In these examples, the learning process and experience is transformed by virtual collaboration. The fourth and highest level of SAMR is redefinition. Students engage in creative and collaborative tasks that would be impossible to accomplish without technology. They demonstrate greater autonomy in gathering information, using Web 2.0, and devising creative ways to use more than one technology tool for meaning making and product creation. At this level, student projects may be described as a sequence or process of using several applications to create unique products such as simulations and animated clips in the final product. They may build upon an existing product and modify or repurpose it to fit a new need. At this level, students use existing technology tools in highly creative ways and may share their presentations with students in other parts of the world demonstrating advanced forms of collaboration and communication.

The pros and cons of using the SAMR model have been debated in the literature. Theisen, (2013) President of the American Council on the Teaching of Foreign Language supported teachers using SAMR as a tool for judging technology integration in learning designs that support the development of 21st century skills and HOTS. Kirkland (2014) supported the use of SAMR is a tool that teachers can use to evaluate the depth and complexity of technology use. Hilton (2016) found the SAMR model useful for judging the rigor of students' technology used in a case study with middle school teachers. Hilton applied SAMR (Puentedura, 2010) and TPACK (Koehler & Mishra, 2009) models to examine iPad technology integration in two eighth-grade social studies classes over one year. TPACK was a well-known model in teacher education for understanding the interaction of three types of knowledge teachers implemented in the learning environment including technological, pedagogical, and content. The two veteran teachers in this study agreed that the SAMR model helped them focus on student use of technology in constructivist learning and they found the TPACK model to be more useful for examining the teacher's use of technology. Cherner and Smith (2017) claimed the TPACK model was not detailed enough and advocated for revision. For example, they asserted that the technological knowledge (TK) definition in Koehler and Mishra's (2009) TPACK simply focused upon knowing *when* and *where* to use new technologies but failed to describe *how* technology was used and for what purpose. Cherner and Smith

(2017) also advocated that TPACK model needed be reframed to include new technologies and related pedagogies that have evolved since 2009 and that content knowledge (CK) should be replaced with contextual knowledge. The researchers clarified that such a reconceptualization would put students at the center of learning and promote the development of 21st century skills needed for college and career readiness. To this end, Cherner and Smith asserted that this recommendation for change "respects the contextual factors that define the student" (p. 345). They suggested that a revised TPACK could be used with SAMR as a tool for understanding how technology was used and to assess levels of integration. Hilton (2016) reported that teachers aligned the lower two levels of SAMR with content acquisition activities and the upper with activities related to applying practical social studies skills. Cherner and Smith (2017) took this thinking a step further and provided a graphical representation of the four levels of SAMR with the first two levels labeled as "Lower Order Thinking" and the upper two levels labeled as "Higher Order Thinking" (p. 342). On the other hand, Puentedura (2013 May 29) labeled the lower two levels as enhancement and the upper levels as transformative. Hence, Puentedura associated project enhancement using technology as lower ordered thinking and technology used to innovatively transform projects with higher order thinking. Puentedura was an invited speaker at conferences around the world and began posting as many as five slide presentations per month in his hippasus.com archives. He began applying SAMR to many learning and thinking models such as RBT and TPACK (Puentedura, 2014) and his booming social media presence drew both admiration and alarm.

As an internationally recognized expert in instructional technology and library media, Green (2014) was skeptical of the SAMR model and asserted that school librarians increasingly serve as instructional media leaders who influence how technology is used and for what educational purpose. Green warned that in this role librarians must be vigilant to assess the educational value of technology integration from a pedagogical perspective that will guide technology-enabled learning rather than promoting technology tools for the sake of increasing technology use in their buildings. Green noted that the SAMR model was rapidly adopted by teachers as a simple and intuitive method of assessing levels of rigor in technology use. Green questioned the validity of the SAMR model as well as the credentials of Ruben Puentedura who developed SAMR and began sharing it via social media in 2006 rather than through established scholarly processes. Hamilton et al. (2016) also expressed concern over the soaring popularity of the SAMR model for selecting and evaluating technology tools among K-12 practitioners despite the lack of available research.

Criticisms of SAMR in the recent literature were like Bloom's (1956) taxonomy regarding hierarchical structure and assessment ambiguity. First, Hilton (2016) warned that the SAMR hierarchy could be misinterpreted by teachers who focus on levels 3 and 4 to promote high-level technology-infused activities and disregard the lower levels of use. Hamilton et al. (2016) agreed and asserted that targeting only the higher levels of SAMR conflicts with best practices. Cherner and Smith (2017) clarified this point by stating that in order for students to be able to locate information quickly and analyze it for meaningful incorporation in tasks, they "must be proficient along all of SAMR's levels" (p. 344). The hierarchical structure of Bloom's (1956) taxonomy was criticized for similar reasons; therefore, Anderson and Krathwohl (2001) emphasized that learning objectives using RBT should be balanced and tracked to promote skill development at all levels. Secondly, Green (2014) found the SAMR model to be oversimplified and ambiguous. Green argued that placing apps or technology tools in a taxonomic hierarchy is meaningless because tools could be placed in several categories depending upon how they are used. Similarly, using Bloom’s (1956) taxonomy of cognitive objectives, a single verb describing a student activity could be placed at multiple levels of the taxonomy and thus, cause ambiguity. It was for this reason that Anderson and Krathwohl (2001) recommended a two-dimensional RBT method to situate learning objectives and activities in context using the four knowledge levels and the cognitive activity verbs. Green (2014) expressed concern that without careful guidance, teachers will confuse technology integration with technology-enabled learning. She criticized colorful graphics shared via social media that aligned technology with SAMR levels and argued that this encourages teachers to focus upon technology rather than pedagogy. Green included a graphic that showed aligned iPad applications, SAMR levels, activities, and action verbs displayed graphically on a colorful wheel and claimed it was “a prime example” of promoting technology tools (Green, 2014, p. 42). The graphic was a version of Allan Carrington’s (2016) Padagogy Wheel that has been translated into many languages and circulated worldwide. The former leader for the International Society for Technology in Education, Matt Harris, expressed a different view of the Padagogy Wheel on Carrington’s blog. Harris praised the wheel in his statement, “This connection of theory, practice, and application makes the Padagogy Wheel an invaluable resource that should be on the wall of every classroom” (https:// designingoutcomes.com). Perhaps the rapid changes that technology brings to education cause some experts to fear misuse while others have more faith that teachers will use technology for learning.

Two articles illuminated issues related to the SAMR model as a hierarchy of tools for changing products rather than as a model to guide technology integration from a pedagogical perspective focused upon learners. Hamilton et al. (2016) argued that the SAMR model emphasized technology tools and the production of products rather than dynamic learning processes using technology tools. Hamilton et al. posited that to understand levels of rigor and purposeful use of technology, it must be couched within the learning context and the teacher's instructional design. Cherner and Smith (2017) suggested that SAMR would be more useful if it were used with a revised version of TPACK that could add learning context to technology uses and shift the focus from tools to the students, their needs, how they used tools for learning, and progress toward mastery of 21st century skills. Despite these concerns in the articles I reviewed, scholars generally agreed that SAMR was useful but the dynamic and complex nature of learning with technology should be kept at the forefront, and revision or expansion to include context was recommended.

To summarize the relationship between PBL and HOTS, several strategies related to assessing specific aspects of PBL and HOTS were described in the literature such as using rubrics, rating forms, and checklists. Most of these assessment tools were specific to one context and were not suitable for application in other contexts. In several cases, this led researchers to conclude that teachers were uncomfortable assessing skills in PBL. Studies in the literature indicated that teachers recognized when HOTS were applied in PBL and when they were not; yet documenting this and tracking the development of

HOTS was challenging. Because PBL is such a complex learning strategy and teachers struggled with PBL assessment, researchers often concluded that new PBL assessment strategies were needed. From the literature review, it appeared that a comprehensive yet adaptable strategy to assess HOTS in PBL was lacking. Because PBL was used in studies from elementary school to adult education, with students who have learning challenges to the intellectually gifted, and in every content subject from music to engineering, a strategy for assessing PBL and HOTS should be meaningful as well as adaptable for use in any context. This is an important yet complex gap. If teachers and students are to feel confident using PBL to develop HOTS, a comprehensive method for assessing these skills was needed. The literature provided clues for how such an assessment could be constructed to bridge theory and practice. PB-LIFTS conceptual framework I developed for this study might make an important contribution to the field by providing students and teachers with a method for identifying and assessing current levels of HOTS in PBL as well as descriptions of the next level that might be used for goal setting. While researchers frequently described student autonomy and self-regulation skills in recent literature, a gap existed regarding how this could be identified and measured by examining pedagogical strategies.

The last section of the literature review addressed pedagogy in classrooms with DHH students and begins with a definition of pedagogy followed by the history of deaf education. Next, connections between the history of deaf education and current issues in deaf education pedagogy were addressed. This might contribute to understanding and interpreting teachers' descriptions expressed during interviews for the study. The section ends with the recent literature related to PBL and DHH students.

Pedagogy in Classrooms with Deaf and Hard of Hearing Students

Pedagogy is a complex concept that is not easily defined as multiple meanings for this term have evolved within a variety of contexts. Moreover, definitions of pedagogy have been shaped by social, economic, and political values of stakeholders, policymakers, and practitioners. To understand key elements of pedagogy that can be applied in this study, a review of several broad definitions of this term were helpful. Watkins and Mortimore (1999) provided a simple theoretical definition of pedagogy as "any conscious activity by one person designed to enhance the learning of another" (p. 3). The Merriam-Webster online dictionary provided a more scholarly perspective of pedagogy defining it as "the art, science, and profession of teaching" (Merriam-Webster, 2018). Dictionary.com included teaching strategy or what educators do by defining pedagogy as the "function or work of a teacher; instructional methods" (Dictionary.com, n.d.). Nind, Rix, Sheehy, and Simmons (2013) claimed that in practice, instructional pedagogy and curriculum were inseparable; therefore, what was taught was integral to the concept of pedagogy. McAuliffe and Winter (2013) accentuated power relationships in their description of pedagogy by asserting that the teacher controlled and determined how, what, when, and where learning took place. Embedded within the construct of power relationships lie the teacher's beliefs regarding the capabilities of the students and the purpose of their work. These beliefs in turn influence expectations, approaches, and instructional outcomes. Taken together, all of these elements associated with the concept of pedagogy could be identified across the evolution of deaf education from its humble beginning over 200 years ago in Hartford, Connecticut with a deaf child named Alice to the fragmented, emotionally charged, and highly political array of programs and practitioners presently serving DHH students in the United States.

Historical Underpinnings of Deaf Education Pedagogy

To understand pedagogical approaches presently used in classrooms with DHH students, it was helpful to understand deaf education pedagogy from a historical perspective. To support this assertion, Thomas Hehir (2002), former Director of the Office of Special Education Programs in the U.S. Department of Education described the case of deaf education as the most vivid scenario where competing philosophies, pedagogical approaches, and discriminatory practices have historically played out. Deaf education in the United States is the oldest branch of special education (Holcomb, 2013; Marlatt, 2014); and from its beginning, primary source documents dating back to 1816 have been preserved providing a rich body of literature for a pedagogical inquiry. *American Annals of the Deaf and Dumb* began publication in 1847 and continues presently as *American Annals of the Deaf*. This journal provided access to a wealth of information such as legislative actions, reports, presentations, debates, and papers shared among educators and administrators serving the deaf in addition proceedings of deaf adult organizations. As active stakeholders, deaf adults have always demonstrated a sense of responsibility for the education of deaf youth through organized activities. In sum, philosophical drivers that have influenced pedagogical change over time could be traced using resources that are now available in digital archives. This portion of the literature review was pursued with an eye for the evolution of pedagogy in deaf education in the United States with two main purposes in mind. First, I hoped awareness of the early years of deaf education would lead to a deeper understanding of current pedagogical practices in classrooms with DHH students; secondly, I hoped these insights would enhance my knowledge of deaf education pedagogy and support the accurate interpretation of teacher interview data for the study.

The early years of deaf education in the United States. In 1817, the first public school for the deaf in the United States was established in Hartford Connecticut with funding secured by Mason Fitch Cogswell, the father of Alice Cogswell who became deaf at the age of two from "the spotted fever" (Clerc, Gallaudet, & Wainwright, 1818, p. 128). Formal instruction began at "The Connecticut Asylum, for the education and instruction of deaf and dumb persons" on April 15, 1817, with seven students and by December of that year enrollment increased to 31 students (p. 130). The principal of the school was Thomas Hopkins Gallaudet, a Hartford clergyman, and the head instructor was a deaf teacher of the deaf named Laurent Clerc from France. Prior to establishing the asylum, Cogswell sent Gallaudet to Europe in search of a method of instruction to implement at the new school.

In the early 19th century there were three dominant European approaches used to teach the deaf referred to as the French, German, and English methods (Fay, 1893; Turner, 1847). The French system used the natural language of signs and a one-handed alphabet for fingerspelling which served as a bridge to written language. Although students were taught basic content such as the rules of grammar, the primary emphasis was placed upon using sign language as a tool for intellectual development through engagement in philosophical discourse and inquiry (Clerc et al., 1818). The French system accepted deaf individuals as mutes and did not require that they learn to speak. Contrary to this, the German system used a strictly oral approach. Instruction was conducted via teachers speaking directly to students at eye level while students received training in articulation with the goal of learning to speak and read lips in addition to reading and writing. Teaching students to move articulators properly to produce desired sounds required significant therapy following a daily regimen of sequenced drills typically in one-on-one settings. The German system was an attempt to assimilate the deaf into the dominant hearing culture of society; further, students would appear to communicate in the same manner as hearing individuals. Last, the English system was a more flexible approach incorporating elements from both the French and German systems. The English method emphasized written language and incorporated a two-handed alphabet with the use of signs for instruction. Students were also taught articulation with the hope that they would one day communicate orally. Thus, sign language was used to train students to communicate orally (Fay, 1893; Turner, 1847).

While in Europe, Gallaudet visited English and Scottish asylums for the deaf but was not permitted to observe their methods of instruction. However, he was welcomed at the Royal Institution for the deaf and dumb in Paris France where he observed Laurent Clerc and others working with students using sign language (Clerc et al., 1818, p.129). Gallaudet was particularly impressed with Clerc's teaching skills and was able to convince Clerc to come to America and help him establish the school in Hartford. On the voyage across the Atlantic together, Gallaudet immersed himself in learning sign language from Clerc, and in return, Gallaudet helped Clerc practice writing in English using a journal. As a master teacher, sign language model, and instructional leader of the school, Clerc instituted the French method which he learned as a student at the institution in Paris (Clerc et al., 1818). Deaf-mutes easily acquired sign language skills for communication and having witnessed the transformative impact, Gallaudet declared signing to be the natural language of the deaf (Gallaudet, 1847).

For this literature review, I was able to access only a few articles in English that Clerc wrote; however, they were content rich as Clerc conveyed his pedagogical approach, attitude toward speech training, and beliefs about deaf learners. One article consisted of a series of three letters in which Gallaudet and Clerc responded to a request for information from Mr. Wainwright, a local minister, who needed information to share for philanthropic activities. In the article titled "Intelligence and Remarks" Clerc described his adapted French method of language instruction in detail (Clerc et al., 1818). When beginning with uneducated deaf-mutes Clerc stressed that the first step is to find out what they already know to make an immediate connection and gain their interest. To do this, he used pantomime, gestures, pictures, or any tool to support understanding and began vocabulary building using conventional signs. He generated curiosity to pique their interest in adding knowledge and raising new questions. Thus, he moved from the known to the unknown and incorporated vocabulary using the natural language of signs which he contended was the fastest method for deaf-mutes to acquire language to communicate ideas and start learning. Clerc acknowledged that his students were intelligent individuals who were simply deprived of language and education prior to enrolling at the school. He thought highly of his students as eager learners in his statement,

> I have the pleasure to inform Mr. Wainwright that the deaf and dumb in this country have very good natural talents, and a great facility and unusual ardour in learning, and an intensity of application which we have rather to moderate than to excite. (p. 135)

Clerc et al. (1818) described how he built vocabulary through interaction with the environment and taught simple grammatical structures using writing such as agent-action and parts of speech. He moved from the concrete to abstract by introducing the verb to-be and used adjectives for describing things based upon students' judgments. He engaged them in critical thinking through comparing, categorizing, and reflection. Clerc encouraged students to express their thoughts and feelings as this supported the concept that they have a soul and a consciousness that directs their will for thoughts and actions. Clerc and his students explored the marvels of nature and through observations, they gained conceptual understandings, such as how the sun and the "celestial bodies" are organized. Eventually, through signed dialog with his students they explored questions regarding spirituality and religion. Turner (1870) stated that Clerc sometimes led catechetical discussions with the whole school and Ray (1847) described some of the questions posed by students in the advanced class concerning abstract topics such as the origin of evil, how God created himself, and the purpose of self-existence. Fay (1893) described the heavy emphasis on intellectual development using Clerc's method in the following statement, "By the French method, attention is exclusively given to the improvement of the mind of the pupil and extending his mental conceptions to the highest degree of expansion and communication by signs as well as by writing" (p. 6).

Clerc et al. (1818) expressed negative attitudes toward teaching speech to deaf-mutes. He considered this training to be a poor use of time to produce "artificial speech" that was "almost always painful, harsh, discordant and comparatively useless" (p. 133). He added that the sense of hearing was needed to modulate speech. He argued that the utterances deaf-mutes produced lacked the expressiveness and speed of sign language or the “precision of writing” (p. 133). Clerc argued that speech training deprived students of learning other subjects as these classes left time for little else. His view of articulation instruction was not positive perhaps from his own experiences. As a 12-year-old at the Royal Institution in Paris, Clerc was forced to attend speech classes after school with an assistant teacher named Abbe Margaron. Clerc was unable to produce the sounds “*taaa, daaa, teee, deee*,” Margaron became so impatient, “he gave me a violent blow on the chin; I bit my tongue and dissolved in tears . . . From that day I never spoke again” (Clerc, 1851/2000, p. 24).

A key component of Clerc’s pedagogical approach was that he believed his students were intellectually capable although uneducated when they arrived at the school. In Clerc’s opinion, false beliefs about deaf-mutes were the true handicap, not deafness. Clerc made his students aware that he respected their thoughts and feelings. This sense of being capable and worthwhile was new to these students who lived in a society that pitied them and believed they were imbeciles incapable of reasoning. According to Peet (1851) this belief had been handed down for centuries from Aristotle who condemned the deaf to “irremediable ignorance and degradation” in a world convinced that without speech there was no language and without language, the deaf were more like animals than human beings; therefore, they could not be educated. The ancients believed that “the ear was the principal organ of communication and of instruction; and articulated words, the instruments of thought.” (p. 17). Deaf scholars have connected this line of reasoning with the modern-day concept of audism, a belief system that poses barriers affecting every domain of human experience for deaf individuals living in a hearing society. Bauman (2004) provided the following definition, “Audism is the notion that one is superior based on one's ability to hear or behave in the manner of one who hears" (p. 240). Stapleton (2016) studied audism and racism at the college level and concluded that a hidden curriculum exists in the behaviors of instructors that marginalize groups of students. Stapleton calls these microaggressions that are embedded in classroom dynamics and asserted that this "pedagogy must be transformed" (p. 163).

Under Clerc's guidance, deaf education in America flourished during the first 50 years. By 1855 Clerc's method of instruction was adopted in 16 new state schools for the deaf (Jones, 1918). Exhibiting the work of deaf students before state legislatures was an "effective method of spreading the gospel of education" for the deaf (p. 6). Jones noted that Clerc was skilled at appealing to Christian values for charitable support and stated that Clerc "perhaps did more to influence the growth of the schools for the deaf in this country than any other man except Gallaudet" (Jones, 1918, p. 12). Clerc's students from the first school for the deaf in Hartford (later named the American School for the Deaf) became members of the teaching force employed in the new schools. By 1870 "forty-two and a half percent" of the faculty in deaf schools were deaf themselves (p.12). The first fifty years after the American School was founded is a period in history revered in deaf culture as the "Golden Age" (Ladd, 2003). As a respected deaf anthropologist, Ladd expanded that deaf people are fascinated with this period of history when deaf people were respected as capable members of society. For example, during this time deaf people were noted as educators and trade workers who were competitively employed and provided for their families. Students from the residential schools competed against the hearing students in athletics, music, and military drills. Through an act of congress signed by President Abraham Lincoln in 1864, the National Deaf-Mute College (later named

Gallaudet College) opened in Washington, DC (Krentz, 2000, p. 212). Deaf individuals were trained for a variety of careers and the college opened the door for deaf scholars.

With regard to pedagogy, it is important to mention that the first school for deaf in Hartford emphasized religious training, and when new state schools opened, deaf individuals were recruited from the American School to serve as superintendents; hence, schools for the deaf in America in the first half of the 19th century had "a strong religious atmosphere" and deaf administrators (Jones, 1918, p.11). The schools for the deaf in America also offered vocational training to prepare older students for employment. Reports published in *American Annals of the Deaf* indicated that beyond communication and literacy skills, curricular offerings expanded, and deaf students engaged in competing with students from hearing schools and graduates of the deaf schools entered a variety of occupations where they were able to earn respect as contributing members of society. Clerc brought the French-based language of signs to America and to this day Clerc is praised and honored by deaf organizations, educational programs, and deaf studies. Beyond Clerc's contribution to the development and adoption of ASL, the literature review revealed that Clerc had a tremendous influence on pedagogy that was adopted in deaf schools all over America in the 1800s. Clerc was a strong advocate of ASL (then called the sign language) as the language of instruction and English was used to read and write. As a result of Clerc's bilingual pedagogical approach, deaf people were able to demonstrate their potential and be viewed as intelligent and capable individuals. This was exemplified in an 1818 quote posted on the website for the American School for the Deaf (https://www.asd-1817.org/about/asd-history); Governor Oliver Wolcott encouraged the public to support education for the deaf to aid…

> in elevating the condition of a class of mankind, who have been heretofore considered as incapable of mental improvement, but who are now found to be susceptible of instruction in the various arts and sciences, and of extensive attainments in moral and religious truth (para. 12).

Forces of change in deaf education. In the second half of the 19th century America not only struggled with the impact of the Civil War and the coming of the industrial age but controversies that had been ongoing beneath the surface since 1817 suddenly erupted in public forms impacting deaf education pedagogy. In the 100-year review by Jones (1918) topics that contributed to pedagogical change and the eventual catharsis were identified such as religious training, vocational education, academic progress, new forms of signs, differing needs of semi-mutes and semi-deaf students, articulation training, communication philosophies, and new schools with opposing instructional approaches. Jones (1918) noted that instructional emphasis shifted away from religious training and vocational training was added. Jones stated that they "laid less emphasis upon soul saving and more upon academic and industrial attainments". Further, Jones noted that "references to God, benevolence, and charity" shifted to "moral and utilitarian training. Fewer ministers of the gospel have been invited into the work either as teachers or superintendents. These are coming more and more from the field of teaching" (p. 11). Perhaps this shift signaled that deaf education was an emerging profession. Also, during this period state schools for the deaf continued to be added as they had in the past, but curricular choices became increasingly diverse. Jones (1918) synthesized from the state school reports in the *Annals* that, "From this broader and richer training with its freedom for intellectual and physical expansion the pupils go out into the world to compete successfully with their hearing brothers in almost all vocations" (p. 24). By the turn of the century, a former Gallaudet professor who became the superintendent of the Indiana School estimated that deaf graduates were employed in 300 different occupations such as farming, agriculture, woodworking, bookbinding, shoemaking, tailoring, and building trades. Some of these trades were not taught at the schools which could indicate that these workers were adaptable, and their training was transferrable.

During the second half of the 19th century, changes in communication methodology appeared regarding teaching speech, and methodical signs were also appearing. New forms of signs were invented for the purpose of improving students' English grammar. There were significant debates regarding methodical signs and their utility. Fay (1869) claimed that the students graduating from the institutions for the deaf and dumb had poor literacy skills in both reading and writing and stated, "We are none of us satisfied with the attainments in language ordinarily made by the deaf and dumb" (p. 194). Peet (1870) theorized that the perceived decline in academic outcomes may have been due to the excessive use of simplified textbooks such as those listed by Hutton (1869) and secondly, Peet posited that the field was no longer novel and perhaps the early pioneers were more highly motivated. Peet also reflected on the impact of the Civil War on the teaching force in deaf schools. Many speaking and hearing teachers were lost during the war and afterward school budgets were too strained to hire educated teachers. Thus, the teaching force was not as strong as it was in the first half of the 19th century.

During the 1860s, oral education and articulation training became increasingly popular in American deaf education and two competing pedagogical approaches emerged. Oral schools were established using Alexander Graham Bell's visible speech system, and a pedagogical shift was felt in state residential schools. Jones (1918) summarized that “the silent method” meaning the communication method adopted at the American School under Clerc “was the prevailing method in all of the schools until 1867 when articulation was added” (p. 13); however, through the literature review it was apparent that the emergence of oralism was not an event, rather, it was a growing philosophical position present from the beginning. Jones contended that teachers had always widely differed regarding the oral versus manual debate since Gallaudet chose the manual method at the American School (Power & Leigh, 2000) and key documents by Gillet (1870) and Fay (1869) supported this assertion. Therefore, it can be argued that even during the golden age of deaf education, controversy existed but it was not officially recognized until two oral schools in Massachusetts and one in New York opened. Oral educators declared that the silent method did not serve the needs of “semi-mutes and semi-deaf pupils” well (Jones, 1918, p. 15).

Although oral education strategies had been steadily gaining popularity in the United States since the founding of the American School, the Milan Convention of 1880 in Italy was a turning point in the education of the deaf. Five Americans were present and one of them was James Denison, the only deaf participant in the entire conference. The resolutions passed there against the objections of the American delegates denounced the use of sign language proclaiming,

> … the incontestable superiority of speech over signs, (1) for restoring deaf-mutes to social life, (2) for giving them greater facility of language, declares that the method of articulation should have the preference over that of signs in the instruction and education of the deaf and dumb. (Jones, 1918, pp. 5-6)

Following the convention, deaf teachers lost their jobs and the sting of the resolutions passed in 1880 is still felt today (Ladd, 2003; Lane, 1993; Van Cleve & Crouch, 1989; Winzer, 1993). Jones (1918) provided statistics regarding the shift to oralism that he synthesized from data in the *Annals*. In 1887 a total of 8,051 deaf students attended school in the United States and 31% of them were oral. By 1917 there were 14,309 deaf students and 75% of them were taught orally. With the increase in oral instruction, the number of deaf teachers of the deaf declined from 42% percent in 1870 to 14% in 1917 (Jones, 1918, p.12). This shift had a devastating impact on the deaf community. The National Association of the Deaf was founded for the preservation of sign language and still exists. Gallaudet College became a mecca for deaf culture and sign language. The President of Gallaudet College, E.M. Gallaudet, the son of Thomas Hopkins Gallaudet emerged as the leader supporting sign language use in deaf education and Alexander Graham Bell, led the oralist movement (Winzer, 1993). According to Longmore (1987) "…this was a clash among hearing professionals for control of deaf education" (p. 357).

Following the Milan convention, questions arose regarding the diversity within the deaf population and whether they should be separated in different facilities instead of mixing two distinctly different pedagogical approaches. Storrs (1883) proposed that deaf-mutes were not an 'absolute' disability group; rather, subgroups existed under that umbrella with diverse abilities, endowments, and propensities for speech and auditory language. Storrs argued that educating all of them together in institutions using the silent method did not meet the educational needs of approximately two-thirds of those students. Storrs estimated that approximately one-third of the students were profoundly deaf from birth which he called *real deaf-mutes* (p. 29) and the others were hard of hearing or late deafened and could benefit from oral education in a different facility using an oral approach. He called them *virtual hearing pupils* and suggested that these students should be removed from institutions that used the silent method (p. 29).

In response to the pressure to provide articulation instruction, many of the traditional state institutions adopted a new pedagogical approach called the *combined system* where speech training occurred “by short periods of special training at intervals during the school-day stolen from the pupil’s regular instruction” (Storrs, 1883, p. 28). The combined system had some resemblance of the English method attempting to take elements of pedagogy from both the French and German methods. Much to the dismay of the proponents of the manual method, E.M. Gallaudet supported using the combined system and adding articulation.

As a strong advocate of the oral method, Bell used his wealth from the invention of the telephone to promote his pedagogical approach. To provide insight regarding the difference between the manual and oral instructional methods, the contrast can be seen between Clerc’s description of his method provided earlier in his letter to Mr. Wainright (Clerc et al., 1818) and the following description from Bell (1883) in which he explained how he weaned a 5-year-old boy named George from using gestures and communicated with him directly through speech and writing. Bell described the general principles of his approach as having two parts, the first focused upon articulation and the second on mental development through writing. Objects in the therapy room were labeled with the written word for each such as doll and window. Bell kept a card rack of about 200 words written in script on cards. He stated that the method of articulation instruction was explained in depth in *American Annals of the Deaf* January 1872 and summarized,

> The general principle is this: The pronunciation of words and sentences is not to be attempted until the vocal organs have been well drilled on elementary sounds and exercises. While, then, the mouth is being brought under control using visible speech symbols, the mind is to be educated by ordinary letters. The pupil must learn to read and write. (Bell, 1883, p. 126)

To promote oralism in the United States, Bell formed the American Association to Promote the Teaching of Speech to the Deaf in 1881 and published *Association Review*, a journal dedicated to dissemination of literature pertaining to the oral method founded in 1887 “for the increase and diffusion of knowledge relating to the deaf” (Deland, 1912, p. 1). This journal was renamed *Volta Review* and still exists today.

Although Storrs (1883) asserted that sign language was unfairly criticized by pro-oralists at the Milan Convention, he nonetheless supported speech and articulation for most students with hearing loss. The highly structured oral pedagogy Storrs (1883) suggested for the virtual hearing pupils contrasted sharply with Clerc’s pedagogical approach using the natural language of signs to encourage curiosity and an internal desire to learn about authentic topics through social interaction (Clerc et al., 1818). The oral and manual methods contrasted with regards to *what* is to be learned and *how*. Clerc’s method was comparable to student-centered constructivist pedagogical approaches used in modern times and the oral method with its highly structured routines was like teacher-centered behaviorist pedagogy. According to Bell’s (1883) description, the primary goal of education was to teach students to speak and developing their knowledge base came later. Clerc's goal was to maximize time for learning as the state-supported each deaf student for a limited period. Clerc believed that active engagement in learning through inquiry was the fastest way to acquire language and use knowledge in authentic ways; therefore, he was opposed to the time-consuming practice of articulation instruction that did not increase student's conceptual knowledge about the world. Clerc believed deaf people should be accepted as deaf and let them have a cultural identity from which to grow intellectually. Winzer (1993) documented the many ways that the deaf were disrespected and treated as second class citizens in the 19th century despite the progress that was made under Clerc's leadership. The outcome of the Milan conference in 1880 reinforced the belief that deaf people could not trust the hearing. Moores (2017) posited that oralism dominated deaf education in the United States from 1880 to the 1960s and referred to this time as *the dark age* (p. 40). Most K-12 schools were limited to oral communication only, but some schools permitted signs at the high school level for vocational education. Tensions between proponents of the two communication modes and associated pedagogies continued to clash and many parallels can be drawn between deaf education in the 21st century and the 19th century although the complexities of the issues grew exponentially.

Deaf Education in Modern Times

By the second decade of the 21st century, many new variables added to conflicts and misconceptions further polarizing proponents of oral versus manual communication methods. Modern education for DHH students was impacted by new technologies such as newborn neonatal screening, cochlear implants and legislation impacting educational placements, types of programs, service delivery, communication modes, and pedagogical strategies (Marschark et al., 2015), as well as specialized licensing requirements (Sindelar, Fisher, & Myers, 2018), and mounting shortages of teachers of the deaf (Johnson, 2013; Rock et al., 2016). With so many variables and associated professionals to navigate, parents are often overwhelmed with the ever-changing web of information, choices, and beliefs about deaf children. Studies indicated that parents of deaf children wanted control over placement and communication mode decisions; they also hoped to forge partnerships with skilled and resourceful teachers of the deaf who would respect their choices and help build promising futures for their children (Chang, 2017; Lalvani, 2015; Matthijs et al., 2017). As deaf education in the 21st century unfolded, the literature review revealed a long history of general failure on both sides of the debate; to make matters worse, teachers of the deaf were trained in programs that did not adequately prepare them for many of the learning environments where they were hired as a teacher of the deaf (Luckner & Ayantoye, 2013). Moreover, it was found that the practices teachers of the deaf were trained to use lacked a strong research base (Beal-Alvarez & Cannon, 2014; Luckner, Sebald, Cooney, Young, & Muir, 2005). The literature also indicated possible misconceptions about the DHH student population and learning needs at the policy level. For example, in 45 states teachers of the deaf hold one of the few remaining categorical licenses in special education due to the *homogeneity* of the DHH student population (Sindelar et al., 2018); yet in reality, DHH students were highly heterogeneous (Crowe et al., 2017). In sum, deaf education is a field rife with conflict and policies driven by beliefs and perceptions rather than empirical evidence.

For many years deaf education evolved as a somewhat exclusive branch with advocates of two approaches maintaining separate scholarly journals, teacher training programs, and professional conferences steering oral and manual pedagogical practices. Despite relentless efforts from both oral and manual educators, learning outcomes overall academic achievement of the DHH student population has always lagged behind hearing peers (Antia et al., 2010; Jones, 2014; Marschark et al., 2015; Marschark et al., 2011; Power & Leigh, 2000; Qi & Mitchell, 2011). Moores (2017) asserted that historically, research in deaf education did not focus on academic subjects and deaf students did not have access to the same curricula as hearing students, but in the 20th century this began to change with the advent of mainstreaming. Although DHH students have shown that they *can* make academic gains comparable to hearing students (Bartlett, 2017; Convertino et al., 2009; Hrastinski & Wilbur, 2016; Marschark et al., 2011), they usually begin schooling with language and math delays (Pagliaro & Kritzer, 2013; Segers & Verhoeven, 2015) and are given standards-based criterion-referenced tests throughout schooling based upon average academic abilities of hearing students for each grade level (Moores, 2017). State-wide test scores for DHH students are generally poor and DHH students frequently graduate from high school unprepared for college or careers due to lags in psychosocial development (Hintermair, 2014), low achievement in core subjects (Nagle et al., 2016), and undeveloped 21st century skills (Kelly et al., 2016).

Medical and cultural models of disability. Literature published since the turn of the 21st century indicated that the oralists and the manualists still have polarized agendas like the first century of deaf education. When applied in modern education, these views are associated with the medical model and the cultural model of disability. Hehir (2002) referred to the medical model as *ableism*, the belief that non-disabled individuals are superior to individuals with disabilities. Abelism marginalized and oppresses people who have disabilities through negative attitudes, stereotypes, and beliefs (p. 4). Hehir described ableism as a pervasive system of discrimination that has been present in education for centuries and he stated that ableism may be partly responsible for low levels of achievement. Expectations of students with disabilities may be low and instructional practices that dwell on a child's weakness rather than strengths may limit their opportunities for learning (Marschark et al., 2011). Moores (2010) asserted that DHH students function differently from hearing students but "differences aren't deficiencies" (p. 452); however, low expectations can cause low performance. Stereotypes and false beliefs related to deafness marginalize DHH students, perpetuate low expectations, and produce unacceptable outcomes (Antia, Stinson, & Gaustad, 2002; Moores, 2017; Ormrod, 2014; Smith, 2013; Tucker, 2014). In the recent scholarly literature and a nationally distributed periodical for deaf educators, several examples of harmful assumptions about deaf learners were highlighted by the authors such as DHH students are concrete learners (Jones, 2014; Williams, 2014), who need a simplified, repetitive, and routine-based instructional approach (Pagliaro, 2015; Smith, 2013), and have limited ability to develop literacy skills (Power & Leigh, 2000). Teachers who harbor negative beliefs and biases regarding student abilities typically have low expectations of them as well. Babad (2016) researched the negative impact of low expectations on student outcomes and noted the occurrence of the Golem effect in classrooms. Named after a Jewish myth, the Golem effect is a psychological phenomenon that takes place in environments where low expectations of individuals lead to low-performance outcomes and examples of low expectations of DHH students were noted in recent studies by Smith (2013) and Salter et al. (2017). Thus, to some degree, social mechanisms may impact DHH student achievement; however, in the early 1980s deaf education was not the only branch under the U.S. Department of Education with dismal academic results.

National reform efforts. In 1983 the government report *A Nation at Risk* sounded an alarm and drew attention to the need for education reform (Gardner, 1983). A number of unacceptable outcomes of the American education system were outlined such as poor SAT scores, high rates of remedial courses in 4-year colleges, lack of higher order thinking, 23 million functionally illiterate adults, the United States falling behind other industrialized nations. This report triggered a flurry of reform efforts under the banner, “All, regardless of race or class or economic status, are entitled to a fair chance and to the tools for developing their individual powers of mind and spirit to the utmost.” (Gardner, 1983, para. 1). Since this time, several waves of educational reform have methodically chipped away at the insular nature of deaf education.

Early in the 21st century, national accountability requirements prompted critical reviews of research-based practices across all branches of education in the United States. Legislative action and initiatives impacting special education such as the Individuals with Disabilities Education Improvement Act (Madaus & Shaw, 2006), No Child Left Behind Act (Simpson, Lacava, & Sampson Graner, 2004), and Common Core Standards (Common Core State Standards Initiative, 2010) fueled the drive for evidence-based practices for all students. Scholars conducted reviews of deaf education studies and found that the research base was generally weak as quality studies were scarce (Beal-Alvarez & Cannon, 2014; Easterbrooks & Stephenson, 2006; Luckner et al., 2016; Luckner et al., 2005; Spencer & Marschark, 2010).

Evidence-based practices in deaf education. Deaf education scholars searched the literature for evidence-based practices using several approaches. Throughout history literacy development has always been an area of challenge for DHH students regardless of communication mode. With a significant body of research available, Luckner et al. (2005) reviewed 40 years of literacy research in deaf education and collected 964 studies. Unfortunately, these researchers were unable to identify evidence-based practices in literacy as only 2% of the studies satisfied the criteria for inclusion. Luckner and colleagues concluded that the paucity of quality research in deaf education indicated a longstanding gap between teaching practices and the evidence base to support them. Another common area of research in deaf education was technology use. Beal-Alvarez and Cannon (2014) investigated research on technology interventions used with DHH students from 2000 to 2013. These researchers were unable to identify evidence-based practices in technology use because none of the studies met the established research criteria. To assess the evidence-base for 20 practices recommended by the Association of College Educators-Deaf and Hard of Hearing, Easterbrooks and Stephenson (2006) examined studies across three content areas including literacy, math, and science. Only 30% of the practices were rated as having a strong body of evidence; the research base for the remaining 70% of the recommended practices was judged as weak, developing, conflicting, or minimal.

Spencer and Marschark (2010) conducted an international literature review to identify outcomes-based models of best practices in deaf education. They found that DHH students as a group had significant language delays across all communication modes and theorized that this was due to not having full access to auditory input or visual language. Spencer and Marschark found literature that supported of all the methods, modes, and models in deaf education but each one had gaps in the evidence base. For example, the literature on bilingual methods showed a strong theoretical base but studies focused primarily on bilingual methodology rather than student outcomes (Emmorey, Li, Petrich, & Gollan, 2019). Cued speech studies focused on selected aspects of language, but not overall language competency. Research on total communication revealed that often service providers were inconsistent or inaccurate in their use of the language coding system; yet like cued speech, some aspects of language learning were positive. Spencer and Marschark also determined that the available data on the auditory verbal therapy approach were inconclusive but that the existing research showed improvement for some targeted communication skills. Commenting on these findings, Spencer and Marschark (2010) stated, “For too long, practice in education of the deaf and hard-of-hearing students has been based more closely on beliefs and attitudes than on documented evidence from research or the outcomes of interventions” (p. 25). Other researchers questioned why there seemed to be such a heavy reliance on reporting beliefs, opinions, and perspectives in deaf education research and looked deeper.

Challenges of deaf education research. The challenges scholars encountered searching for evidence-based practices brought to light how difficult it is to design quality studies in deaf education. Researchers summarized that group experimental or quasi-experimental studies on effective programs and instructional strategies are complicated due to the low-incidence and highly heterogeneous nature of the deaf student population (J.E. Cannon et al., 2016). Further, DHH students are widely dispersed in a variety of placements and service delivery models. Gathering enough participants for randomized selection is time-consuming and can be costly. According to NCES (2017) DHH students age 3 to 21 served under the Individuals with Disabilities Education Act (IDEA) represented only 1% of the 6.7 million special education students in public schools (p. 110). Regarding DHH students and educational placements, NCES (2016) reported that 87.5% of all DHH students ages 6-21 who received services under IDEA attended regular public schools with hearing peers; however, service delivery and the amount of time spent in general education versus resource room or self-contained class varied significantly.

Marschark et al., (2015) described a range of variables that came into play and were difficult to control in deaf education studies. Researchers must consider participant characteristics such as type and degree of hearing loss, the age of onset, etiology, assistive listening devices, family support and demographics, mode of communication, and language use. In addition to these variables, Guardino, Cannon, and Eberst (2014) asserted that almost 25% of DHH students are English Language Learners (ELL) due to a language other than English spoken in the home and Guardino and Cannon (2015) documented a high rate of DHH students with secondary conditions. Securing funding for expensive studies on a small population is difficult to achieve; therefore, experts in deaf education research recommended that scholars consider case studies or single-case design for deaf education research that can build on previous studies (J. E. Cannon et al., 2016). Enns (2017) supported the use of case studies to investigate specific variables within the DHH population and asserted that this type of qualitative inquiry in deaf education "…can provide rigorous and powerful evidence" (p. 203). For this reason, Cawthon and Garberoglio (2017) provided a balance of quantitative and qualitative studies in their book on deaf education research to show applications of findings from experimental studies applied in practice with select program and learner characteristics.

Communication modes, placement types, and pedagogical orientations. Several factors can influence pedagogy in classrooms with DHH students such as parent decisions, functional hearing, communication modes, and educational settings. Ninety-five percent of DHH infants were born to hearing parents (Mitchell & Karchmer, 2004) who most often had much to learn and important decisions to make regarding communication mode and possible medical interventions while the child was in a critical period for language acquisition. Often parents made these important decisions without access to objective, unbiased and well-rounded information (Humphries et al., 2017; Moores, 2013) or without having ever met a deaf adult (Matthijs et al., 2017). Delaying decisions could cause the child to experience language deprivation (Allen & Morere, 2020; Cheng, Roth, Halgren, & Mayberry, 2019; Humphries et al., 2014); parents found themselves caught between proponents of oral versus manual methods (Washington, 2018, p.70) that could require time to sort out (Chang, 2017). In sum, whatever communication mode parents chose they found a range of possible placement options for schooling and this was usually determined by a combination of parents' philosophical beliefs about deafness, the child's communication mode or language, and available resources.

To study language and literacy development, Lederberg, Schick, and Spencer (2013) simplified the landscape of learning environments for DHH students into three models including spoken language, sign language, and simultaneous language. In a more recent literacy study, Luckner et al. (2016) examined studies of the three models of deaf education programming regarding hearing function, communication modes, and placements. Using the framework from Lederberg et al. (2013), Luckner et al. (2016) reviewed DHH literacy research from 1967 to 2013 by grouping services according to three main communication modes including oral methods, manual methods, and simultaneous methods to discover patterns of recommended literacy practices within each group. In oral programs students typically had some functional hearing and used assistive technology to access auditory language which might have included cochlear implants, hearing aids, infrared, and FM systems. Programs for oral students existed in a variety of settings from the mainstream, to a few residential schools and day programs as well as private schools. Enhancing listening and spoken language skills was an important pedagogical focus with oral students.

The second group identified by Luckner et al. (2016) was manual methods where students in these programs typically had limited functional hearing and used ASL as their native language and English was taught as a second language via reading and writing. Studies suggested that ELL instructional strategies should be used with DHH students whose second language was English (Howerton-Fox & Falk, 2019; Strassman, Marashian, & Memon, 2019). Linguists declared ASL as a bona fide language with all the key features such as grammar and syntax. Thus, ASL and written English were taught using a bilingual-bicultural approach and these programs were usually found in separate environments such as residential, day, and charter schools. In these programs, deaf culture and deaf studies were valued across the curriculum (Simms & Thumann, 2007). The third category identified by Luckner et al. (2016) was simultaneous communication methods or *total communication* where signs were used at the same time English words were spoken; signs were produced in English word order thus, many of the linguistic features of ASL were lost and both languages were compromised. Total communication programs were most often found in mainstream programs where both oral and signing students might be present in the same classroom and their functional hearing abilities might range from low to high.

Hearing function and evidence-based reading practices. The results of the Luckner et al. (2016) study of evidence-based literacy practices were found to be limited, similar to the Luckner et al. (2005) study; however, practices that supported the development of reading comprehension with regard to two groups of hearing abilities were deemed worthy of mention. Luckner et al. (2016) presented general literacy practices for students with functional hearing and students with limited functional hearing. He found that for both groups, effective instructional practices were reported in the literature. For students with functional hearing, research supported increasing auditory access to spoken language for the purpose of enhancing language acquisition and the ability to apply phonological cues for decoding text. Further, the research base supported teachers implementing interventions recommended by the National Reading Panel (2000) for hearing students.

For students with limited functional hearing, Luckner et al. (2016) found evidence in the literature supporting the use of fingerspelling to enhance decoding skills and the association of signs with printed words to enhance sight word recognition. Several effective reading strategies for both groups of DHH readers were listed; however, these were also effective with children who could hear. One difference might be that the strategies were taught more explicitly and with greater opportunities for DHH students to practice. For example, these strategies included elaborating on concepts and vocabulary through conversation, repeated readings, and teaching comprehension strategies through story structures, thinking skills, prior knowledge activation, vocabulary building, word attack, and use of computer programs for practice. Two recommended practices reversed past assumptions that DHH students must acquire language skills prior to teaching reading skills and that reading should be taught using controlled vocabulary and grammatically simplified text. Luckner et al. found evidence that teaching reading skills enhanced language development and DHH students should read high-interest materials that were not simplified. In sum, the drive to identify research-based practices revealed the influence of hearing ability on teachers' pedagogical approach to literacy instruction.

Service delivery and pedagogy. Types of placements and service delivery can impact pedagogical choices with DHH students, and both placement and services are addressed in each student's Individualized Education Program (IEP). As stated earlier, 87.5% of DHH students ages 6 to 21 years served under IDEA in the United States attended regular public schools; however, within mainstream environments, common service delivery models are center-based and itinerant. The differences between the two models are important because they can influence pedagogical strategies. In the center-based model, DHH students within a school district are transported to one school site for elementary, middle school, and high school. Center-based DHH students may receive direct instruction from a teacher of the deaf based at the school in self-contained classes or a resource room with other DHH students. In this model, DHH students also spend part of the day in general education classes with support from a teacher of the deaf as needed. In settings where there may be only one DHH student in the school, services are usually provided via the itinerant model where a traveling or itinerant teacher of the deaf provides direct services according to each student's IEP. These students usually spend much of their day in general education classes. Itinerant teachers of the deaf often take DHH students out of classes to work with them, but they can also serve DHH students in general education classes. These are called pull-out and push-in services.

The National Center for Education Statistics (NCES) reports the total amount of time students with disabilities spend in the general education environment and the information is disaggregated by disability category (https//nces.ed.gov). Therefore, data indicating the amount of time DHH students spend in the regular room with hearing students can be identified; however, NCES does not differentiate between center-based or itinerant services. NCES (2016) reported the percentage distribution of DHH students in three subdivisions of time spent in general education during the school day:

- 59.3% of DHH students were in general education 80% or more.
- 16.0% of DHH students were in general education 40-79% of the time.
- 12.0% of DHH students were in general education 40% or less of the time.

Marschark et al. (2011) asserted that DHH students served in mainstream environments have steadily increased in the United States for over a quarter of a century, yet research findings showed minimal variability (1 to 5%) in academic achievement across placements (p. 4). NCES (2016) also reported that 10.8 percent of all DHH students served under IDEA attended separate schools for students with disabilities and of that number only 3.1 percent were in residential schools. Prior to the passage of the Education for all Handicapped Children Act of 1975, the vast majority of DHH students were educated in separate facilities for students with disabilities and residential schools for the deaf (Nagle et al., 2016). Due to the increase in DHH students being mainstreamed, residential schools have faced declining enrollments and some school closures (Marlatt, 2014; Moores, 2010). Most of these schools have been in operation since the 1800s and with rich social traditions, they have been the center of ASL use and deaf culture (Reagan, 2018). With the decrease in residential school enrollments research indicates a sharp increase in itinerant services to students attending their neighborhood schools (Antia & Rivera, 2016; Johnson, 2013; Luckner & Ayantoye, 2013; Luckner & Dorn, 2017). Spencer and Marschark (2010) recognized the trends in placements and service delivery to DHH students and contended that research on the academic and social outcomes for DHH students in any of the placements was quite limited.

Luckner and Ayantoye (2013) asserted that best practices on itinerant teaching with DHH students were not available and with the suspected growth of this model, research was needed. Barbara Raimondo, Esq., a well-known attorney in deaf education and national advocate for deaf children stated in her blog that, “There is no evidence that placing a student in a local neighborhood school rather than a specialized program or school results in better outcomes” and expressed concern that it would be difficult to track progress of students receiving itinerant services in her statement, “States and districts generally do not disaggregate data based on disability category, so it is not possible to compare the achievement of students with similar characteristics who are placed in different settings” (Raimondo, 2014, para. 1). Luckner and Dorn (2017) conducted a national study surveying 495 teachers of the deaf and the demographic information indicated that the itinerant model was in fact widespread. Forty-one percent of the teachers of the deaf identified themselves as itinerant and they represented the largest group of all teachers of the deaf that responded.

Although empirical studies on the itinerant service delivery model for DHH students are limited, several recent studies could be used to gain an understanding of pedagogy used in these placements with DHH students. In 2013, Luckner and Ayantoye surveyed 365 itinerant teachers of the deaf across the United States to learn more about their preparation, practices, and perceptions using a mixed method design. Similarly, Rabinsky (2013) conducted a small case study of itinerant teachers to discover the perceived advantages and disadvantages of this model. Following these, several other mixed method studies investigated the itinerant model regarding teacher’s attitudes and beliefs on social-emotional learning (Norman & Jamieson, 2015); the nature of itinerant services and decision making processes (Antia & Rivera, 2016); job satisfaction and concerns across subsets of teachers of the deaf (Luckner & Dorn, 2017); and types of itinerant support services (Davison-Mowle, Leigh, Duncan, & Arthur-Kelly, 2018). Collectively, their findings provide a general overview of the itinerant pedagogical approach including challenges.

Overall, studies on itinerant teachers of the deaf were consistent regarding descriptions of the role, student characteristics, and perceptions of their work. These teachers traveled from school to school providing IEP services to DHH students and according to Luckner and Ayantoye (2013), depending upon where they worked, itinerant teachers of the deaf can spent as much time driving between schools as they provided direct services to students and consulted with staff. They usually served all levels of students from preschool through high school located within a geographical area and in many cases, they did not have dedicated space. Due to scheduling constraints they most often provided pull-out services to students one-on-one in available areas such as hallways, staircases, and lunchrooms rather than push-in services in general education. The average amount of time a DHH student received direct services from an itinerant teacher of the deaf was about 2 to 2.5 hours per week and on the average, DHH students spent approximately 76% of the school day in general education. Luckner and Ayantoye (2013) found that a majority of the 365 itinerant teachers of the deaf in their study did not feel adequately prepared by their teacher training programs; they did not receive instruction or field experiences for itinerant teaching and 40% of them stated that they did not have a job description. Despite this, a high percentage of the itinerant teachers of the deaf (88%) believed that this service delivery model was an effective way to meet the needs of DHH students most of the time and 97% of the itinerant teachers of the deaf felt they were effective at least most of the time. In a large national study of job satisfaction and teacher of the deaf, Luckner and Dorn (2017) found that 89% of the itinerant teachers of the deaf were overall *satisfied* to *very satisfied* with their job and this was slightly higher than teachers of the deaf who were not itinerant providers.

With regard to student characteristics in itinerant placements, Luckner and Ayantoye (2013) found that 78% of them used spoken language and listening as their primary mode of communication and 85% of the students used assistive listening devices such as hearing aids, cochlear implants, and FM systems. Twenty-two percent of the students used ASL and an interpreter in general education, and some used simultaneous communication. Students’ degree of hearing loss ranged from mild to profound and approximately two-thirds of the students had a moderate to severe hearing loss.

Regarding academic goals for students who received itinerant services, the Luckner and Ayantoye (2013) study showed that IEP goals typically targeted language, reading, and writing; non-academic goals targeted auditory training and self-advocacy. Although some students in itinerant placements were reported as doing very well, data also indicated that a significant number of students were not, although more than half of itinerant teachers in this study felt the service model was effective. Luckner and Ayantoye acknowledged that some of the findings seemed contradictory raising issues of concern and suggested that more research on the itinerant model was needed.

The literature review revealed that the itinerant model poses several pedagogical challenges regarding access to the learning environment, academic achievement levels, professional collaboration, and social-emotional learning. Rabinsky (2013) found that a major barrier for DHH students learning in general education was classroom noise levels. Students who used assistive listening devices to access the general education curriculum struggled when background noise was present. Twenty-first century general education classrooms tended to be active environments where there were often many voices interacting in the classroom at the same time. Across all of the studies on the itinerant model in this literature review, a high percentage of the students used FMs, hearing aids, and cochlear implants to access learning and they spent an average of three-quarters of the day in an environment where they often struggled to hear.

Regarding academic growth, reading comprehension scores were commonly used as an indicator of general academic functioning. Luckner and Ayantoye (2013) found that two-thirds of the DHH students were one year or more below grade level in reading and 23% of them were more than two years delayed. It was also reported that 35% of the

DHH students had an additional disability which could compound learning challenges. It was unknown if the general education teachers had other specialists present to assist learners in need of more intense support beyond simple differentiation, but the study results showed that the itinerant teachers spent little if any time in the general education classes due to scheduling difficulties. Luckner and Ayantoye found that the two most important duties of the itinerant teacher of the deaf were to provide direct services to students and secondly to consult with other professionals and parents; however, the top two factors that limited their effectiveness were scheduling difficulties and not having sufficient time to collaborate with general education teachers. The lack of time to collaborate with school staff was also a top concern of the itinerants in the large national study of teacher of the deaf job satisfaction (Luckner & Dorn, 2017). Despite this, itinerant teachers of the deaf estimated that 80% of general education teachers understood the learning needs of the DHH students (Luckner & Ayantoye, 2013). General education teachers typically had full classes of students with diverse needs and although they might be *aware* of student needs, without additional help on site meeting those needs would be constant challenge.

Regarding the instructional focus of itinerant teachers of the deaf, Davison-Mowle et al. (2018) conducted a small mixed method study to explore direct instruction in language and communication provided by 14 itinerant teachers of the deaf. They found that 73% of these teachers' direct instruction was devoted to accessing the auditory environment and specialized communication therapy rather than supporting student success in the general curriculum. Marlatt (2014), a professor of Speech Pathology and Audiology at Adelphi University observed that DHH students in the general education environment were increasingly receiving therapy from service providers focused on speech and listening. He voiced strong objection to this practice and advocated that these students should receive direct support for general education content from trained teachers of the deaf.

In a 5-year longitudinal mixed method study of 197 itinerant teachers in Arizona and Colorado, Antia and Rivera (2016) found that reading and writing instruction was the top academic areas and self-advocacy was the top non-academic area of instruction provided by itinerants. Antia and Rivera also found that itinerant teachers of the deaf were often solely responsible for deciding how much time DHH students would receive their services and the researchers argued that guidelines for service time need to be established with wide support from the field.

Recent studies suggest that integrating DHH students socially in hearing environments can be challenging. Although 87% of the itinerant teachers of the deaf indicated the DHH students were socially accepted by hearing peers, other findings seemed to conflict as only 31% of the DHH students had good social skills and 25% had IEP goals for social skill improvement (Luckner & Ayantoye, 2013). In itinerant placements, DHH students were often the only child in the entire school with a significant hearing loss and they frequently struggled socially and emotionally (Hintermair, 2014; Oliva et al., 2016). Luckner and Dorn (2017) found that the lack of deaf adult role models was a top concern among itinerant teachers of the deaf. Experts in the field of deaf education recognized the need for DHH children to interact with deaf adults as well as deaf peers and argued that this interaction was critical to identity development and self-determination for successful transition to adulthood (Cawthon, Johnson, Garberoglio, & Schoffstall, 2016).

A recent study investigated social-emotional learning (SEL) in itinerant placements with a sample of 53 itinerant teachers of the deaf from a western Canadian providence. The itinerant teachers of the deaf reported that across grade levels, their students experienced social isolation, and this was their greatest area of concern (Norman & Jamieson, 2015). As an expert in bilingual education, Reagan (2018) explored the assumptions behind the inclusion movement and asserted that for some groups of children the general education environment may be least restrictive but deaf children who are unable to communicate seamlessly with hearing peers might be *physically* present but not *socially* included. Reagan argued that the inclusive environment for deaf children is most likely more restrictive emphasizing that, “it is abundantly clear that the proper and healthy cognitive and social development of every child is dependent on his or her access to communication with peers” (p. 87). Inclusion for DHH students can be complex and requires careful consideration of many variables and therefore, successful inclusive practices might depend upon the learning context.

Regarding pedagogical practices with DHH hearing students, current research on this topic appeared to focus on the itinerant model. Scholars raised concerns regarding SEL, academic achievement, the content of direct service provision, and IEP decisions, as well as scheduling and professional collaboration concerns. It must be emphasized that many of these aforementioned issues have been topics of controversy across all placements but the itinerant model seems to be in the spotlight due to the rapid increase in itinerant teachers of the deaf and the lack of research on this model. In general, mainstreaming and inclusion have been highly controversial since the late 70s when DHH students began leaving residential school placements for a free and public education under IDEA. An older study on key concepts related to the social-emotional wellbeing of DHH students in the mainstream can be applied to the itinerant model and is worthy of discussion.

Antia et al. (2002) studied DHH students placed in inclusive environments where they were unable to fully participate due to the lack of access to auditory communication and the impact of this upon social-emotional wellbeing. Antia et al. introduced the concept of *visitorship* verses *membership*; students who experienced feelings of isolation due to lack of access were relegated to the role of visitor. Further, Oliva et al. (2016) asserted that hearing peers have fluid access to incidental learning via the auditory channel, but for students with hearing loss incidental learning is fragmented. They argued that the extent to which DHH students could access formal and informal learning was frequently overlooked when placement decisions were made which might cause these students to function as *bystanders* in general education classrooms. Service providers for DHH students in inclusive environments should collaboratively address strategies that would increase DHH students' sense of membership (Braun et al., 2018; Miles et al., 2018; Olsson et al., 2017).

Antia et al. (2002) described the role of a teacher of the deaf in the inclusive environment and how to foster the DHH student's sense of membership by being present, being seen as a co-teacher, and assuming responsibility for all students in the class. Constraints on the itinerant teacher's time presented barriers to developing ownership in inclusive classrooms with DHH students. Antia et al. described programming that could cause DHH students to feel like visitors in general education. Specifically, the authors argued that children with hearing loss who are routinely pulled out of class and have adults coming in and out of the general education environment cannot foster a full sense of membership and belonging. By the same token, itinerant teachers of the deaf cannot cover their caseloads and spend significant time co-teaching with general education teachers. To do so would require major systemic changes. With the co-teaching model in mind, Antia et al. explored the applicability of three pedagogical approaches in inclusive classrooms including behavioral, cognitive, and social constructivist pedagogies. They concluded that “the social constructivist perspective seems more consistent with a quality education in the regular classroom” (p. 218). Although scholarly studies on PBL were still in infancy at this time, Antia et al. asserted that social constructive instructional pedagogy had the greatest potential for learning and the development of membership for students, educators, and community members including deaf adult role models. Antia et al. recognized the need for deaf educators to be more open to innovative ideas and broader systemic thinking regarding educational programming, social skills learning, and sense of belonging in the learning environment.

A recent meta-analysis of social skills research from 1990 to 2015 in deaf education may support the assertion of Antia et al. (2002) regarding the potential of social constructivist pedagogy with DHH students. Cawthon et al. (2018) summarized that traditionally the approach in deaf education research has been from the perspective that social skills development is an individual process; however, their analysis indicated that social skills should be studied from the perspective of “the individual-in-context” (p. 484). Cawthon et al. (2018) asserted that this could have implications for research and practice. A PBL study with secondary level public-school students by Culclasure, Longest, and Terry (2019) found that PBL engagement supported social emotional development. Perhaps the use of PBL in classrooms with DHH students could support social and academic learning.

Calls for Pedagogical Change in Deaf Education

Deaf education leaders have advocated for innovative thinking and educational change. James Tucker (2014) addressed the harmful effects of pedagogical wars on learning. As Superintendent of the Maryland School for the Deaf, he asserted that "dueling philosophies" place attention on communication rather than learning; further, "there is too much emphasis on *deaf*, and not enough on *education".* Accentuating the need for higher expectations, Tucker argued that a pattern of poor educational outcomes among deaf graduates has needlessly persisted as a result of low expectations and a "watered down curriculum" that causes students to "flounder" (p. 90). He asserted that they "deserve demanding academic instruction that leads to fluency in English reading and writing as well as acquired knowledge of mathematics, sciences, and social studies" (2014, p. 90). Tucker advocated shifting the emphasis on raising educational expectations and increasing levels of rigor in practice to provide students with an education that will prepare them with the knowledge and skills needed for success. Realizing the changes in education and the threat of inclusion to residential schools, the former editor of *American Annals of the Deaf*, Moores (2010) asserted, "If deaf children are to thrive, both residential and public schools must embrace new paradigms; both must be flexible enough to experiment with new models" (p. 454). Referring to the dark ages in deaf history, he warned that resisting current realities in education for the deaf could backfire;

“the Deaf community may revert back to maintaining itself in the face of an oppressive world” (p. 454). Two deaf education teacher trainers Johnson and Mertens (2006) encouraged deaf educators to embrace the 21st century skills movement to better prepare students for the modern workplace. They advocated for the establishment of “a classroom environment that encourages both teachers and students to become increasingly effective and efficient learners” (p. 239). Many of the practices they highlighted aligned with PBL such as increased student autonomy, technology integration, and collaborative learning, as well as project-based problem-solving activities.

A number of scholars in special education and deaf education have called for change in instructional pedagogy to better prepare students for the 21st century (Ayantoye & Luckner, 2016; Harris et al., 2015; Johnson, 2013; Smith & Pastor, 2016; Swanwick et al., 2014; Swanwick, 2017). Rock et al. (2016) summarized that special education teachers experience tremendous job ambiguity with regard to their role in a variety of placements, teaching multiple subjects across grade levels to students with a variety of needs and asserted that under these conditions students cannot be served well. Rock et al. made a call to action for general education teachers and specialists to consider a new model that allows them to work together focused on preparing all students with the skills needed to succeed in the modern world. Rock et al. provided a framework based upon change drivers for moving forward. Included in this framework was the need to engage students in using technology as a learning tool for authentic projects and constructivist strategies where given as examples of best practices.

The PBL evidence base with hearing students. The literature review of recent PBL studies revealed that a wide body of research across age levels, student needs, and content areas show a strong evidence base for this instructional method with groups that were not identified as DHH students. Positive benefits of PBL have been shown with students who were high and low achievers in elementary and high school (Catapano & Gray, 2015; Martelli & Watson, 2016; Smith & Pastor, 2016), high school math (Holmes & Hwang, 2016; Remijan, 2017), STEM (Edmunds et al., 2017), social studies (Ilter, 2014; Summers & Dickinson, 2012), and across all levels of music education (Tobias, Campbell, & Greco, 2015). Additionally, studies have shown the effectiveness of using PBL in online learning (Shadiev et al., 2015), college-level ICT (Thamarasseri, 2014), engineering (Moliner et al., 2015), and business education (Zhao et al., 2017). PBL has been used effectively with struggling learners in life skills (Wurdinger & Qureshi, 2015), developmental studies (Butler & Christofili, 2014), and with students whose native language was not English such as ELL (Almaguer, Diaz, & Esquierdo, 2015), English as a Second Language (ESL; Petersen & Nassaji, 2016), and English as a Foreign Language (EFL; Putri, Artini, & Nitiasih, 2017; Shiraz, & Larsari, 2014). Overall, these studies indicate that PBL strategies have been effectively applied in a wide variety of settings; through engagement in real-world collaborative problem-solving students can become active knowledge builders and meaning makers. Using PBL, teachers can promote the development of 21st century skills and higher levels of thinking needed in the modern workplace. To this end, studies have shown that student-centered PBL strategies could more effectively prepare learners for college and careers than traditional instruction where teachers transmit knowledge to passive learners. Despite this broad evidence-base and the impetus in deaf education to implement research-based practices, empirical studies using PBL with DHH students are scarce in the scholarly literature.

The potential for PBL use with DHH students. Although I found a multitude of recent empirical studies on PBL with a wide range of learners, the literature review revealed that available empirical research on PBL or similar forms of constructivist learning with DHH students were extremely limited. Easterbrooks and Stephenson (2012) suggested that experienced teachers of the deaf may be hesitant to implement constructive learning. These two well-known teacher trainers reflected on the findings of an earlier study in which they explored pedagogical practices and beliefs of master teachers of the deaf. Easterbrooks and Stephenson stated, "As a group, they did not employ collaborative, case-based, real world, authentic problem-solving, and they were ambivalent about teaching high-ordered critical thinking and problem-solving skills." (2012, p. 44). However, more recently a few articles from both scholarly journals and a nationally distributed publication for DHH practitioners highlighted instructional strategies that are common to PBL and taken together, they might suggest the potential for using PBL in classrooms with DHH students.

For this literature review only one study using PBL with DHH student participants was identified (Bellman, Burgstahler, & Ladner, 2014) and it was part of a larger case study of multiple work-based learning efforts at the University of Washington. With funding from the National Science Foundation (NSF, 2000), instructors designed a series of activities and programs with the aim to increase participation of individuals with disabilities in science, technology, engineering, and math (STEM) careers. One of the work-based activities involved high school DHH students in a 9-week summer academy at the university to advance their skills and knowledge in computing. The PBL aspect of this academy was called *The Saturday*

Computing Experience in which students learned about computer programming via PBL strategies. According to Bellman et al., students engaged in PBL teamwork over an extended period and demonstrated collaborative problem-solving. Specific data collection and analysis, assessment methods, technology use, or actual products produced by students as a result of the PBL were not provided; however, Bellman et al. reported that high school students across cases rated their experiences positively with regard to developing self-determination and autonomous learning in addition to increasing their awareness of career options.

Another recent STEM article bearing the words *Project-Based Approaches* in the title promoted using PBL with DHH undergraduates at the National Technical Institute for the Deaf (NTID) in Rochester, NY (Pagano et al., 2016). The authors were NTID instructors whose intent was to share with the field how PBL could be used to engage DHH students in learning science and working in the laboratory. NTID instructors shared a cross-disciplinary approach designed to engage DHH students in conducting a series of science lab experiments. Pagano et al. (2016) presented a historical narrative about the black plague and the nutmeg seed to interest students in conducting predesigned experiments. The authors suggested ways that DHH students could be involved metacognitively in the planning and data collection processes and thereby actively participate in authentic group-based activities that “pique the interest of postsecondary students” (p. 16). Data were not collected on student engagement in PBL specifically, but the NTID instructors indicated the potential for using PBL as an innovative strategy to engage DHH college students in learning science. Similarly, McBride and Goedecke (2012), instructors who taught DHH students at the model elementary and secondary programs on the Gallaudet University campus, also supported using PBL with DHH students who have disabilities in addition to being deaf. This article published in *Odyssey*, a government-supported practitioner magazine from the Clerc National Deaf Education Center offered strategies for aligning PBL with standards. McBride and Goedecke provided step by step instructions for designing and implementing PBL along with photos of students engaged in PBL although research on the effectiveness of PBL with DHH students was not provided. Bellman et al. (2014), McBride and Goedecke, (2012), and Pagano et al. (2016) made strong recommendations for using PBL with, but the empirical evidence to support their beliefs was not found; therefore, the literature review was expanded to find studies on instructional approaches that have features similar to PBL.

Several studies that did not specifically address PBL with DHH students but used constructivist strategies were found for this literature review. Parveen (2017) conducted an experimental study with DHH adolescents from a deaf school in Pakistan using the 5Es, an inquiry-based approach to learning science. The 5E circular framework was a systemic inquiry method for learning through the five stages engage, explore, explain, elaborate, and evaluate Thirty-four students in level VIII science were randomly assigned to experimental and control groups and given pretest and post intervention assessments of cognitive engagement including knowledge retention, comprehension, and application. Deaf students in both the control and experimental groups studied classifications of organisms for six weeks. The control group was taught using traditional strategies and the experimental group used the 5Es inquiry approach. The results showed that the students using the 5Es used higher cognitive functions than the control group at the comprehension and application levels. In an *Odyssey* magazine article for practitioners, Neria (2014) also supported using the 5Es as a systemic method that can be used successfully to engage K-12 DHH students in authentic learning.

The literature review revealed that reports from the National Science Foundation (NSF) which supported the development of Next Generation Science Standards (NGSS) have impacted pedagogy in some classrooms with DHH students. Researchers became interested in investigating the status of science instruction with DHH students when reports from NSF (2000, 2001, 2017) showed that DHH individuals have been underrepresented in STEM fields since the turn of the 21st century. Jones (2014) found that teachers of the deaf were not given training in science instruction and as a group, they underemphasize science with DHH students. Further, Jones found that over a 40-year period, only 12 studies on science with DHH students were identified. To increase the STEM focus in deaf education and increase participation of DHH college students in STEM fields, the NSF made grants available targeting underrepresented populations. The NGSS promoted active student-centered learning through constructivist strategies which align with PBL and other approaches such as inquiry-based, problem-based, discovery, and experiential learning strategies. As a result, two empirical studies with DHH students were selected for this review as examples of research on constructivist pedagogy with DHH students; like the Bellman et al. (2014) study, they were supported by NSF grants.

Kahn, Feldman, and Cooke (2013) designed a cross-case study at three high schools for the deaf to study how teachers' interactions could foster or hinder deaf student autonomy when engaged in inquiry-based Earth science studies. The researchers posited that if DHH students were to succeed in STEM careers, teachers should guide them to exercise autonomy and critical thinking. The researchers asserted that DHH students tended to be dependent upon adults because they were not given opportunities to think and act independently; furthermore, deaf education has a long history of being highly structured and controlled by adults (Gormally, Sullivan, & Szeinbaum, 2016). To explore how DHH students performed using an inquiry-based approach, three teachers of the deaf used an apparatus called the SANDBOX for science problem-solving activities with small groups of students. Analysis of videotaped classes revealed that the three teachers impacted student thinking and learning behaviors in three ways. The teacher of the deaf in the urban Midwestern program had seven students and fostered the greatest collaborative relationships and interdependence among students. The second teacher of the deaf had a class of four students in a small city in the Midwest. His instructional style was controlling and the students in this class exhibited dependence on the teacher rather than autonomous learning behaviors. In the third case, the teacher of the deaf had a class of five DHH students in a major city on the east coast. This teacher was an excellent example of how teachers of the deaf could foster high-level inquiry while giving autonomy. The researchers found that when the teacher gives DHH students autonomy, they can solve problems without being teacher directed. From this study, it appeared that PBL could be successful with DHH students given a skilled teacher.

A second case study by Marshall, Carrano, and Dannels (2016) took place at NTID over three years with undergraduate DHH students working toward an associate degree in engineering studies. The researchers developed an intervention that consisted of a series of hands-on modules designed after experiential learning best practices. The modules engaged students in problem-solving activities in an industrial engineering laboratory environment that mirrored real-world work sites. The overarching goal of the study was to test whether DHH students immersed in experiential learning were better prepared to problem-solve than peers educated using the traditional approach. Thirty-four students participated in the control group and the intervention group consisted of 40 students. Both groups of students were tested on their problem-solving skills given case studies. The results showed a marked improvement in problem-solving among the students in the intervention group. This study also supported that active, collaborative learning using a social constructivist approach could positively influence DHH students' thinking skills when applied in authentic scenarios.

In sum, this section of the literature review included the early history of deaf education to provide background for understanding current issues that impact teachers of the deaf and DHH students. This section highlighted the philosophical divisions among practitioners in the field that began in the 19th century coupled with 21st century political and technical changes that impacted pedagogy in classrooms with DHH students. The literature review illuminated three basic types of programs for educating DHH students based upon communication modes. These were oral programs that use listening and spoken language, bilingual programs that use ASL and written English, and programs that had a variety of DHH students who use a combination of communication methods. This understanding was important for this study on PBL because students must collaborate in small groups where good communication is critical. Further, opportunities for teachers of the deaf to engage students in PBL units may be impacted by the type of service they provide as well as placement.

Overall, this section of the literature review revealed that studies on PBL with DHH students were extremely limited but that a few studies with DHH students that explored similar approaches to PBL showed positive results. None of the studies examined student products or learning processes. None of the studies provided in-depth awareness of how DHH students worked collaboratively or how they used technology as a learning tool. Clearly, there is a gap in the literature regarding PBL use with DHH students. The purpose of this qualitative study wasto explore the experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the areas of PBL pedagogy, product, and process. The study was designed to capture an in-depth understanding of how PBL may foster higher order thinking with DHH students and could serve as first step toward filling the gap and promoting innovative learning strategies with DHH students.

Summary and Conclusions

This chapter was a literature review. The literature search strategy section included an explanation of which databases and key terms were used to identify the articles included in the review. Next was the conceptual framework I developed called PB-LIFTS. This was based on constructivist learning theory and well-known theoretical frameworks were applied for evaluating HOTS in the dimensions of teacher PBL pedagogy, student PBL products, and student PBL processes. To gain multiple perspectives of how these three dimensions of PBL have been addressed in the recent scholarly literature related to the research questions for the present study, literature review topics included PBL, history of PBL, benefits of PBL, challenges of PBL, teacher perceptions of PBL, relationship between PBL and HOTS, and pedagogy in classrooms with DHH students.

Through the process of the literature review, several themes and gaps were identified. The 21st century skills imperative applies to all students including a range of diverse learners to be prepared for success in the modern workplace (Germaine et al., 2016; Soulé & Warrick, 2015). Twenty-first century skills were also referred to as HOTS in the literature and these skills can be developed through social learning strategies (Przybysz-Zaremba et al., 2017; Zhao et al., 2017) such as PBL which is a comprehensive method within the constructivist paradigm for learning content, making meaning, and developing HOTS (Holmes & Hwang, 2016; Lin et al., 2015; Wurdinger, 2018). PBL can be applied across a continuum of constructivist pedagogies and the extent to which HOTS can be developed is dependent upon the skills of the teacher, the pedagogical approach, and the learning context (DeWaters et al., 2014; Häkkinen et al., 2017; Kwan & Wong, 2015; Peng et al., 2017; Schulz & FitzPatrick, 2016). The literature indicated that when implementing PBL the teachers' pedagogical approach can impact the development of HOTS, yet a method for differentiating pedagogical approaches in PBL studies was not found. Further, in recent literature researchers often reported that PBL promoted HOTS but assessing overlapping skills in PBL products and processes was frequently challenging (Georgiou, 2020; Habók & Nagy, 2016; Lee et al., 2014; Stolk & Harari, 2014) and in studies that reported positive outcomes related to HOTS it was often unclear how products and processes were assessed (Alves et al., 2016; Molinar et al., 2016). In several studies researchers concluded a balanced method for assessing HOTS in PBL that could be easily adapted and applied in a variety of contexts was needed (Alves et al., 2016; Du & Han, 2016; Schulz & FitzPatrick, 2016; Smith, 2016; Williams, 2017; Zhao et al., 2017). Thus, due to the widespread use of PBL and gaps in the research literature, a problem exists at the societal level regarding the persistent need for a comprehensive PBL evaluation strategy that could illuminate levels of HOTS within the multiple layers of PBL. This study addressed the assessment gap by applying PB-LIFTS which could be applied in any learning context to identify levels of HOTS in a teacher's described PBL pedagogical approach, in the product students produced, and in four student learning processes common to PBL units.

In addition, the literature review revealed a gap in the research exists regarding PBL research with DHH students. PBL studies have shown that this strategy can be easily differentiated (Du & Han, 2016; Galvan & Coronado, 2014) and has been successfully used with a range of diverse learners in multiple contexts (Chiang & Lee, 2016; Han et al., 2015; Hovey, & Ferguson, 2014; Lambert, 2015; Martelli & Watson, 2016; Petersen & Nassaji, 2016; Shin, 2018); yet empirical studies on PBL with DHH students were scarce. Although the 21st century skills imperative applies to all student populations, and there exists a wealth of research indicating the benefits of using PBL to promote HOTS, it is unknown how teachers of the deaf have experienced using PBL in classrooms with DHH students. Experts in the field acknowledge that deaf education outcomes have been historically poor due to low expectations (Salter et al., 2017; Smith, 2013) and misguided assumptions regarding learning needs based on beliefs and opinions rather than evidence-based practices (Crowe et al., 2017; Spencer & Marschark, 2010) causing DHH students to receive concrete, simplified, and repetitive instruction (Jones, 2014; Pagliaro, 2015; Williams, 2014) with controlled syntax and vocabulary (Power &

Leigh, 2000). Experts in the field advocated that DHH students need opportunities to develop 21st century skills with higher expectations and social constructive learning (Antia et al., 2010; Ayantoye & Luckner, 2016; Johnson, 2013; Kelly et al., 2016; Swanwick, 2017); however, research with DHH students using constructivist pedagogy for the development of HOTS is still in infancy. The present study addressed this research gap to extend knowledge in deaf education by exploring the experiences of teachers of the deaf using PBL to promote HOTS. Therefore, the purpose of this qualitative study was to explore the experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the areas of PBL pedagogy, product, and process. The self-designed conceptual framework, PB-LIFTS, was applied to assess HOTS in PBL and addressed a second gap in the literature.

The following chapter on research methodology includes a description of how the study was designed to investigate the identified research gaps. This research methodology chapter includes a discussion of the research design and rationale, the role of the researcher, participant selection, instrumentation, and recruitment, participation, and data collection. A thorough description of the data analysis plan is also included as well as a discussion of issues related to trustworthiness in qualitative research and ethical procedures.

Chapter 3: Research Method

The purpose of this qualitative study was to explore the lived experiences of teachers of the deaf in using PBL to build HOTS with DHH students. To accomplish this purpose, I developed a conceptual framework called PB-LIFTS to explore HOTS in three dimensions of a favorite PBL unit selected by each participant and described in-depth through semistructured interviews and reflective journals. I incorporated multiple tools in the PB-LIFTS framework for assessing HOTS that I drew from the literature review to discover levels of thinking skills in the dimensions of the teacher's pedagogical design, the product students produced, and PBL processes students used.

In this chapter, I provide a detailed description of the research methodology for this study organized in five sections. The chapter begins with an explanation of the selected qualitative research design and its applicability for this study. Next, I discuss my role as the study's sole researcher. Third, I provide a detailed description of the methods for this study including participation logic, instrumentation, procedures for recruitment, participation, and three phases of data collection and analysis. In the fourth section, I address issues related to trustworthiness and ethical procedures. The chapter ends with a summary of the research methodology.

Research Design and Rationale

In this section I present the research questions for this qualitative study and discuss the central concepts addressed, the research tradition, and rationale for the selected design. The phenomenon I examined was how teachers of the deaf experienced using PBL to build HOTS with DHH students. This was explored using one CRQ as a focusing lens and four RRQs. The questions aligned with the PB-LIFTS conceptual framework that I developed for this study based on a thorough review of the scholarly literature. The CRQ and RRQs for this study follow:

CRQ: How do teachers of the deaf describe their lived experiences designing and implementing PBL to build HOTS with DHH students?

RRQ1: How do teachers of the deaf describe HOTS in their pedagogical approach for PBL?

RRQ2: How do teachers of the deaf describe HOTS in student PBL products?

RRQ3: How do teachers of the deaf describe HOTS in student PBL processes?

RRQ4: In what ways could the PB-LIFTS framework be useful to teachers for assessing HOTS?

The research design I chose for the study was IPA, and I selected this over several other designs. The study is an investigation of teachers' perceived experiences and therefore required a qualitative approach using inductive reasoning rather than a quantitative approach most often used to test a theory using deductive reasoning (see Miles, Huberman, & Saldana, 2014). Quantitative research often begins with a hypothesis tested by controlling environmental variables. Maxwell (2013) asserted that quantitative educational research has had little impact on instructional practice because it fails to reveal authentic teaching experiences in realistic learning environments that matter to teachers. Qualitative research methods have the potential to capture and illuminate key understandings about education processes from teachers' experiences in specific contexts, and therefore, selecting a qualitative method for this study had greater potential to inform practice.

Five major qualitative research strategies include case study, ethnography, grounded theory, narrative, and phenomenology (Creswell, 2013); by examining the general focus of each I was able to quickly eliminate four of them and move to explore the remaining research approach and subtypes in greater depth to determine which would be the best fit. I decided that the focus of the following methods did not align with my interest to explore how individual teachers experienced using PBL to build HOTS with DHH students: case studies focus on an event, individual, or organization; ethnography focuses on a particular context or culture in a specific time and place; grounded theory studies develop a theory from extensive data collection and analysis; narrative studies examine experiences of one or two individuals to tell their story (see Creswell, 2013). Phenomenological studies focus upon human experiences of a phenomenon from the subject's viewpoint; thus, on the surface, a phenomenological approach for the study seemed to be a good fit as teachers' experiences using PBL to build HOTS was the phenomenon of interest.

Although a number of qualitative methods exist under the umbrella of phenomenological research approaches, two seminal philosophical orientations are Husserl's (1970) descriptive phenomenology and Heidegger's (1962) interpretative phenomenology; I believed the latter aligned best with this study because of the importance of context, the role of the researcher, use of a conceptual framework, and application of the findings. While the aim of both descriptive and interpretative phenomenological studies is to discover how phenomena were experienced from the point of view of the participants, the basic tenants of Husserlian and Heideggerian phenomenology are significantly different. Husserl was influenced by traditional scientific research practices and included procedures to safeguard objectivity in his descriptive approach to studying human consciousness of phenomena (Lopez & Willis, 2004). For example, to increase the objectivity of the findings, Lopez and Willis (2004) asserted that the study must be devoid of history and context and apply to all individuals who experience the phenomenon. Rather than focusing on conscious awareness of phenomena, the interpretative approach focuses upon human experience and incorporates a hermeneutic interpretative process to reveal hidden meanings. Heidegger believed that the experiences of individuals are influenced by the personal and social world around them and therefore, understanding the context in which phenomena occur is critical. This is particularly important in educational research as teachers design learning experiences with the needs of their students in mind. Thus, to understand how educators experience phenomena in teaching, each teacher and each learning context must be considered as unique.

Another major difference between descriptive and interpretative phenomenological research is the stance of the researcher. In the descriptive approach, the researcher keeps their personal biases *bracketed*, or removed from exploring the participant's account of an experience (Patton, 2015). According to Lopez and Willis (2004), some scholars claim that the descriptive phenomenological researcher should not pursue an in-depth literature review prior to conducting a study to free the researcher of presuppositions and potential bias regarding the phenomena. On the other hand, in the interpretative phenomenological approach, the researcher's knowledge serves as a guide for the inquiry although some bracketing may be necessary to keep the experiences of the participant from their perspective at the forefront of the inquiry (Smith et al., 2009).

Heidegger (1962) believed that it is impossible for researchers to completely shed personal bias, and Lopez and Willis (2004) added that the researcher's understanding of the topic and awareness that a gap exists most likely led to the desire to pursue a study in the first place. Heidegger also believed that the interpretative phenomenological researcher should establish rapport with each participant to gather rich descriptions that can lead to understanding the essence of the participant's lived experience through the interpretative analysis process. Lopez and Willis (2004) asserted that there is no single true meaning in interpretative studies but the "findings must be logical and plausible within the study framework and must reflect the realities of the study participants" (p. 730). The interpretative phenomenological researcher who uses a conceptual framework must explain how it was used at all stages and show that the framework did not influence or bias the participants. Lastly, Lopez and Willis' description of what phenomenological researchers do with their findings confirmed that this approach aligned with the intent of this study; they stated that the researcher will "go further by interpreting the meanings for practice, education, research, and policy" to create knowledge that is informed by the study and is culturally sensitive (p. 730).

Because phenomenological research centers upon a phenomenon, it is important to clarify that PBL and HOTS were the two major concepts central to the phenomenon of interest for this study. PBL is defined as an instructional strategy in which students work in small teams and collaboratively investigate an authentic problem or question (Larmer et al., 2015). Through PBL engagement for a sustained period, students are asked to produce a product representing their learning for presentation to an audience. HOTS and 21st century skills are often used interchangeably and can be defined as constructive learning behaviors such as student engagement in problem-solving, critical thinking, metacognition, collaborative communication, creativity, and meaning-making (Germaine et al., 2016; Kivunja, 2015; Pellegrino, 2017). A phenomenon can be described as an observable experience or circumstance that is perceived as extraordinary although the observer may not fully understand why or how it occurred (Moustakas, 1994).

One recurring phenomenon reported in the recent PBL literature was that this instructional strategy promotes the development of 21st century skills that are manifested in various forms of HOTS. According to Maxwell (2013), theory provides a model for studying a phenomenon and "the simplest form of theory is two concepts joined by a proposed relationship" (p. 49). The major concepts of this study were PBL and HOTS, and I sought to understand how teachers experienced the phenomenon of students demonstrating HOTS as an outcome of engagement in PBL. The purpose of this study was not to generalize but to understand how each teacher experienced this phenomenon from their personal viewpoint. Realizing that an interpretative phenomenological approach may be a good fit for my study, I explored newer analytic methods and discovered IPA, which has become increasingly popular in the last 20 years. IPA is rooted in phenomenology and hermeneutics and began in the United Kingdom with a paper by Smith (1996) published in *Psychology and Health*. IPA studies have expanded from health psychology to human and social sciences including research in education.

IPA is a qualitative inductive research method designed to gain detailed understandings of personally meaningful lived experiences of a small number of individuals. Smith et al. (2009) defined IPA as a meaning-focused phenomenological method for systemic interpretation of first-person accounts of experiences valued by the participant (p. 3). Key underpinnings of IPA are that humans are naturally compelled to make sense of experiences that they care about and everyone is unique with their own private perspectives about how they experienced a phenomenon. According to Smith (2011), the IPA approach provides a method for participants to make meaning of their experiences in their own contexts through introspection within a bounded study while the researcher tries to make sense of what the experiences are like from the participants' subjective perspective (p. 10).

One strength of IPA as an ideographic research method for this study was that it allows the researcher to gain deep insights from detailed personal accounts that can lead to understanding perceptions of phenomena within learning contexts. According to Schulz and FitzPatrick (2016), teachers may have an intuitive sense of HOTS and recognize it when they see students demonstrate these skills; however, the researchers found that teachers are less confident when trying to define and assess HOTS. PBL is a comprehensive learning strategy with many layers and activities involved; therefore, when reflecting on teaching experiences using a conceptual framework such as PB-LIFTS to explore common elements of PBL, teachers may become aware of student demonstrations of HOTS that they hadn't previously recognized. Although IPA is an inductive process, it was my hope that using a framework of theoretical constructs and elements of PBL to guide the semistructured interviews, teachers would discover how their PBL unit fostered the development of HOTS.

Role of the Researcher

As the sole investigator for this qualitative study I assumed responsibility for multiple tasks. I was responsible for designing the study, developing procedures for participant recruitment and selection, determining sources of data and procedures for data collection, developing data collection and analysis instruments, and assuring data security. Further, I took steps to assure the trustworthiness of this research and observed ethical procedures.

During the recruitment phase of the study I introduced myself as a former teacher of the deaf but as the sole researcher, I maintained the role of the observer to gather in-depth descriptions in order to understand the PBL experience from the participant's point of view. In the final debriefing interview, I shared the findings and data collection tools and my role shifted to engage in co-interpretation of the data. Such a relationship is not uncommon in qualitative research. As mentioned in Chapter 1, a well-known phenomenological researcher, Clark Moustakas, worked closely with his participants to understand their perspectives and sought to discover the depth of their experiences through joint interpretation; hence, he referred to his participants as coresarchers (Moustakas, 1994). Whether I was in the role of the researcher or coresarcher, it was critical to consider issues of bias, personal and professional relationships, and potential power over participants that could jeopardize the trustworthiness of the study. For this study I conducted and recorded one-on-one interviews with teachers of the deaf; thus, as a former teacher of the deaf and current mentor, the potential for bias could exist. For this reason, I did not recruit teachers of the deaf with whom I had a personal or professional relationship as this could have influenced the results of the study. In 2009, I was selected as a state Teacher of the Year and National Finalist. In this role, I presented extensively around the United States and consequently participants might have been familiar with my name, but I had no authority over them either directly or indirectly. I also served on the

Gallaudet University Board of Trustees for 13 years and oversaw model demonstration programs through my committee work as a trustee. Since 2006, I have had no supervisory involvement with Gallaudet and did not recruit teachers with whom by chance I had a personal or professional relationship.

In deaf education, issues regarding teachers' preferred mode of communication could be perceived as a source of bias. For this study I had hoped to find teachers with diverse communication preferences such as spoken English or ASL. In the flyer used to recruit participants I stated that there were no limitations regarding communication preferences and interested teachers who met the study criteria were encouraged to contact me. I am late deafened and use a hearing aid but cannot discriminate speech; therefore, when planning for recruitment I expected to hire certified ASL interpreters as a communication accommodation for interviews with participants who did not sign. For this reason, it was important to ask interested participants in the screening interview about their preferred mode of communication. To protect privacy, interpreters signed confidentiality agreements.

Program settings for DHH students are another source of controversy that has been hotly debated since the 19th century; therefore, the program settings in which study participants worked could be scrutinized as a potential source of researcher bias. Much of my classroom experience was spent teaching in mainstream environments; however, teachers for this study could teach in mainstream, residential, or itinerant settings. Over the course of my career, I have been involved with all these settings and do not advocate for one over another. It was my hope that teachers from a variety of settings would be included in this study although the goal was not to judge or compare learning environments or communication modes. Rather, in this study I focused on how teachers of the deaf experienced using PBL to build HOTS with students who are deaf or hard of hearing. As a researcher using IPA, establishing rapport with my participants was crucial to collecting rich descriptions of their experiences using PBL. To build rapport it was vital to be cautious of possible sensitivities regarding communication preferences and teaching environments.

Methodology

The methodology section includes a description of the rationale for identifying and selecting participants, including participant criteria, procedures for recruitment, and details related to participation. In this section I also describe instrumentation for data collection and data analysis and describe the data analysis plan. Next, issues of trustworthiness are addressed regarding study credibility, transferability, dependability, and confirmability. Last, this section includes a description of ethical procedures and concludes with a summary of the study methodology.

Participant Selection Logic

To answer the research questions guiding this qualitative study, I used a purposeful sampling approach to identify a small number of homogenous participants (see Creswell, 2013; Maxwell, 2013). The overarching goal of IPA studies is for the researcher to gather rich and detailed accounts of participants' lived experiences pertaining to a phenomenon of interest that can be methodically analyzed to reveal insights and answer research questions (Smith et al., 2009). Thus, IPA studies are ideographically characterized by in-depth examinations of a few purposefully selected participants who have knowledge of the research context and care about the topic of interest (Hefferon & Gil-Rodriguez, 2011; Smith et al., 2009). IPA studies most often have a sample size of 3-6 and a single case can generate a substantial amount of data. The strength of IPA methodology lies in the depth and richness of the interview data gathered from a small sample of homogeneous participants, rather than a large sample interviewed more superficially for the purpose of generalizing. To assure homogeneity of the participant sample and reproducibility of the study, it was critical to confirm that each participant met well-defined criteria for inclusion in the study during the recruitment process.

Because participants in this study were known for using an innovative instructional strategy that according to the literature review was uncommon in deaf education, they could be considered exemplary practitioners. Maxwell (2013) noted several benefits of using purposeful sampling in studies with exemplary practitioners. Teachers who are aware that they were selected because of their success are usually willing to share their experiences freely and will allow the researcher to develop a productive collegial relationship. Creswell (2013) recommended a criterion-based selection process to assure that participants had knowledge of the phenomenon and context of interest provided data pertinent to the research questions.

The target sample size for this study was four participants and no less than three if someone dropped out. Smith et al. (2009) recommended a sample size of three cases for novice IPA researchers. To determine the participant selection logic, it was necessary to first consider the available pool of potential participants. Hearing impairment is a low incidence category of special education and it was difficult to estimate the number of practicing teachers of the deaf in the United States as they are widely dispersed in a variety of settings; thus, it was anticipated that finding interested teachers of the deaf who met the criteria for this study not would be readily accessible. NCES (2017) reported a total of 50.7 million students age 3-21 enrolled in public schools in the United States. Fourteen percent of these students received special education services under IDEA and less than 1% of them were identified as having an educationally significant hearing loss. Thus, there were approximately 76,000 DHH students who qualified to receive services from teachers of the deaf in the United States. The literature review revealed that these students received services from teachers of the deaf whose caseloads varied widely across educational placements; therefore, it was impossible to estimate the total number of practicing middle and high school teachers of the deaf who might be eligible for participation in the study. Because studies on using PBL with DHH students were scarce, I predicted that finding qualified participants would be challenging; therefore, I developed creative recruitment procedures.

Smith et al. (2009) asserted that participants in IPA studies are typically identified through purposeful selection as opposed to probability sampling because the researcher seeks participants who are experienced with the phenomenon of interest. Additionally, the participants do not represent a population; rather, they represent a perspective and should be homogeneous. Most often participants are identified via snowball sampling; participants are identified through referrals from gatekeepers, the researcher's contacts, and participants. Merriam and Tisdell (2016) stated, "Snowball, chain, or network sampling is perhaps the most common form of purposeful sampling" (p. 98).

Using a criterion sampling strategy, I sought to identify qualified teachers of the deaf for participation from anywhere in the United States and created a flyer for public distribution seeking teachers who met the following criteria for study participation:

- five or more years of teaching experience
- licensed to teach DHH students
- taught middle or high school DHH students
- experienced in planning and implementing PBL units
- willing to be interviewed regarding a previous PBL unit in which
  - a minimum of three DHH students participated as a team
  - students focused on an authentic problem or question
  - students worked collaboratively for an extended period
  - students collectively produced a product for presentation

Regarding educational settings for qualified teachers, I stated in the flyer that there were no limitations regarding subject matter, communication mode or language, technology use, service delivery, or learning environment or such as mainstream, itinerant, or special schools. Details of the recruitment process are addressed in the procedures section.

Instrumentation

As the sole researcher for this IPA study, I served as the primary instrument for data collection and analysis (see Merriam & Tisdell, 2016) and I used the dimensions of the PB-LIFTS conceptual framework as my roadmap to conduct this study in three phases. To begin, I collected preliminary information from each teacher by sending an e-mailed demographic form (Appendix B). Using this instrument teachers shared information related to their background, teaching experience, contact information, and preferred mode of communication for interviews. To study teachers' PBL experiences, I developed several instruments for three phases of data collection including a PBL overview form, reflective journal prompts, and semistructured interview guides

PBL overview form. The first data collection instrument was a simple e-mail attachment called the PBL overview form (Appendix C). Using this form teachers identified one PBL unit that they would focus on throughout the study. Teachers provided the PBL title, course subject, grade level, essential question, learning objectives, and a description of the product students produced. These data contributed to answering RRQ1 and RRQ2 related to PBL pedagogy and student products in Phase 1.

Participant reflective journals. I developed three reflective journal prompts (Appendix D) that corresponded to the three study phases. Prior to each interview, teachers replied to a reflective journal prompt via e-mail. The first journal prompt provided an opportunity for participants to share their reasons for choosing the learning objectives listed on the PBL overview and to provide background regarding the learning context and learner needs. The second journal prompt was an opportunity for participants to share the types of HOTS they had *hoped* to see students demonstrate when they planned the unit and to identify skills that were evident in the final product. The third prompt asked teachers to reflect on the HOTS they *did* observe students demonstrate over the course of the unit. The reflective journal prompts were intentionally broad so that teachers could freely share their thoughts about the PBL; therefore, it was possible that responses could contribute to answering more than one research question. Table 8 shows the alignment between the reflective journal responses and the research questions.

Table 8

Reflective Journal Prompts Alignment with Research Questions

Reflective journal prompts	CRQ	RRQ1	RRQ2	RRQ3	RRQ4
RJ-1. On the PBL overview form, you selected a favorite PBL unit and provided the learning objectives. Please give some background for choosing them.	X	X			
RJ-2. Describe the 21st century skills or HOTS you hoped to see students develop when you planned the PBL. Were any of these evident in the final product? Explain	X	X	X		
RJ-3. Describe the times you were particularly pleased with student learning and engagement during this PBL. What were they doing? What skills and talents were they showing?	X			X	

Semistructured interview guides. PBL is a multilayered instructional strategy and Smith et al. (2009) recommended using a semistructured yet flexible interview method to focus on interview topics, allow for discrepant data, and set boundaries for collection using interview guides (Appendix E). In Phase 1, the first interview consisted of six questions targeting teacher PBL pedagogy and student products. In Table 9, I provide the Phase 1 interview questions and show the alignment with two related research questions RRQ1: How do teachers of the deaf describe HOTS in their pedagogical approach for PBL? and RRQ2: How do teachers of the deaf describe HOTS in student PBL products?

Table 9

Phase 1 Interview Questions Alignment to Research Questions

Interview questions	CRQ	RRQ1	RRQ2	RRQ3	RRQ4
P1-1. Tell me the story of how this favorite PBL came about. What inspired it? What did you hope students would gain?	X				
P1-2. What process did you use for planning this PBL? Did the original plan change as the PBL progressed? How and why?	X	X			
P1-3. How did you introduce the PBL and engage students in learning processes? What expectations did you convey to students? How?	X	X			
P1-4. Over the course of the project what roles and responsibilities did students take on and how were they decided? If you were a bug on the wall how would you describe your role(s)?	X	X			
P1-5. Describe the final product students produced. What learning activities did they engage in and what skills did they use to make it?	X		X	X	
P1-6. Tell me about assessment strategies for this PBL. Other than project presentations, how did you decide what to assess and how to assess it? What about the product assessment? Explain	X		X	X	

In Phase 2, the second interview consisted of six questions targeting PBL processes to collect data to answer RRQ3: How do teachers of the deaf describe HOTS in student PBL processes? Table 10 shows the alignment of the interview questions with the research questions.

Table 10

Phase 2 Interview Questions Alignment to Research Questions

Interview questions	RRQ1	RRQ2	RRQ3	RRQ4
P2-1. Tell me how the PBL was managed. How did students know what to do and when?			X	
P2-2. Tell me about resources students used to answer the PBL question or problem. How were they selected? How did they use resources and information in the product?			X	
P2-3. Tell me about how students functioned in teams. What was collaboration like? Did it change over time? How?			X	
P2-4. If students used technology for this PBL, what did they use and for what purpose?			X	
P2-5. Considering both the final product and the processes that produced it, can you identify skills, talents, or awareness that you hope they will continue to develop?		X	X	
P2-6. Is there anything related to PBL and how this unit helped build HOTS that you did not have a chance to share?			X	

Phase 3 took place with each teacher after several rounds of data analysis following IPA methodology and member checking which I describe in the data analysis plan. Phase 3 interview questions were included at key intervals within a packet of materials I developed for the final debriefing (Appendix F). I developed the questions to elicit responses that would answer RRQ4: In what ways could the PB-LIFTS framework be useful to teachers for assessing HOTS? Table 11 lists the debriefing questions and shows alignment with RRQ4.

Table 11

Phase 3 Debriefing Questions Aligned to the Research Questions

Debriefing questions	RRQ 4
P3-1. We used two methods for identifying HOTS in the PBL pedagogy design. First, we used learning objectives and RBT and secondly, we used pedagogy indicators. Both methods gave us data for placing the PBL in the pedagogy dimension. Can you share your thoughts about using these methods to identify the pedagogical approach? Can you address how the results may or may not be useful to you if you were to plan another PBL unit with this group of students?	X
P3-2. We used two methods for judging HOTs in the students' final product to identify the level of innovation. First, we used RBT and secondly, we used product indicators. Can you share your thoughts on using these two methods to assess HOTS? What do you think about the results? Can you address how the results may or may not be useful to you if you planned another PBL unit with these students?	X
P3-3. We examined the third dimension of PBL, student processes. We used several methods to assess HOTS in the areas of task, thinking, teamwork, and tool use (4Ts) using data from the second interview. What are your thoughts regarding the results for this group of students? Consider any or all the following: • Which skill do you see as a priority for improvement? • Which of these skills do you think will improve with more PBL opportunities? • Which skills do you think contributed the most to the final product? • Do you think you might use the 4Ts in some way to help students increase HOTS? How?	X
P3-4. Look at the cell placement for this unit with this group of students on the PB-LIFTS. Please look at the dimensions of instructional pedagogy and student innovation separately. Can you share your thoughts on what you see? The intersecting cell indicates that there is a relationship between the approach and the product outcome. Do you agree or disagree? What are your thoughts about next steps with the group to keep HOTS moving upward diagonally?	X
P3-5. I want to thank you for helping me learn more about how teachers of the deaf use PBL to build students' HOTS. Do you have any other thoughts to share?	X

Procedures for Recruitment, Participation, and Data Collection

For recruitment, participation, and data collection, several steps for each process commenced following approval from the Walden Institutional Review Board (IRB) to pursue this study May 21, 2019 (number 05-21-19-0158438). For transparency and organizational purposes, I maintained a log of these activities. To gain access to potential participants, I posted an advertising flyer in social media groups and educational news bulletins following established rules. I also sent the flyer to a list of professional contacts requesting that they share the flyer and encourage interested PBL teachers to contact me for more information. The flyer contained the title, purpose, and importance of the study, criteria for participation, benefits, expectations, and how to contact me.

With each potential participant who responded, I conducted a telephone screening interview using a script. Following this, I sent a letter of invitation and consent form to teachers who met the requirements for participation, and I thanked those who did not in a sensitive manner. The consent form included background information for the study, procedures, expectations, the nature of the study, sample interview questions, risks, and benefits of being in the study, payment, privacy, and security of identifying information. On the consent form I outlined the data collection sequence, types of data collected, and how teachers would be asked to participate. I also stated that participation was voluntary and that participants would be free to opt out at any time. In appreciation all participants would receive a $100 gift card regardless of when they exited the study. Last, the consent form contained Walden contacts for additional questions and a procedure for consenting electronically.

I accepted the first four teachers for participation in the study who electronically consented and closed the recruiting process. At this point I began data collection by e-mailing teachers the demographic and PBL overview forms. Following this, I conducted two phases of data collection that were completed with each teacher within three days before moving to the next. According to Smith et al. (2009) researchers using IPA should stay completely focused on the experiences of one participant at a time.

Phase 1 data collection activities focused on PBL teacher pedagogy and student products. For this phase I collected data from the PBL overview form, the first reflective journal prompt, and a semistructured interview of six questions. As soon as the interview dates were set, I e-mailed the first reflective journal prompt and upon receiving a response I e-mailed the interview questions for the teacher to consider before the first interview. The Phase 2 data collection process was like the first, but the focus was on PBL processes. As soon as the Phase 1 interview concluded, I sent the Phase 2 journal prompt. Upon receiving the second journal response, I sent the questions for the second interview to participants.

All interviews lasted no longer than 1 hour, and I conducted them remotely with each teacher from my home office computer using recorded Zoom video conferencing technology. For back up, I recorded the Zoom interviews using a Canon Vixia camcorder set up behind me on a tripod and focused on my computer screen showing both the teacher and I signing in the Zoom interviews. I recorded the interviews on a secure digital (SD) card and stored them on a password protected flash drive. A certified ASL interpreter came to my office to produce audio recordings of the video footage by viewing and interpreting the ASL interviews and voicing them in English using Zoom Audio recording technology. Using the flash drive, I played the Zoom interview recording on my laptop for the interpreter to watch while making a Zoom audio recording on my desktop computer as she interpreted. I transmitted the audio recordings digitally through a secure link to Caption Access for a professional captioner to produce a verbatim transcript of each interview in printed English for analysis. Caption Access sent the transcripts to me as an attachment that I downloaded and saved in a password protected file for analysis.

As described in the data analysis plan in the next section, I followed IPA processes to organize and analyze all Phase 1 and 2 data from each teacher. Teachers reviewed text excerpts from the data and emergent themes for conceptual accuracy. Prior to the debriefing interview, I sent each teacher a PBL-HOTS Analysis Packet (Appendix F) with the results applied in the PB-LIFTS conceptual framework and further analyzed using assessment procedures. Teachers were encouraged to analyze the results using the packet so we could compare our thinking during the debriefing interview discussion.

The third phase of data collection included an e-mailed journal prompt then a debriefing interview with each participant and this was guided by the PBL-HOTS Analysis Packet. I provided five debriefing interview questions within the packet and I recorded and transcribed the debriefing interviews in the same way as described for Phases 1and 2. The debriefing questions answered the fourth RRQ to gather teachers' perspectives of PB-LIFTS and this concluded the data collection process. At the close of the debriefing interview I thanked teachers for their participation, informed them that they would soon receive a gift card in the mail as an expression of my appreciation, and that I would send them a link to the completed study if they would like.

Data Analysis Plan

For IPA studies, Smith et al. (2009) recommended a 5-step procedure for data analysis including (a) reading and re-reading, (b) initial noting, (c) developing emergent themes, (d) searching for connections (e) moving to the next case. For this qualitative study exploring teachers' experiences using PBL, I combined a prestructured approach (see Miles et al., 2014) and a modified IPA data analysis process (see Smith et al., 2009). Using the PB-LIFTS conceptual framework, I collected data in the three dimensions and explored HOTS using multiple methods of analysis embedded within the framework. PB-LIFTS could be considered a prestructured instrument for analysis. Miles et al. (2014) described a "prestructured case" as serving as an outline or "a shell for the data to come" (p. 154). To organize data for analysis, I used the three dimensions of PB-LIFTS as a guide then applied basic analysis procedures recommended for IPA studies (see Smith et al., 2009) to distill text excerpts and discover HOTS in the PBL experiences teachers shared.

First cycle analysis. In the first cycle I organize the data into large segments that aligned with the topics of the first three related research questions: pedagogy, product, and processes. Focusing on data from one teacher at a time, for first cycle I reviewed entire Phase 1 and Phase 2 ASL video recordings and jotted notes to myself with time stamps related to the dimensions of PB-LIFTS and language use that aligned with RBT analysis (Anderson & Krathwohl, 2001). I also made a note of areas I wanted to double check for meaning against the transcript text for accuracy of my interpretations. Then I read and re-read all data collected in Phase 1 and 2 including interview transcripts, reflective journals, and PBL overview. Using hard copies, I made notes to myself above the text indicating questions or thoughts that come to mind and noting indicators for pedagogy, products, and processes from PB-LIFTS. Smith et al. referred these notes as exploratory comments that can lead to discovering emergent themes (p. 91). Miles et al. (2014) referred to this as an analytic memo that is helpful for finding concept patterns. I made notes associating text excerpts to the structure of PB-LIFTS. To prepare for second cycle analysis I electronically copied and pasted data into three separate files: pedagogy, products, processes and marked excerpt chunks that corresponded with the PB-LIFTS constructs for assessing levels of HOTS. Data from each teacher were kept together and treated as a single case.

Second cycle analysis. For the second cycle of analysis, I used charts to arrange data for two types of HOTS analysis using RBT and PB-LIFTS indicators for pedagogy and product. For the four process skills I used indicators for analysis only. To organize original data to answer the first three RRQs, I used charts. I included text excerpts in the far-left column and emergent themes in the next column. For each of the three RRQs, I added data to these charts, and asked teachers to review the text excerpts and the emergent themes to critique the accuracy of my interpretations. After receiving approval, I added two columns to the indicators table matching the emergent themes to the corresponding level in the PB-LIFTS constructs and a column for discrepant topics teachers described that did not align with PB-LIFTS but might be valuable to consider across cases later. With these charts filled out, I moved to the third cycle of analysis.

Third cycle analysis. In the next cycle I applied the results from the second cycle in the PBL-HOTS Analysis Packet (Appendix F) which I used for the debriefing interview to answer RRQ4: In what ways could the PB-LIFTS framework be useful to teachers for assessing HOTS? For this cycle I showed the results of RBT by plotting cognitive activity verbs and knowledge levels using the taxonomy table to reveal the dominant quadrant for thinking (see Anderson & Krathwohl, 2001). For PB-Lifts constructs I highlighted the levels indicated in the emergent themes for pedagogy type, student product innovation, and the levels of task, thinking, teamwork, and tools. I sent the packet containing the results to teachers to review and prepare for discussion in the debriefing interview. In the last step of my data analysis plan, I searched for common themes to report across cases as well as the discrepant topics that were raised more than once in the data and were outliers to the PB-LIFTS constructs but related to the research questions. Discrepant topics are considered by experts to be of value in research; according to Merriam and Tisdell (2016) addressing discrepant topics strengthens the trustworthiness of a study.

Issues of Trustworthiness

Incorporating established strategies that are known to increase the trustworthiness of research is imperative to pursuing a scholarly study that may influence instructional practices and impact education experiences for students as well as teachers. In this section I address four elements that determine the trustworthiness of qualitative research including credibility, transferability, dependability, and confirmability. I describe how these features and sub-strategies were incorporated in this study to strengthen trustworthiness. Secondly, in this section I address ethical procedures that were in place to assure respectful treatment of study participants.

Credibility

The credibility of a study can be established through qualitative mechanisms such as triangulation, prolonged contact, member validation, peer review, and reflexivity. Triangulation is the most complex, but all these elements were included in this study. Before addressing each, it is essential to clarify that the design for this inquiry is an eclectic approach to explore the experiences of teachers of the deaf using PBL to build HOTS. Denzin and Lincoln (2018) suggested that it may more appropriate to use the term qualitative *inquiry* rather than qualitative *research*; when paired with the word qualitative, the word research may imply to some that in order to be considered trustworthy the study methods must not depart too far from the rigid experimental designs of yesteryear. Denzin and Lincoln, the renown editors of the *SAGE Handbook of Qualitative Research*, remarked in the introduction to their fifth edition that we are amid an innovative period for qualitative researchers. The field is in a state of transition on a global scale as “21st century interpretive communities of practice” are moving qualitative research “in several directions at the same time” (2018, p. 1). Further, they alluded that qualitative strategies are not static and as the millennium progresses, scholars are witnessing unprecedented growth in interpretative methods for truth-seeking in the human sciences. A centerpiece of this paradigm shift is the concept of *crystallization* rather than *triangulation* in postmodernist texts to increase credibility (Richardson & St. Pierre, 2005) and I have embraced this concept in the study design.

The metaphor of the crystal prism rather than a triangular two-dimensional object was proposed by Richardson to illuminate the philosophical underpinnings of qualitative inquiry. Richardson posited that a fixed triangle used to conduct an inquiry imposes limits on exploration; on the other hand, crystals have “multiple dimensions that reflect externalities and refract within themselves, creating different colors, patterns, and arrays casting off in different directions. What we see depends on our angle of repose-not triangulation but rather crystallization” (Richardson & St. Pierre, 2005, p. 963). The concept of crystallization aligns with Moustakas’ (1994) assertion that an interpretative study has no endpoint or final discovery of truth to explain a phenomenon because there will always be another angle or lens to continue exploring. In the present inquiry, the concept of crystallization is most prominent in the multidimensional conceptual framework of PB-LIFTS. HOTS were explored in three dimensions of PBL including the teacher's pedagogical design, student products, and student learning processes. Multiple learning theories will be applied across the three dimensions to capture HOTS in PBL from several angles. Taken together, the concepts of inquiry and crystallization open the door for a plethora of unchartered methodical possibilities; however, according to Merriam and Tisdell (2016) this study also employs traditional applications of triangulation in the areas of multiple sources of data, multiple data collection methods, and the application of multiple theories.

I analyzed teacher's descriptions of their experiences with PBL using multiple sources of data for the three dimensions of PB-LIFTS that were collected at different times using the PBL Overview form, e-mailed reflective journal responses, and semistructured interviews. I applied multiple theories and assessment procedures to understand how teachers experienced using PBL to build HOTS, the three dimensions of PB-LIFTS, including the following:

- Teacher instructional pedagogy
    - RBT cognitive verbs and knowledge levels (Anderson & Krathwohl, 2001)
    - BUCK rubric criteria (BIE, 2013)
- Student PBL product
    - RBT cognitive verbs and knowledge levels (Anderson & Krathwohl, 2001)
    - BUCK rubric criteria (BIE, 2013)
- Student PBL processes
    - Task: BUCK rubric criteria (BIE, 2013)

- Thinking: DOK (Webb, 1997)
- Teamwork: Tuckman's Team Development Model (Tuckman, 1965)
- Tools: Resources materials (BIE, 2013); technology SAMR Model (Puentedura, 2006)

With multiple methods of data collection and analysis of HOTS within each teacher's PBL unit to discover HOTS, this exhaustive process could be considered as a method of achieving saturation within each case.

Aside from a crystalline inquiry approach and triangulated data sources, collection, and analysis to enhance credibility, the study also featured prolonged contact, member validation, peer review, and reflexivity. The researcher interacted with each participant through video telephone screening, initial data exchange via e-mail, reflective journal responses, Phase one and Phase two interviews that occurred one to three days apart, member checking preliminary results and the results of PB-LIFTS prior to the third debriefing interview. The three interviews lasted up to one hour each and for each participant, the data from Phase 1 and 2 were collected prior to moving to the next case. Smith et al. (2009) recommended this procedure to keep the researcher's attention focused on one case at a time. Thus, the study methodology incorporated prolonged contact and member validation that allowed me to gain insights into each teacher's experience with the phenomenon and to gather data in three dimensions to answer the study questions. The most helpful assistance for assuring data accuracy came from each participant's comments regarding text excerpts and associated emergent themes, as well as their perspectives shared regarding data analysis and application in the PBL-HOTS Analysis Packet (Appendix F).

Two mechanisms were in place to assure credibility regarding reflexivity and peer review that helped me understand the phenomenon of interest from the participant's perspective and thereby help me "get the blinders off" (Patton, 2015, p. 674). Regarding reflexivity, Patton emphasized the importance of active self-reflection and self-discovery as the study progresses. In the description of my role as the researcher I discussed issues that may contribute to personal bias based upon my background and possible preconceived ideas about my participants' experiences. Immediately after each interview I reviewed the recorded ASL video and made notes regarding areas of possible bias or misconceptions and documented time stamps on the audit trail log to revisit later and resolve through peer review with a deaf education expert or by checking the transcript produced from the audio recording made by a certified ASL interpreter and professionally transcribed.

To assure accurate interpretation of the data, two experts agreed to assist me as needed and signed confidentiality agreements. These individuals provided two types of expert consultation. One critical friend is a highly qualified sign language interpreter who was asked on two occasions to double check signed video segments that I questioned against the accuracy of the English transcript. The second critical friend holds a Ph.D. in deaf education and is a skilled qualitative researcher. This friend reviewed and approved the alignment of the research questions and the data collection instruments.

Transferability

In qualitative research, transferability is related to external validity and involves the extent to which the study could be replicated and applied in other contexts by other researchers. According to Miles et al. (2014), the key to transferability is providing study procedures that can be replicated in other settings to compare findings. The procedures must be clear, and I believe sufficient materials are provided for this study such that it can be replicated with other groups of teachers. Miles et al. raised another issue related to transferability and study outcomes stating that the findings should be "congruent with, connected to, or confirmatory of prior theory" (p. 314). This study draws together several theories that have been tested numerous times with a variety of samples. Miles et al. stressed that "any theories and their transferability (should be) explicitly stated" (p. 314). I believe this has been achieved in the methodology description and I will take care to explain in detail how the theories relate to the findings. Further, to strengthen transferability it will be important to provide detailed descriptions of how the data were analyzed and how discrepant data were used to add insight and deepen understanding of the phenomenon across cases.

Dependability

Dependability relates to multiple data sources concerning a topic that shows conceptual consistency when analyzed. The three dimensions of PBL were explored in reflective journals, semistructured interviews, and interview notes that participants shared. Keeping a careful record of how the study unfolds and decisions are made using the audit trail log provides details that can strengthen dependability from participant selection through collecting, coding, and interpreting data. Some researchers interpret dependability to mean that the tools and processes for a study can be replicated with another sample and arrive at the same findings. The tools and processes of the study can be replicated but the findings for the study are specific to the contexts in which the study is situated; therefore, dependability with regard to replication of detailed findings conflicts with the purpose, assumptions, and world view of the study. Merriam and Tisdell (2016) pointed out that not all common measures of trustworthiness in qualitative research will be congruent with the paradigm upon which every qualitative study is based.

Confirmability

Confirmability is like reflexivity which serves to strengthen the credibility of a study addressed earlier. According to Merriam and Tisdell (2016), confirmability is the counterpart of objectivity in experimental research. To increase the confirmability of the study, being transparent with explicit assumptions, methods of checking researcher bias, and keeping an audit trail of self-reflection and decision-making processes were in place. Engaging two experts will support confirmability as these peers will provide feedback regarding the accuracy of interpretations and potential researcher bias. Thus, for the study to have meaningful coherence, resonate with multiple audiences, and make a significant contribution, issues of confirmability cannot be undervalued.

Ethical Procedures

As the sole researcher for the study, consistent and conscientious observance of ethical procedures will heavily contribute to the trustworthiness of the study. These include several broad areas of ethical protections that will be addressed including gaining access to participants, treatment of human subjects, and treatment of data (Seidman, 2019). All three of these areas of ethical procedures have rigorous requirements in the application for Walden University Institutional Review Board (IRB) approval to conduct a research study. I obtained IRB approval on May 21, 2019 (Approval No. 05-21-19-0158438).

Summary

In this chapter, I provided a description of the research method for the study. This included an introduction to the study, detailed rationale, and selected method, how trustworthiness was established and ethical procedures. The methodology section included several topics including the logic behind participant selection, instrumentation, and procedures for recruitment, participation, data collection, and data analysis.

In Chapter 4, I provide detailed information regarding the results of this study with each of the four teachers including settings, demographic data, data collection and analysis, evidence of trustworthiness, and the results from analyzing PBL data from each teacher, and the results across all four teachers applied to answer the research questions.

Chapter 4: Results

Introduction

The purpose of this qualitative study was to explore the lived experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the areas of PBL pedagogy, product, and process. To accomplish this purpose, I developed a conceptual framework called PB-LIFTS that I applied to assess HOTS using in-depth reflections of teachers of the deaf on a previously implemented PBL unit. I explored how teachers of the deaf who are experienced in using PBL planned a favorite PBL unit and how they described the product students produced. In addition, I explored how teachers described the processes students used to produce the product.

The following CRQ and four RRQs guided this study:

CRQ: How do teachers of the deaf describe their lived experiences designing and implementing PBL to build HOTS with DHH students?

RRQ1: How do teachers of the deaf describe HOTS in their pedagogical approach for PBL?

RRQ2: How do teachers of the deaf describe HOTS in student PBL products?

RRQ3: How do teachers of the deaf describe HOTS in student PBL processes?

RRQ4: In what ways could the PB-LIFTS framework be useful to teachers for assessing HOTS?

In Chapter 4, I present the results of this IPA study. It is organized in six sections: setting, demographics, data collection, data analysis, evidence of trustworthiness, and study results. The study results include an analysis of all data sources from each teacher addressing pedagogy, product, process, and PB-LIFTS. In addition, the results section addresses how the findings across all four participants were applied to answer the research questions.

Setting

The four teacher participants for this qualitative IPA study taught in special school settings for DHH students located in four different regions of the United States. A total of 10 teachers expressed an interest in participating in this study but only four of them met all the criteria for participation and returned the signed consent form. Three of the teachers taught in state residential schools and one taught in a charter school. All four schools serve only students who are deaf or hard of hearing ages 3-21 with enrollments ranging from less than 100 to over 500 students. Although I attempted to recruit a variety of participants regarding PBL subject matter, communication mode, language, technology use, learning environment, or service delivery such as mainstream, itinerant, or special school settings, all four participants were from special schools for DHH students where the language of instruction was ASL.

Demographics

All four participants in this study were certified teachers of the deaf and had master's level degrees in Deaf Studies, Deaf Education, or Teaching the Hearing Impaired. One teacher also had a M.Ed. in Natural Sciences. Three of the participants were deaf and one was hearing. Of the four participants, two were male and two were female. All four teachers taught high school students who are deaf or hard of hearing and reported a high level of comfort using PBL. The number of years in teaching ranged from 5 to 33 years. Table 12 summarizes participant demographics.

Table 12

Participant Demographics of Experience, Gender, and Current Position

Participant pseudonym	Years teaching	Gender	Subject area	Grade level
Teacher 1	5	M	Theater + Media Communications	9-12
Teacher 2	24	F	Deaf History Studies	9
Teacher 3	33	F	Science	9-12
Teacher 4	12	M	Science	9 &10

The four participants and PBL descriptions for this study follow.

1. Teacher 1 taught high school theater and media communications. The selected PBL unit was implemented during the 2018- 2019 school year with teams of 4-6 DHH students in grades 9-12.
   - PBL Title: A Social Justice Documentary.
   - Essential question: How can using media impact or lead to social change?
   - Product: An impassioned documentary that included interviews and reenactments addressing the topic of elitism in deaf schools.
2. Teacher 2 taught high school deaf history studies. The selected PBL unit was implemented during the 2007-2008 school year with ninth graders. Working with another teacher, two classes of 4 and 7 DHH students were combined.
   - PBL Title: The Laurent Clerc Movie based on the novel by Cathryn Carroll *Laurent Clerc: The Story of His Early Years.*

- Essential question: Who was Laurent Clerc and what was his impact on deaf education and deaf people?
- Product: A nineteen-chapter educational film based on the novel.

3. Teacher 3 taught high school science. The teacher implemented the selected PBL unit during the 2018-2019 school year with DHH students in grades 9-12 who worked in teams of 3-4.
    - PBL Title: The PBL ROV
    - Essential challenge: Construct an underwater ROV (SeaPerch kit) capable of completing a "rescue challenge" and timed obstacle course run.
    - Product: The students had to fully assemble a SeaPerch ROV and control box and accomplish various underwater tasks for participation in regional SeaPerch competition.
4. Teacher 4 taught secondary science. The selected PBL was implemented during the 2018-2019 school year with a team of 3 students.
    - PBL Title: Blue People of Kentucky
    - Essential question: What was the cause of Ella's blue skin?
    - Product: Case study and creation of a pedigree tracing the lineage of the Fugate family to identify an inheritance pattern to determine the cause of Ella's blue skin.

Data Collection

As described in Chapter 3, I collected data for this IPA study from several sources over three sequenced phases that began after each of the four participants digitally consented to be part of this study. Phase 1 and 2 data collection was completed within 3 days for each teacher. Phase 1 data included the e-mailed PBL overview form and the first reflective journal response followed by the ASL recorded Zoom interview focused on teacher pedagogy and student product targeting RRQ 1 and RRQ 2. Phase 2 included the second reflective journal response and ASL interview recorded using Zoom focused on PBL processes targeting RRQ3. I recorded all interviews using a desktop computer and camcorder for backup from my home office. Phase 1 and Phase 2 interviews were then voiced in English by an ASL interpreter and audio recorded using Zoom in my home office. I sent the audio recording of each interview to Caption Access via secure link to produce transcripts that were then sent back to me as an e-mail attachment. Because Phase 1 and 2 occurred within a short time frame for each teacher, I report them together as follows.

Phases 1 and 2

Teacher 1 completed data collection for Phase 1 on July 24, 2019, and Phase 2 on July 25, 2019. Data were collected in the described sequence. Teacher 1 interviewed from his home and both interviews began promptly at 9:00 a.m. and lasted nearly an hour. Both interview transcripts were audio recorded and sent for professional transcription within a week of the second interview; however, due to staff vacations, I received both transcripts later than I had expected on September 6, 2019.

Teacher 2 completed data collection for Phase 1 on July 25, 2019, and Phase 2 on July 29, 2019. Both interviews began at 9:00 a.m. and lasted a full hour. Teacher 2 used a classroom laptop at her school to interview. Data were collected in the planned sequence with one addition: she typed out her notes for the first interview and e-mailed them to me.

Both interview transcripts were audio recorded and professionally transcribed; I received the transcripts August 16, 2019.

Teacher 3 completed data collection for Phase 1 on September 7, 2019, and Phase 2 on September 8, 2019. Data were collected in the described sequence. Teacher 3 preferred to interview from home using her personal laptop over the weekend and both interviews began at 12:00 noon. Phase 1 interview lasted a full hour. As a result of technical problems during Phase 2 interview, we went overtime. The internet froze a few times for a couple of seconds causing the recorded signing to skip. I had to ask the teacher to back up and repeat to be sure I captured everything accurately. At one point, we agreed to stop and reboot our computers hoping to resolve the problem. This improved the momentary video skipping. This teacher was very patient and was not concerned about the need to repeat segments. She also sent me a photo of the notes she had taken on the interview questions prior to the interview. To get an accurate calculation of the length of this interview, the Canon Vixia camcorder ran the entire time and showed 1 hour, 5 minutes and 33 seconds. By subtracting the time spent repeating and rebooting, the interview footage for captioning was 59 minutes. Both interview transcripts were audio recorded and professionally transcribed; I received the transcripts October 3, 2019.

Teacher 4 completed data collection for Phase 1 on September 17, 2019, and Phase 2 on September 20, 2019. Data were collected in the described sequence. Teacher 4 interviewed from his classroom computer during his planning period beginning at 8:40 a.m. The first interview lasted the full 60 minutes and the second interview was 54 minutes in length. An error occurred in the first interview with Teacher 4. I did not properly click on the Zoom recording button and I did not realize this until late in the interview. Fortunately, I had the Canon Vixia backup recording. Although the camcorder was focused on my computer screen to capture the zoom meeting showing both the teacher and me, the footage was clear enough for audio interpreting and data analysis. Both interview transcripts were audio recorded and professionally transcribed; I received the transcripts October 9, 2019.

Phase 3

Following the data collection for Phase 1 and 2, several steps took place before the debriefing interviews for Phase 3 could be conducted. As described in Chapter 3, I organized all the data collected from the first two phases for each teacher, selected text excerpts, and provided interpretations aligned with the PB-LIFTS conceptual framework for member checking. Next, I incorporated the results in the PBL-HOTS Analysis Packet to share with teachers in preparation for the Phase 3 debriefing interview targeting RRQ4. The debriefing interviews were conducted in the same way as Phase 1 and 2. We set the interview date and time, I e-mailed the reflective journal question, and after receiving their journal response, we interviewed for Phase 3 using Zoom, recording, interpreting, and transcribing. Scheduling the debriefing interviews was challenging as the teachers' availability was limited prior to Winter Break of 2019. Prior to scheduling the debriefing interview, teachers needed time to review the packet, which was 13 pages in length, and let me know they were ready. Teacher 1 and Teacher 2 completed the debriefing interview the last week of the semester before break from their schools on December 17 and December 19, respectively. Teacher 3 scheduled during break when she went to her school on December 27, and the debriefing interview with Teacher 4 occurred the first day back to school after break on January 6, 2020. All four of the teachers engaged in the

Phase 3 Zoom interview from school. Three of the four debriefing interviews lasted the full hour and one was 40 minutes long. Despite conducting the debriefing interviews at a hectic time for teachers, three of them engaged deeply in the data analysis and discussion; however, one teacher arrived late, had just come from a difficult meeting, and did not seem well prepared for the interview. The teacher did not want to reschedule so we went ahead with the debriefing and this may have influenced the data.

Data Analysis

For this study I used a modified IPA data analysis process described by Smith et al. (2009) combined with a prestructured qualitative approach recommended by Miles et al. (2014) to explore HOTS using my PB-LIFTS conceptual framework. I collected in-depth data from four teachers describing a PBL unit and applied multiple methods of analysis embedded in three dimensions of PB-LIFTS to capture the essence for their experience related to thinking skills. The PB-LIFTS framework contains descriptions of four levels of thinking from lower ordered thinking skills to HOTS in PBL pedagogy, product, and processes. As described in Chapter 3, I studied the ASL video interviews, and printed transcripts, journals, and data collection forms making handwritten notes and highlighting. Through this process of reading, re-reading, and initial noting, I discovered emergent themes and connected them to PB-LIFTS. More specifically, I organized all data collected for each of the four PBL units according to three dimensions of PB-LIFTS that aligned with three RRQs for analysis: PBL pedagogy, product, and processes. I used RBT to identify HOTS in the teacher’s descriptions of objectives and the PBL product. I also used indicators to discover HOTS across the three dimensions of PB-LIFTS. I did not use any coding software, and I followed the three-cycle data analysis procedure I described in Chapter 3 to answer the RRQs.

For each dimension of PB-LIFTS, pedagogy, product, and processes, I used a three-column chart adapted from Smith et al. for IPA data analysis using conceptual coding (2009, p. 93). For each dimension, I used indicators as subtopics to organize the excerpts in the far-left column. For example, RRQ1 addressed pedagogy; therefore, to organize the text excerpts I added the PB-LIFTS indicators for pedagogy: teacher role, student role, and learning design. I re-arranged text excerpts from all data sources under the indicators. Next, in the middle column I identified emergent themes from the excerpts, and last, made connections to PB-LIFTS and identified corresponding levels of HOTS in each dimension of the framework as described in Table 13.

Table 13

Research Question Data Analysis Table

Related research question: How do….		
Text excerpts	Emergent themes	PB-LIFTS
Place text excerpts from all data organized by three RRQ topics: pedagogy, product, and processes. For each of these dimensions, list the PB-LIFTS indicators in this column. Consider the meaning of excerpts and rearrange them according to each indicator for interpretation.	Interpret text excerpts in relation to PB-LIFTS indicators, analyze the meaning of excerpt chunks, capture the essence of the PBL experience and provide a succinct description. Note discrepant topics.	Distill themes and find semantic connects to PB-LIFTS. Identify placement and level of HOTS in PB-LIFTS

Evidence of Trustworthiness

As described in Chapter 3, I upheld issues of trustworthiness using techniques that supported the credibility, transferability, dependability, and confirmability of this study recommended by Merriam and Tisdell (2016). Qualitative research mechanisms that were used in this study and served to increase credibility were triangulation, prolonged contact, member validation, and peer review. I used two methods of triangulation; one method described by Richardson and St. Pierre (2005) called crystallization, allowed me to understand how teachers used PBL to foster HOTS by applying multiple theories to explore PBL pedagogy, product, and processes and gain access to multiple viewpoints. The second was a traditional form of triangulation using multiple sources of data and collection methods including e-mailed responses to forms, three reflective journals, two semistructured interviews and one debriefing interview using Zoom. The data collection, analysis, and debriefing process included prolonged contact and two instances of member validation. Peer review included the use of two experts, one in interpreting and the other in deaf education. The interpreter expert helped increase accuracy of interpretations that were professionally transcribed, and the other expert approved the alignment of the research questions with the instruments used to collect data. The interpreter expert was most helpful as several instances arose where I challenged the accuracy of the transcript when compared to reading the interviews in ASL. There were times I thought the voice interpreter embellished or changed the meaning that the teacher of the deaf expressed, and a couple of times the interpreter’s word choice skewed the meaning. Having the opportunity to review and discuss with this expert helped with reflexivity as well to keep bias in check.

As described in chapter 3, in addition to credibility, I employed other techniques including transferability, dependability, and confirmability to increase the trustworthiness of this study. I provided the theories embedded in PB-LIFTS as well as the tools used to apply them and analyze the data so this study could be replicated and therefore, would be considered transferable. Regarding dependability, the multiple sources of data showed conceptual consistency when analyzed and I kept a detailed record of how the study progressed at all phases. According to Merriam and Tisdell (2016), confirmability is like reflexivity in that the researcher must be transparent and actively guard against the potential for researcher bias. To support confirmability, I maintained a research journal documenting instances of suspected misinterpretation and possible bias. As mentioned earlier, I consulted with the expert interpreter when this occurred and studied the video tapes making constant comparisons with the transcript. Another way that I maintained transparency was through member checking. I shared the excerpts from which I drew emergent themes and made connections to the PB-LIFTS framework. Further, in the debriefing interview I invited each participant to engage in interpreting the data as a coresearcher with me. There were numerous times that we had subtle differences in our conclusions using the teacher analysis packet to summarize findings. When this occurred, I listened carefully to the teachers' views and we negotiated. In sum, I believe that the mechanisms described here successfully increased the trustworthiness of this qualitative inquiry.

Results

Using IPA methodology described in Chapter 3, I analyzed data collected from four teachers of the deaf. In this section, I first present the results of data analysis organized by teacher and then consolidate my findings aligned to each of the research questions and the PB-LIFTS framework. I also discuss discrepant data which were topics that participants addressed that were outliers to the framework but may contribute to better understand the findings of this study.

Teacher 1: Social Justice Documentary

Teacher 1 selected a favorite PBL unit taught in the spring of 2019 that addressed elitism as a social problem in a deaf school. Students collaboratively selected this topic after deep class discussions sharing socially oppressive personal experiences that developed their awareness of social justice issues. Students created a documentary film incorporating interviews as a tool for sharing perspectives to impact social change. Using RBT, I analyzed HOTS in teacher pedagogy and student product. Secondly, I used indicators to analyze HOTS in each dimension of PB-LIFTS.

Revised Bloom's taxonomy analysis. Using the cognitive activity verb chart (Figure 7) and RBT to analyze objectives and the product description provided by Teacher 1 on the PBL overview, the results revealed that this unit engaged students in multiple cognitive activity levels including understand, analyze, evaluate, and create, while using procedural and metacognitive knowledge levels to produce a documentary in response to the essential question, "How can using media impact or lead to social change?" I used RBT cognitive activity verbs and knowledge levels to identify levels of thinking embedded in the teacher's three PBL objectives and product description on the overview.

The first objective was "The students will explore the value of interviews in creating original theatre." To 'explore the value' implied that students assessed, and this matched with the cognitive verbs analyze and evaluate. The knowledge level for performing these verbs related to using interviews to create original theater implied that students would know how to interview, indicating procedural knowledge, and to use this skill to create original theater implied strategic knowledge classified in the RBT taxonomy as procedural and metacognitive. In the debriefing interview we identified two pairs of cognitive verbs and knowledge levels for objective 1: analyze/procedural and evaluate/metacognitive.

The second unit objective was “Students will explore and articulate how social justice impacts an individual and a community.” This objective contains multiple cognitive activities and implied that students would research, comprehend, and explain which is classified at the cognitive level, understand, and the procedural knowledge level to know how to do these activities. Secondly to determine how a complex concept impacts people on two social levels, I classified at the evaluate cognitive level and metacognitive knowledge level where thinking processes and perceptions would be considered. In the debriefing interview we identified two pairs of cognitive verbs and knowledge levels for objective 2: understand/procedural and evaluate/metacognitive.

The third unit objective was “Students will explore how performance and digital media/technology create the opportunity to impact social change.” Again, within this objective there were multiple layers of cognitive activities. Students would need to evaluate to explore how something can create opportunity and secondly, they would need to imagine possibilities, indicating the cognitive activity, create. The objective also implied that students have procedural knowledge for technology use and metacognition would be needed to consider capturing viewpoints that could cause social change. In the debriefing interview we identified two pairs of cognitive verbs and knowledge levels for objective 3: evaluate/procedural and create/metacognitive.

For the product description, Teacher 1 described the students' final product on the overview as "An impassioned documentary that addressed the topic of elitism in deaf schools and incorporated interviews and re-enactments, appealing to all learning styles." This description implied that to produce this product students engaged in cognitive activities at the levels of analyze, evaluate, and create. Further, students needed procedural knowledge to know how to produce the film as well as metacognitive knowledge to present a variety of viewpoints from interviews. In the debriefing interview we identified three pairs of cognitive verbs and knowledge levels for the product description: analyze/metacognitive, evaluate/procedural, and create/metacognitive. We plotted the cognitive activity verbs and knowledge levels for the learning objectives and the product description using RBT Taxonomy Tables. The results showed strong dominance for both pedagogy and product in the highest quadrant for HOTS indicating that the PBL was designed by the teacher with HOTS embedded in the objectives and the students produced a product showing evidence of HOTS engagement.

Indicator analysis. To identify levels of HOTS in the three dimensions of PB-LIFTS for the Social Justice Documentary PBL unit, I used indicators from the literature review to analyze data collected from Teacher 1. For each area of analysis, the PB-LIFTS framework contains four levels of embedded thinking skills from level 1 (lower ordered thinking skills) to level 4 (HOTS). The results showed that the teacher's pedagogy type for this PBL unit was social constructive. Prior to the debriefing interview, Teacher 1 used PB-LIFTS product level descriptions and felt that the social justice documentary was both level 3 and 4; however, during the debriefing interview he felt strongly that the student product was at level 4, Innovate. The data analysis results of the skills used to produce the product were task level 3, thinking level 4, teamwork level 3, resource tools level 3, and technology tools level 4.

Pedagogy indicators. To identify the pedagogy type for the Social Justice Documentary, I studied the language and concepts Teacher 1 used to describe this PBL in reflective journals and semistructured interviews using indicators. By identifying the teacher role, student role, and learning design, the results indicated that the teacher's pedagogy type on the horizontal dimension of PB-LIFTS was social constructive.

In regard to teacher role in interview 1, Teacher 1 explained that one challenge of teaching an elective class is that high school students are "not grouped based on their academic level" and because students had a range of skills and background experiences, by leading discussion-based instruction "they would be learning from each other and a PBL is great for doing that." In the first interview, Teacher 1 described how he prepared students for engagement in the social justice PBL addressing knowledge gaps and explained, "this class involved a lot of group discussion that really is critical, you have to [help students] understand the topics and what they mean." For example, to help students understand the concept of social justice and the power of interviewing as a means of sharing perspectives, he showed a documentary film, The Laramie Project, that incorporated interviews showing the impact of a hate crime on community members. Teacher 1 described how he supported social learning using this film and stated, "So the students watched the movie, and periodically we would pause the movie so that we could discuss it, and I could expand and clarify. And at the end of that, we would have group discussions."

When students understood the concept of social justice and were ready for PBL engagement, Teacher 1 gave them greater autonomy to collaborate. In interview 1 when reflecting on how students decided on their social justice topic, it was evident that the teacher encouraged them to take charge of their learning in his statement, "I tried not to influence them and give them ideas about the topic. I just let the group discuss that, and trust that they would make of list of things that were important to them." It was also evident from a reflective journal 1 comment that student-directed learning continued in his remark, "they get to pick their topic they want to address, and they fly with it." In sum, the theme that emerged from the data indicated that Teacher 1 described his role as a supportive guide for social learning.

Regarding student role, students engaged in student-led collaborative activities beginning with the process of deciding their PBL topic. To come up with a topic for their documentary, Teacher 1 suggested that students share their personal fears that cause them to feel socially oppressed. In interview 1 Teacher 1 recounted that students brainstormed a list of topics that were important to them and then they had to "whittle down that list of ideas" to agree one significant topic that applied to everyone in the group. They identified elitism as a "big problem at the school because elitism is oppressive to other students."

After the preteaching activities, Teacher 1 described in interview 1 the many ways that these students exercised student-directed learning and collaborative decision making such as when they decided who they would interview and developed interview questions. Further, the students decided "who would be filming, who would be doing the editing, who would write the skit or the script." Teacher 1 described other ways that students exercised autonomy for student-driven learning by giving them independence to conduct interviews, "I gave the trust and the freedom to leave class." They used their time responsibly as described by Teacher 1 in his interview 1 comment that when the students came back to class, "they typed up what they got from the interviews, and then they picked a situation that could be developed into a script or a skit." The theme that emerged from the teacher's descriptions regarding student role in this PBL indicated that the learning was student-led, collaborative, and interactive.

Learning design is the last pedagogy indicator for on the PB-LIFTS and several excerpts from the data indicated that this PBL was social constructive learning which includes social interaction, co-construction, and an unpredictable product. As described earlier, in interview 1, Teacher 1 described how the product for this PBL was developed through student engagement; therefore, prior to this, the product outcome could not be predicted. In interview 1 Teacher 1 described himself as a co-learner, "learning along with the class" when students shared their experiences with social oppression. In interview 1 he also commented that "we set up agreements about when things were due" indicating that he engaged in co-construction for the assignment.

In both reflective journal 1 and interview 1, Teacher 1 described his learning design as social interactive. Drawing from 3 years of experience with this PBL unit, in reflective journal 1 he stated that it "has always been one of my favorite lessons" as it "teaches my students about leadership, organization, and communication, as well as what social justice is and how it applies to them." In interview 1,when explaining why he wanted his students to learn about social justice, Teacher 1 remarked that he saw this as an opportunity for students to develop needed “social-emotional skills” and inferred that this can be developed through social interaction discussing “topics that are meaningful and important to them.”

In interview 1, Teacher 1 clarified that his teaching design was influenced by Augusto Boal and referred to Boal’s instructional approach as “theater for oppressed people.” Teacher 1 shared that he and his students had experienced oppression and inequality in a variety of ways, and he predicted that students might suggest topics such as racism, audism, growing up in a hearing home, and homophobia. He saw the social justice PBL as an opportunity to discuss these issues and develop social-emotional skills by learning to “understand other people’s perspectives” and elaborated that, “they have to develop that ability to step outside themselves and look from a different perspective.” Teacher 1 described theater as a “beautiful vehicle to help them learn a different perspective” while “learning about themselves...and where they fit” at many social levels including within the “general human community.” In sum, emergent themes regarding the learning design for this social justice PBL indicated intensive social interaction. Thus, across the indicators for pedagogy type on the PB-LIFTS, the emergent themes indicated a social constructive pedagogy type characterized as teacher supported, collaborative student engagement, and co-constructed knowledge and products.

Product indicators. To identify the level of innovation for the students’ PBL product, I studied the language and concepts Teacher 1 used to describe the social justice film in reflective journals and semistructured interviews using indicators. Analyzing excerpts related to product originality, creativity, and content indicated that the social justice documentary on elitism was at the highest level of innovation on the vertical dimension of PB-LIFTS.

For the first product indicator, product originality, Teacher 1 described in interview 1 that by watching the movie, The Laramie Project, students saw how the use of interviews in film could “raise awareness” about a social problem. In interview 1, Teacher 1 described the students’ process of choosing elitism for their topic with the goal to create an original documentary that could “help everybody understand” the meaning of elitism and “how it impacts the academic culture” at their school. Because this product was personalized addressing issues within a specific learning context, the emergent theme to describe the film produced was “original theater” which was the teacher’s hope stated in Objective 1 for this PBL.

For the second product indicator, product creativity, in interview 1 Teacher 1 recounted technical and theatrical skills such as using iMovie, directing, editing, use of lighting, skit writing, narration, and acting that his students applied to produce a unique and creative film intended to raise awareness about elitism. In reflective journal 2 Teacher 1 stated that “by creating a final documentary project, they were able to share experiences and knowledge with the entire school” when the video was broadcast on the school television system.” Thus, the emergent theme for this film was that it was creative and unique.

For the third product indicator, product content, Teacher 1 described in interview 1 the details of how he engaged his students in deep thinking so “they opened their minds” about social justice issues. This dialog led to their choosing a complex topic “that’s important to them.” To gain insights about elitism and various perspectives, they explored individual and collective identities and the teacher commented “really that's high-level thinking.” For example, in interview 1, he recounted how he guided his students to explore their “self-identity” as deaf individuals, as members of a deaf school, and larger deaf community to illustrate that social group affiliation can be multidimensional. The teacher expressed in interview 1 that the content of the product was complex with many issues for his students to consider in the creation of a film showing people’s perspectives about social status. As a result, emergent themes describing the product content were that the topic of the PBL was complex and rich in deep thinking. Therefore, across the indicators for the level of product innovation on the PB-LIFTS, the emergent themes placed at the highest level on the vertical dimension on PB-LIFTS, *innovate*. At this level students create a unique and original PBL product and demonstrate deep-open-ended multifaceted learning. Based on this analysis process, in the debriefing interview, Teacher 1 decided that the product level was rightfully at level 4, not levels 3 and 4 as he originally thought.

Process indicators. To gain a deeper understanding of the level of HOTS students used to produce the Social Justice Documentary, I examined the 4T processes that the teacher described in reflective journals and semistructured interviews. The language and concepts Teacher 1 expressed relative to the 4Ts revealed emergent themes for four process skills. Using emergent themes, the level of HOTS for each process could be identified in the third dimension PB-LIFTS. Emergent themes for task, thinking, teamwork, and tool use indicated varied performance levels.

Regarding task, PB-LIFTS indicators include PBL planning, organization, and accountability. In interview 2, when asked how students planned the PBL, Teacher 1 explained that the four student members of this PBL team were used to working together and inferred that the students learned planning skills in his class prior to the spring of 2019 in his comment, “the students have been in my class, and they've gotten used to my structure. They're used to my expectations.” Teacher 1 stated, “they know (what to do) and they've agreed within their groups when everything's due. And then they let me know they've written all this stuff down.” From these remarks, the planning process was not highly structured, but adequate. Regarding organization, Teacher 1 described in interview 2 that students were organized. He stated that the moment class begins, “they get up and they start working” For example, “they grab the lights and set up the cameras…. They make sure the batteries are charged… they get all the papers that they need…and planning sheets.” Thus, their project organization was good. Regarding accountability, in interview 2, the teacher described a time when he had to intervene because one student “was just coasting along” and the team was unable to keep him engaged and accountable. The teacher explained in this interview that because the student lacked technical skills, he felt “uncomfortable” and “overwhelmed.” The teacher described how he led a discussion with the whole class to help them become aware of “different kinds of learners.” Teacher 1 stated that following that, “they just took off, because they had learned how they learn” and understood the different needs among the group. For PBL task, the excerpts led to emergent themes that matched the PB-LIFTS task level 3, systematized. PBL planning was adequate, organization was good, and the team was usually accountable.

Regarding thinking, PB-LIFTS has four levels ranging from low to high including recall of facts, comprehend, strategic, and extended thinking. Data from interviews 1 and 2 and reflective journal 2 with Teacher 1 revealed that the students were engaged in significant critical thinking at all stages of the project; therefore, we rated this PBL at the highest level 4: extended in the debriefing interview. In reflective journal 2, Teacher 1 listed the thinking skills such as collaboration, leadership, critical thinking, social emotional skills that were “evidenced in the production process as well as their final documentary.” In interview 1 Teacher 1 described social-emotional learning that occurred because of collaborative engagement in PBL saying, “Because they work together and they’re learning from each other, they have to communicate with each other.” In interview 2 Teacher 1 commented that students used communication skills to problem-solve when frustrations occurred; He shared that students were able to “take a step back and explain things, and maybe approach it in a different way.” In interview 1 Teacher 1 said his students had to “really think” deeply about their experiences with social oppression when brainstorming topics for the documentary considering both the present and desired state by asking themselves, “how can I change my community?” During this interview Teacher 1 described stages of critical thinking that students engaged in to choose the PBL topic; they presented their idea to the group and advocated for it, listened to the ideas of others, weighed the significance of topics, and came to an agreement on a topic that applied to everyone and had the potential to positively impact the school community.

During interview 2, Teacher 1 shared an incident that occurred during the process of making the film where students needed to honor privacy issues and used critical thinking and technology skills to problem-solve. During the debriefing interview Teacher 1 expanded on this point and explained that students signed a confidentiality agreement so when a student who was interviewed decided he was uncomfortable being shown on the film, to honor his right to anonymity, the team “developed a script to represent the situation and they pieced [the film] together and edited then gave feedback to each other. That’s a lot of critical thinking.”

In interview 2, Teacher 1 described the value of reflective thinking at the end of the PBL for self-evaluation and how skills used in the PBL might be applied beyond high school:

> They reflect on their own contribution, what they brought to the project. They reflect on each other, on the team, on the process, the final product, and they reflect on what they've [done] so far and how that might apply to their future job. . . . So [this is] deep reflection.

Across all data sources, Teacher 1 shared many examples of HOTS that students demonstrated. The emergent themes related to levels of thinking included prolonged engagement in working with complex concepts. Hence, for thinking, this team achieved the highest level on PB-LIFTS, extended thinking which requires complex reasoning.

Regarding teamwork, PB-LIFTS has four levels of team development including forming, storming, norming, and performing. During the debriefing interview Teacher 1 felt that this team was at a level 3, norming, and admitted that in the class he focused on, three of the team members were rather “high functioning” but one student was not; and in these elective classes, “lower students will just follow.” In the debriefing interview Teacher 1 stated that he felt “teamwork is an area where they could improve. I want to make sure that the work is more balanced” because the team tended to rely on the leader. In interview 2 Teacher 1 explained that he was “fascinated” watching teams evolve through engagement over the school year. In the fall it is “kind of magic, but it just seems…in every class there's one student who is just the natural leader." Then "about spring, that student starts to kind of relinquish that role" and another student would take over. In interview 1, Teacher 1 explained that in the production of the video, there were roles such as director, narrator, and actor and "all of the students had to be involved in the video. . . . So they would take turns." Although in interview 1 Teacher 1 expressed pride reflecting on how the team worked collaboratively and said, "They learned to figure out their own strengths and bring those to the group", this occurred after the teacher needed to intervene because one student was not participating equally with his peers.

When asked in interview 2 if they had formal descriptions of roles, Teacher 1 inferred in interview 1 that it was a natural process and "they just kind of pick it up." However in interview 2, Teacher 1 remembered that when a director gave the role to another student, he thought the student would know what to do from observing him, but he learned that he needed "to actually do it, maybe with them the first time so they [sic] get it." In the debriefing interview Teacher 1 suggested that in a future PBL "I could start with a discussion about the skills that they have and what they are good at related to the different processes" and he named acting, script writing, and editing as examples. Teacher 1 suggested in the debriefing interview that starting with all students being recognized for their strengths would be a good place to start, then after feeling positive about what each student does well, they could expand to other roles. In sum, across the data, Teacher 1 described an informal dynamic for teamwork with some norms beginning to take shape. By the debriefing interview he suggested this was an area for improvement and stated they were at level 3 for teamwork norming.

Regarding resource tools, Teacher 1 in interview 2 stated that the Laramie Project video was the main resource used to “open up the topic” of social justice, but for this PBL, the greatest resources were the students’ own experiences and the stories that were shared with them in interviews. The stories related to elitism the students gather in interviews were varied and could therefore, be considered as having multiple resources as an emergent theme. In interview 2, Teacher 1 described how an actor in the film had one person explain the meaning of elitism or give the definition, but Teacher 1 did not suggest that students used research to gain this knowledge and he rated resources at a level 3 in the debriefing interview. In contrast, he rated technology tools at a level 4, because they used technology that allowed for the creation of an innovative product. To produce this one-of-a-kind film that was shown school-wide and generated discussion about elitism, in reflective journal 2, Teacher 1 commented that skills in technology and media were evidenced in both their production process as well as their final documentary video. In interview 2 Teacher 1 expanded on this and listed a variety of technology tools they used such as green screen, iMovie, projectors, cameras, iPad, laptops, and they used communication technology to work collaboratively using several “different ways to communicate with each other.” During interview 2 Teacher 1 described students as resourceful technology users for the creative process; He explained that when they “saw an example of technology use… they looked on YouTube to find a description and the instructions of how to do that in iMovie.” Thus, the emergent theme for technology use was that it allowed them to create something that was once impossible. The film for this PBL designed to foster social change was rated at the highest level of PB-LIFTS, Unique and Innovative.

PB-LIFTS. Using pedagogy indicators, the emergent themes across the data aligned with social constructive pedagogy type C on PB-LIFTS and using product indicators, the emergent themes aligned with level 4, innovate. Plotting the pedagogy and product results within the 16-cell matrix of the PB-LIFTS framework, the intersecting cell for this PBL unit was C,4. This finding aligns with the RBT analysis that showed the PBL unit was in the highest quadrant for HOTS. I superimposed the RBT quadrant on PB-LIFTS by adding a bold square around the perimeter of C3, D3, C4, and D4. To show where the PBL unit described by Teacher 1 placed within that quadrant on the PB-LIFTS, I added a large font T1 in cell C4 as shown in Figure 10.

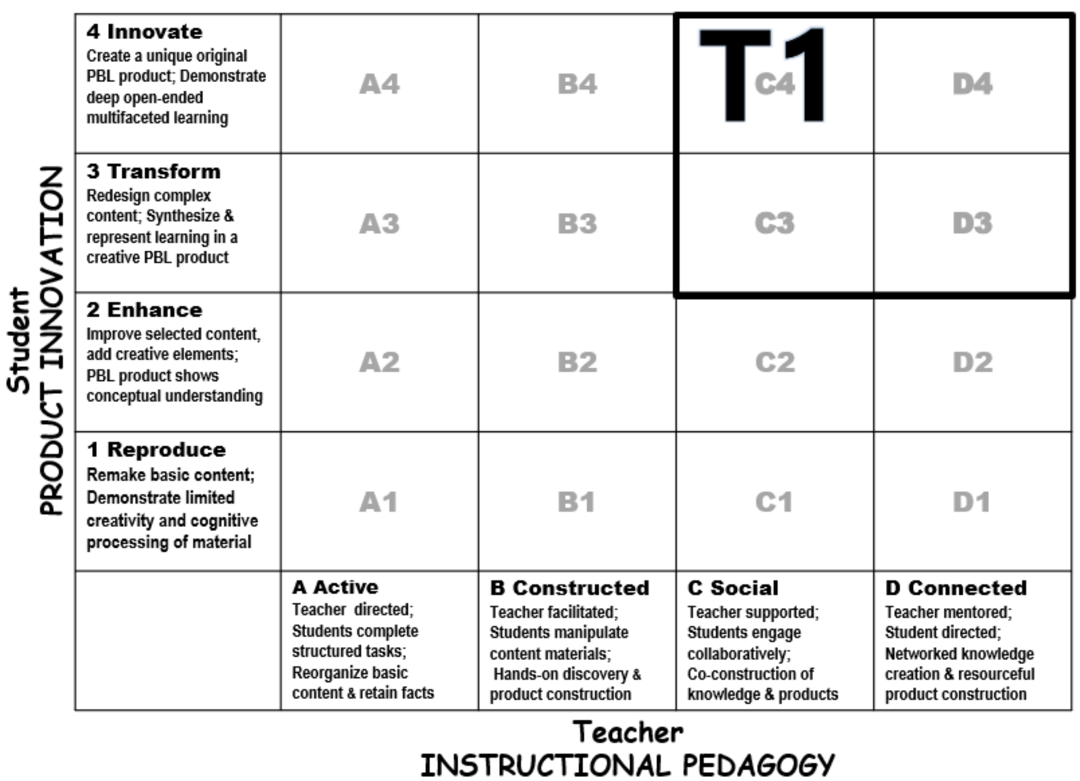


Figure 10. Unit from Teacher 1 plotted on PB-LIFTS framework. Note1: T1 = Teacher 1 Note 2: Bold square represents the revised Bloom's Taxonomy, the highest quadrant for higher order thinking.

By examining the results of the process skills that were used to produce the product, thinking and technology tool use were remarkably high which supported the score for this innovative product. He was especially pleased with the complexity of the thinking students demonstrated. Teamwork and task were at a level 3. For task, the teacher was active in guiding the daily process but once a structure was understood, students took responsibility. Teacher 1 identified teamwork in the debriefing interview as an area that he would focus on for improvement. He explained that three of the students in his class were “pretty high functioning” and one student was lower and would just follow. He “wanted to make sure that the work is more balanced.” For the next PBL Teacher 1 suggested “I could start with a discussion about the skills they have and we could think more about what they are good at and…decide the roles” this would give them ideas for “how they can contribute.” Teacher 1 implied that the PBL process skills might be more useful for conversations with individual students.

When considering the use of RBT compared to the use of indicators to identify HOTS, Teacher 1 said that he had not used RBT before and was somewhat familiar with RBT because he knew of Bloom’s work. He stated that the cognitive activity verb chart (Figure 7) could be useful for planning a new PBL. When looking at the results from RBT, Teacher 1 acknowledged that “this PBL is in the highest quadrant but that isn’t very meaningful” and he agreed that perhaps using indicators could be more informative but scoring the whole group using the process indicators was difficult and would be more useful with individual students. Teacher 1 stated that PB-LIFTS could be useful for showing an administrator how his PBL promoted HOTS.

Teacher 2: The Laurent Clerc Movie

The focus of Teacher 2's PBL unit was for two academically diverse groups of students to create a movie in ASL about the first deaf teacher of the deaf in America based on a 19-chapter novel, *Laurent Clerc: the story of his early years* (Carroll & Lane, 1991). The setting for this book was 18th century France and was one of several recommended books for the 9th grade curriculum at this school. In interview 1 Teacher 2 explained that there were two distinct classes of 9th grade students in 2007-2008; Teacher 2 had a class of four "academically advanced students" she referred to as Team A. She added that these students were college bound and "came from deaf families". Another teacher had a class of seven students (Team B) who struggled with the story of Laurent Clerc because they "were non-readers or low readers and needed the information provided to them in ASL." In interview 1, Teacher 2 recounted that "Team B is really why we did the movie and the acting piece." She added that Team B wanted to act it out…. they wanted the story to come to life, and they wanted to understand." In reflective journal 1 Teacher 2 shared that "the higher group can always benefit from story signing" and she believed that although there was "a big gap, we decided to combine the two classes for PBL." In interview 1 Teacher 2 stated that "after a bit of trial and error, teachers realized" how Team A and Team B could work together and agreed that "a video recording would be a great project." In reflective journal 2 Teacher 2 listed many high-level skills students used for this PBL and in interview 1, she stated that the students "were immensely proud of their product. It was used as a teaching resource in future Deaf Studies."

Teacher 2 explained in reflective journal 3 that she chose this PBL from 2008 for this study because of the lasting impact it had on students. For example, in 2011 she accompanied a group to France and one student who was in group B for the Clerc movie PBL amazed local experts with his detailed knowledge of Clerc. When they visited Clerc's hometown of La Balme. Teacher 2 recalled an incident that still gave her "goosebumps." She said, "my student was standing on the cliff at that church overlooking the town and Clerc's ancient residential home and was bawling saying he wished the other students could see this." She felt that the Clerc movie PBL would be excellent for studying HOTS. To identify HOTS for this PBL, I used RBT to analyze the learning objectives and product description. Secondly, I used indicators to analyze HOTS in each dimension of PB-LIFTS.

Revised Bloom's taxonomy analysis. I used the cognitive activity verb chart (Figure 7) and RBT to identify HOTS embedded in three objectives and the product description provided by Teacher 2 on the PBL overview. The results revealed that this unit engaged students in multiple cognitive activity levels including understand, apply, analyze, evaluate, and create, while using procedural and metacognitive knowledge levels to produce a movie in response to the essential question, "Who was Laurent Clerc and what was his impact on Deaf Education and Deaf people?"

The first objective was "Group A will critically analyze text, collaborate, synthesize main points, translate English print to ASL, and teach Group B." Objective 1 contained and implied several cognitive activity verbs from the RBT taxonomy; Group A had to understand the text, sort main points, negotiate with group members, and translate for adapting the story into a visual language. Thus, this objective includes five taxonomy levels understand, apply, analyze, evaluate, and create. The knowledge level for performing these verbs implied strategic knowledge classified in the RBT taxonomy as procedural for working with the text and collaborating with Group B in sequence. As Group A progressed through the chapters, they had to keep the learning and communication needs of Group B in mind which required metacognitive skills to judge the effectiveness of their teaching. In the debriefing interview we identified three pairs of cognitive verbs and knowledge levels for objective 1: evaluate/procedural

The second unit objective was "Group B will understand the story including historical and cultural background needed to contribute dramatic and artistic skills in the production of an original film." This objective contains multiple cognitive activities and implied that students will not only understand the story signed to them by Group A, but they also had to learn about life in the late 18th century in another country to grasp the historical and cultural background needed to contribute dramatic and artistic skills. Group B worked with knowledge at three levels, the conceptual to understand elements and relationships of a larger structure, procedural to make inquiries and follow sequential steps in the production process, and metacognitive knowledge to strategically work through cognitive tasks. In the debriefing interview we identified three pairs of cognitive verbs and knowledge levels for objective 1: evaluate/procedural

The third unit objective was "All students will collaborate to dramatize and film a 19-chapter movie correlated to the book illuminating the story of Clerc and his profound impact on the deaf community." This objective implied multiple layers of cognitive activity with two diverse groups learning to work together on a large project. Collaborating to dramatize and film implied that they would share creative ideas for acting and portraying characters which also implied that they would need to consider period costumes and props. To do this, they would use strategic metacognitive knowledge and then to correlate these activities to the book would require procedural knowledge. Last, they were to think beyond the story to understand Clerc's profound impact on the American deaf community this implied that they would know what Clerc did to become so famous. In addition, they would evaluate Clerc's experiences growing up and make suppositions regarding how those experiences may have shaped his actions later in life. They would need to brainstorm ideas to make these connections. Teacher 2 pointed out during the debriefing interview that on the surface, Objective 3 includes cognitive activity verbs at all levels. When assessing the higher order cognitive activities paired with knowledge levels, we found that this objective contained two sets of HOTS including evaluate/procedural and create/metacognitive.

For product description, Teacher 2 described the students' final product on the overview as "A nineteen-chapter educational film based on the novel." This description implied that students engaged in cognitive activities at the upper levels of the taxonomy including analyze, evaluate, and create. Regarding knowledge levels, they had to use procedural knowledge to follow the book and to produce a film and they would use metacognitive knowledge to judge their work as coherent to an audience. Thus, for objective 3 we plotted four sets of pairs on the taxonomy table: analyze/procedural, evaluate/procedural, evaluate/metacognitive, and create/metacognitive. Last, we plotted the cognitive activity verbs and knowledge levels for both the learning objectives and the product description on the RBT Taxonomy Tables to identify the level of HOTS for pedagogy and product. The results showed strong dominance in the highest quadrant for HOTS.

Indicator analysis. To identify levels of HOTS in the three dimensions of PB-LIFTS for the Laurent Clerc Movie PBL unit, I used indicators from the literature review to analyze data collected from Teacher 2. For each area of analysis, the PB-LIFTS framework contains four levels of embedded thinking skills from level 1 (lower ordered thinking skills) to level 4 (HOTS). The results showed that the teacher's pedagogy type for this PBL unit was social constructive. The student product innovation results showed some qualities in both level 3, transform, and level 4, innovate. The data analysis results of the skills used to produce the product were task level 3, thinking Level 4, teamwork Level 3-4, and resources tools Level 3 and technology tools Level 3-4.

Pedagogy indicators. To identify the pedagogy type for the Laurent Clerc Movie, I studied the language and concepts Teacher 2 used to describe this PBL in reflective journals and semistructured interviews using indicators. By identifying the teacher role, student role, and learning design, the results indicated that the teacher's pedagogy type on the horizontal dimension of PB-LIFTS was social constructive.

Regarding teacher role, Teacher 2 stated in interview 1 that both teachers were "very kid-centered; we focus on what [the students] need." She also admitted that when she and the other teacher first agreed to make a movie, "we had no idea how we were going to divide up the tasks and make sure all students were involved." The first few chapters were trial and error until we could see clear strengths and roles of specific students. It also took the students a bit of time to see how this routine would work."

In interview 1 Teacher 2 facilitated the development of routines early in the PBL using a whiteboard and said, “my role was just kind of organization….to put down what needed to be done, and then it was their role to just do it” and after a while, the students took over the process. She remarked that “there was a conceptual structure to the busyness…everybody had to do something for that main goal…and the kids were motivated...not one kid sat back and observed.” In sum, in interview 1 Teacher 2 reflected on her role in this PBL. She clearly described herself as a facilitator in the early stages and then supported learning as students took over. When I matched these characteristics with PB-LIFTS, the role Teacher 2 described aligned with social constructive pedagogy.

In regard to student role, Teacher 2 described in interview 1 that students “knew after a while how to run everything themselves” they became leaders they “didn’t rely on us so much and this included team B as well.” They managed the organizational aspects for example, “I’d look at the whiteboard and see the list was there. The kids just started doing it independently.” Team A read sections of the story in ASL to Team B and they collaboratively decided what should be acted out. Together they figured out challenging parts and problem-solved for example, “what props to use…like for horses.” Pointing out how challenging some parts of the story were for acting, she added in interview 1 that “some of the chapters had 20 characters, and so we had to decide, with 20 characters the costuming and what we would wear, and we had to kind of just finagle those pieces.”

In interview 1Teacher2 listed many details the students collaboratively worked out together illustrating that this PBL engaged students in rich interactive and constructive learning:

> Together students chose main ideas from the chapter that stuck out in their memory as important. They discussed how they could perform this, props needed, background color and design, costumes, roles of characters, where to properly stand on stage, correct entrance/exit, visually pleasing, pace of signing, etc…

Through this collaborative interaction students had an opportunity to work on developing "soft skills" and in reflective journal 2, Teacher 2 had stated this was one of her hopes for this project. In sum, Teacher 2 described the student role for this PBL unit as student-led, collaborative, and interactive learning; these emergent themes aligned with the PB-LIFTS indicators for social constructive pedagogy.

Learning design was the last pedagogy indicator for on the PB-LIFTS and several excerpts from the data indicated that students learned through interactive collaboration and co-construction. Teacher 2 described in interview 1 how she led discussions to co-construct next steps with the students and then turned it over for the students to figure things out. The teachers were careful not to take over the learning process and served as coaches cheering on students in the statement "we would just encourage them, think, think, think, and they would have to be creative and keep going." In journal 2 Teacher 2 listed several 21^{s} century skills she hoped students would develop Teacher 2 described her classroom as a "comfortable environment" where students could get help from anyone when needed. She also said, "a lot was going on at the same time in the classroom, some were drawing, some were researching, some were reading, some were doing the narrative piece." Everyone was expected "to participate, suggest, and give feedback." By engaging all students in the PBL project, Teacher 2 achieved one of her goals described in interview 1 related to the "lower students." Group B went from struggling learners who were "[stuck] on the receiving end 100% of the time" to active participants in learning and knowledge construction.

In both reflective journal 1 and interview 1, the learning design Teacher 2 described aligned with PB-LIFTS social constructive pedagogy but touched on all four descriptions. Students learned primarily through interactive co-construction. One indicator of social constructive pedagogy is that the product cannot be predicted ahead of time. Although the teacher and students wanted their movie to tell Clerc's story by following the book, the quality and style of the final product could not be predicted as it was created collaboratively. In fact, Teacher 2 was surprised by the accuracy of finish product when she commented in interview 1, "it was 'mind-blowing' to think the students got it right by the time they acted."

Thus, across the three indicators for pedagogy type on the PB-LIFTS, the emergent themes indicated social constructive pedagogy characterized as teacher supported, collaborative student engagement, co-constructed knowledge, and unpredictable product.

Product indicators. To identify the level of innovation for the students' PBL product, I studied the language and concepts Teacher 2 used to describe the Laurent Clerc Movie in reflective journals and semistructured interviews using indicators. Analyzing excerpts related to product originality, creativity, and content indicated that the Laurent Clerc Movie was at the highest level of innovation in the vertical dimension of PB-LIFTS.

For the first product indicator, originality, Teacher 2 described in interview 1 that there were no instructional resources available for the novel "so we didn't have a guidebook or a workbook" and there were no resources in ASL. At first the teachers tried explaining chapter content but "Team B was still struggling a lot with the concepts, and they were getting further and further behind. We wanted them to be active and involved." Teacher 2 added, "We did not want the lower students to simply" listen to others explaining information to them. Therefore, creating an accessible version of the story in ASL incorporating visual cues that allowed struggling readers to access the curriculum through active engagement was an original project. Because students used the novel, I was unsure if the project was between level 3, redesign, and level 4, unique project for originality. Teacher 2 was very convincing that this project should be solidly at level 4 for originality:

> There was nothing for them to visualize. Nothing in their first language. There was nothing available at that time. No movies, nothing. They had to get [the story] in their second language, English, and then translate for the play into their first language, ASL. Really it was a first. It was a struggle. They went from 2D, English print, to 3D, the performance. They had to change it from one language to another language. The product was their design. There was no redesign."

In other words, they did not create a remake of another movie and this became an instructional resource for future deaf studies classes. Therefore, for the PB-LIFTS indicator, originality, I agreed with Teacher 2 that this project was at level 4 for product originality.

For the second product indicator, creativity, perhaps the students borrowed the story line, but the ingenuity that went into the play and making the film was highly creative. In interview 2 Teacher 2 explained that there were several ways the background for the sets were creative. “Green screen wasn’t out yet, so we bought white and light blue for the background that we hung.” The background drawings were historically accurate. In interview 1 Teacher 2 gave the example that, “one *kid was the artist and a few kids helped him research the details of a 1795 kitchen in France.”* Students from Team B were able to use their visual artistic skills for “drawing backgrounds and doing the filming.” Thus, the emergent theme for this product was a level 4, creative and unique.

For the third product indicator, product content, Teacher 2 stated in interview 1 that the film content was “surprisingly” accurate, *“we had almost no really big mistakes or misunderstandings in the facts.”* Teacher 2 expressed another point illuminating that the content of the film was accurate when recounting the process students used to eliminate extraneous information from the play in the debriefing interview. Students had to decide what points were important to include and which were insignificant and could therefore be eliminated to make the length of the film manageable. Sometimes the students realized that they had eliminated information that was critical to understanding scenes later in the story. “To include that part, we had to go back” and “that was kind of hard” they had to make sure the inserted scene had the right costumes and props but they did it to correct omissions and maintain coherence. Considering these two examples, product content was accurate and multifaceted. Therefore, connecting these emergent themes to the vertical dimension on PB-LIFTS, the product was at the highest level 4, Innovate, because the product was uniquely original, creatively ingenious, and the content was deep and multifaceted.

Process indicators. To gain a deeper understanding of the level of HOTS students used to produce the Laurent Clerc movie, I examined the 4T processes that the teacher described in reflective journals and semistructured interviews. The language and concepts Teacher 2 expressed relative to the 4Ts revealed emergent themes for four process skills. Finding semantic correlations matching the themes with the indicators in the third dimension PB-LIFTS, the level of HOTS for each process could be identified. Emergent themes for task, thinking, teamwork, and tool use indicated performance in both level 3 and level 4.

Regarding task, PB-LIFTS indicators include PBL planning, organization, and accountability. Teacher 2 in interview 1 described the planning process which she modeled early in the PBL and described listing jobs on the board, having students sign up for them, and then they would get busy. The format for chapters of the film was organized in two parts. Each chapter was introduced and summarized by a student narrator then the chapter was acted out with students playing the character roles complete with costumes and background sets. Teacher 2 described how this was organized by "dividing up in groups, we had three different parts." Group A "did the reading and then did a narration of what they read." From the narration segment that was filmed, Group A made a list of main ideas then they "translated the story in sign" and with Group B watching, "they told the story over again." They checked for comprehension the two groups discussed how it could be acted out." In addition to listing jobs on the board, Teacher 2 in interview 2 said they had many other lists for keeping organized. For example, remembering costumes was critical "there were 75 different characters by the end of the book." Using props consistently also supported acting. Students found that "having tangible things associated with each character helped them remember "how that character behaved" so having a reference list of clothing items and props was helpful for keeping organized. Teacher 2 mentioned there were times when they needed to go back through the footage to double check what characters wore. Task planning was adequate, having routines in place, task organization was good with flexible systems in place.

Regarding accountability, Teacher 2 consistently described students as actively engaged with no accountability issues mentioned across all the data sources. In interview 2, she emphasized that a key to their success was that the students were all "able to give and receive feedback [this gave] them confidence to be able to help each other and ask for help." Therefore, I rated task on PB-LIFTS at level 3, systematized. PBL planning was adequate, organization was good, and the team was usually accountable, and Teacher 2 agreed with this rating in the debriefing interview.

Regarding thinking, PB-LIFTS has four levels ranging from low to high including recall of facts, comprehend, strategic, and extended thinking. Data from interviews 1 and 2 and reflective journal 2 with Teacher 2 described several types of complex thought processes students engaged in over the course of this PBL unit. One example was regarding managing several roles, "one girl had three-or-four-character roles in one chapter. She was so awesome using ASL facial expressions and body language to portray various characters back to back."

In addition to role management, in interview 1 Teacher 2 described complex thinking involved in "stage skills" that were new to these students including issues related to signing and fingerspelling on stage; "it has to be clear on the video and it has to be 3D." Students "had to know when . . . to come in and where they had to stand, and they couldn't talk to each other. They had to face out to the camera" and spelling right or left-handed "really makes a difference." Students had to think strategically about who had which character and whether they were right or left-handed for shoulder placement and what direction they should be looking." They picked up those stage skills as well as leadership skills advising two or three students who were in action on stage. They took turns running the camera and managing lighting "there were a lot of those kinds of [thinking skills] that really impacted their learning." The many examples of HOTS that Teacher 2 described during interviews provided insights that gave me a clear picture of what she might have been thinking of when she wrote a long list of skills she wanted her students to develop as a result of being involved in this PBL unit.

Teacher 2 described times that involvement in this PBL unit provided opportunities for students in Group B to show strong thinking skills for problem-solving. For example, one of the students who was "a nonreader was really good with math and could figure out measurements and drawings" for background scenes. The background scenes were projected from the ceiling at an angle which distorted the picture. "By projecting the background down from above, the pictures had to be drawn and projected at an angle so when it showed on the wall behind the actors it would appear straight on." This problem challenged students "to use math to figure out the right angles for the drawings to be projected and a lower student did it. His English was poor but math and visual skills were amazing."

Aside from the thinking processes involved in learning the Clerc story and making the film, in interview 1 Teacher 2 described another layer of rigorous thinking in this PBL. Although the PBL focused on making a movie of Laurent Clerc's life experiences, as a history teacher, she needed to connect the movie to the curriculum content. She described how she carefully wove in concepts as they worked on the movie to “relate it to the other information.” For example, topics included the influence of the American Revolution on the French Revolution and issues of empowerment, social conditions in France during Clerc’s time, and the importance of the institution for the deaf. Teacher 2 explained during interview 1 that access to an education was reserved for the wealthy like “royalty and government bureaucrats”. Teacher 2 emphasized the importance of this historical time for deaf people at the institution in Paris and recounted, “for 25 years, deaf people were studying and learning how to read and write” this point was fascinating for her and her students because “All the rich people, had access to education. All of the common people couldn’t read, but deaf people could.” Thus, Teacher 2 tried to balance her role as a history teacher while supporting the movie development and made learning history authentic and engaging for her students and thereby increased the level of rigor.

The emergent themes for this PBL related to thinking included prolonged engagement in working with complex concepts. In the debriefing interview both Teacher 2 and I felt that thinking skills for this PBL unit were especially strong and we rated thinking at the highest level on PB-LIFTS, level 4, extended thinking.

Regarding teamwork, PB-LIFTS has four levels of team development including forming, storming, norming, and performing. In the debriefing interview when I described these 4 levels of team development, Teacher 2 felt her students were naturally collaborative and “that’s why PBL is successful.” In interview 2 Teacher 2 compared the culture of deaf schools to Japanese “group society” They’re a group, and they function as a group, not individually….to be successful, they collaborate." Teacher 2 felt her students were naturally suited for PBL and elaborated that, "subconsciously, they don't realize what they're doing because they've been taught that way of life, and it's been modeled to them. And as the older they get, they're all just doing that naturally." In interview 2 Teacher 2 admitted that at one point "some of the students complained" and implied that the project was long and involved, and "Group A had a lot of core work" for the chapters. "Group A functioned like additional teachers" guiding Group B's understanding so they were like natural leaders throughout the PBL unit. A few times students would get mad at each other for example if they did not get a part they wanted. Teacher 2 reminded me that they were "still very young". She told them, "as a group you have to finish it on time.…and then they accepted that and moved on." Overall, everyone "wanted to do a good job and they wanted to be proud of their work." The emergent themes indicated that they used a collaborative model, used interpersonal skills, and clarified roles and goals which is a level 3, Norming but they also showed constructive synergy which is at level 4, performing. Therefore, considering both teams as one, the level of teamwork was between norming and performing.

Regarding resource tools, Teacher 2 in interview 2 stated that resources were from the novel that the movie was based on, the internet, the drama department, and the technology department. Teacher 2 in interview 2 explained that the students had to research images to draw scenery from the late 1700s in France and to research and discuss what clothing they should choose from the drama department for costumes. Teacher 2 mentioned that searching for images, Group B students were able to help with research, "if historical content needed to be looked up, sometimes teachers gave team B the spelling or key words and let them go look in images on internet." Because they did not do a lot of research for the movie, in the debriefing interview Teacher 2, agreed that a level 3, Multiple resources with a vetted selection matched this area of assessment.

Regarding technology use, Teacher 2 in interview 2 listed the equipment the students used to make the movie including a projector for the background, 3-4 computers, video camera, internet, PowerPoint, and stage lighting. The used technology to redesign or transform the novel to another medium. This emergent theme matches the PB-LIFTS level 3. The movie was also Unique and Innovative, level 4 because the technology they used allowed them to create a product that was once impossible and they were very creative with their use of technology by inventing their own form of green screen for background and mathematically calibrating images so they could be projected at an angle behind the actors. For these reasons, we agreed in the debriefing interview that the technology use was between level 3 and level 4.

PB-LIFTS. Using pedagogy indicators, the emergent themes across the data aligned with social constructive pedagogy type C on PB-LIFTS and using product indicators, the emergent themes aligned with level 4, innovate. Plotting the pedagogy and product results on the PB-LIFTS matrix of 16 cells, the intersecting cell for this PBL unit was C,4. This finding aligns with the RBT analysis that showed the PBL unit was in the highest quadrant for HOTS. This quadrant includes C3, D3, C4, and D4 as shown in Figure 11.

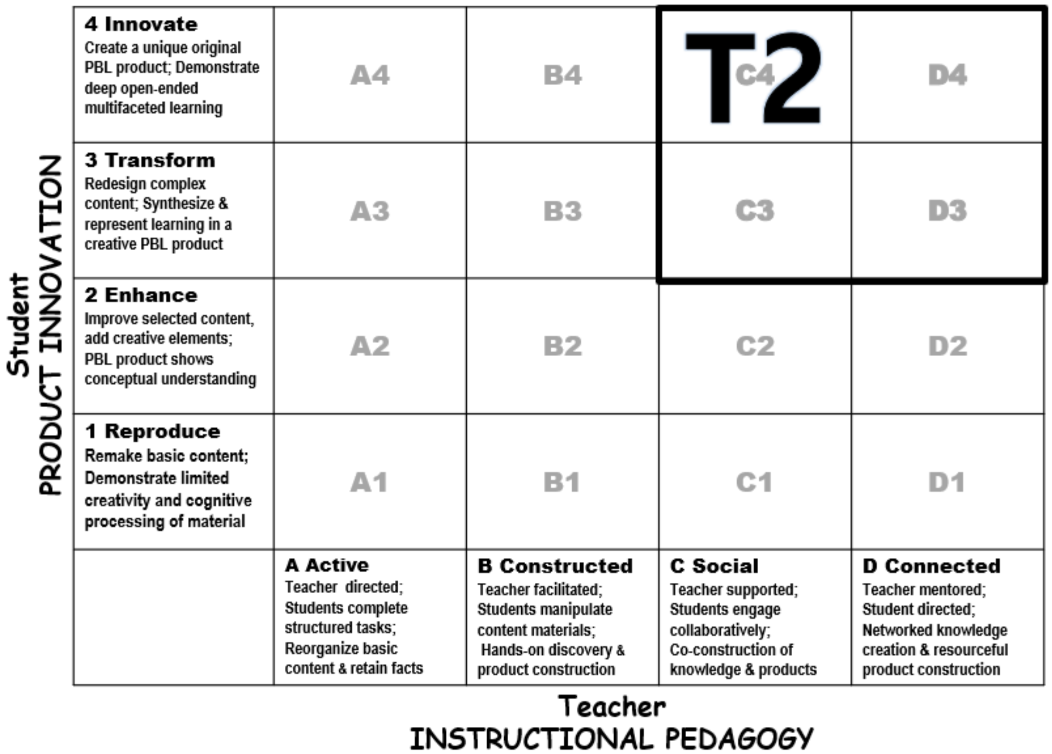


Figure 11. Unit from Teacher 2 plotted on project-based learning and innovations for teachers and students matrix.
Note 1: T2 = Teacher 2; Note 2: Bold square represents the RBT highest quadrant for higher order thinking skills.

By examining the results of the process skills that students used to produce the product, thinking and teamwork were rated the highest at level 4. Tools included resources at level 3 and Teacher 2 felt technology tool use was exceedingly high so in the debriefing interview we agreed that tools fell between level 3 and level 4. This supported the highly creative and innovative product score on PB-LIFTS. Teacher 2 was aware that she supported the product development and that not all of the students were independent, but she said her “four high functioning students were like teachers” guiding Team B and the “lower language students worked very hard.” She implied that students appreciated this type of learning and said, “most work in schools is very individualized and in turn is very isolating." After reviewing the process skill results in the debriefing interview, Teacher 2 expressed great pride in all the students' growth in HOTS through collaboration. She stated that as a group, the greatest growth area as a result of this PBL experience was in "teamwork collaboration" and she added "that's because most of the students don't get that exposure anywhere else in the school." She remarked that this project gave students an opportunity to develop soft skills and to function as a team…other than sports, where else do they get that?" Teacher 2 implied that teamwork also fosters thinking skills which she identified as the second greatest area of improvement. Thinking skill development was evident in their collaborative interactions and leadership roles.

Regarding PB-LIFTS pedagogy, she explained that good teachers have innate understanding of the continuum of pedagogical types, but it is good to have the continuum in print to refer to as a "cheat sheet" to pinpoint where individual student are and how their needs can best be met. She saw the process skill levels as useful for seeing where each student might be functioning and use to keep track their progress. She felt that teamwork was not only the greatest area of achievement because of this PBL, but she believed that teamwork would also be the greatest area of improvement in the next PBL. Teacher 2 wondered if PB-LIFTS could be applied in all subject areas and considered what a math class or economics would need and said, "I don't think you can have one chart that fits all areas." As a final thought in the debriefing interview, Teacher 2 voiced her support for having a chart like PB-LIFTS to keep students moving upward.

Teacher 3: SeaPerch Remotely Operated Vehicle

Teacher 3 introduced her SeaPerch remotely operated vehicle (ROV) unit on the PBL overview and in reflective journal 1, where she gave background for choosing the SeaPerch Program. The focus of this PBL unit was for teams of deaf high school students to build functional SeaPerch ROVs from kits and participate in regional SeaPerch underwater competition. The kits included the parts to build functional SeaPerches, which are “flown” underwater. With support from the Barnes Foundation the high school science department purchased the kits with the goal to expose students to “real world” science applications incorporating NGSS science standards to learn STEM concepts while building a functional machine and developing soft skills by working in teams. In reflective journal 1, Teacher 3 expressed that her school has been committed to ensuring “robust science content that dovetails with STEM programs provided at all grade levels.” Teacher 3 added in interview 1 that her department was “connected with the University science and technology staff” and they had implemented projects related to oceanography. Therefore, she implied that the ROV project was consistent with previous STEM topics.

To study HOTS in the SeaPerch ROV unit, it is important to understand the class composition related to team knowledge and skill levels as well as needs of team members. Teacher 3 explained in interview 1 that the DHH students in the ninth grade had diverse skills and “some may not go to college, but their technology, computer, and measurement skills might be awesome.” During interview 1 she explained that “some of these students might be reading on a second-grade level but had very strong thinking and [ASL] communication skills.” She implied that experiential learning could position students with language barriers to build on other strengths and gain experiences that might be applicable to a future job. Teacher 3 in the debriefing interview clarified that during this study she referred to two levels of ROV teams and these students are in Grades 9-12. In interview 1 Teacher 3 stated “each year our classes have about eight students” and there were two teams in the class for this study. One team was “advanced or experienced” students who were mostly in eleventh and twelfth grades. In the debriefing interview she explained that the advanced students, for example, may have participated in a robotics class the year before and had transferrable skills. Teacher 3 had another team of mostly 9-10th grade students who might be new to the program or “rookies” who had limited experience with the STEM content.

To identify HOTS in the SeaPerch ROV unit, I used RBT to analyze HOTS in teacher pedagogy and student product. Secondly, I used indicators to analyze HOTS in each dimension of PB-LIFTS.

Revised Bloom’s taxonomy analysis. Using the cognitive activity verb chart (Figure 7) and RBT to analyze objectives and the product description provided by Teacher 3 on the PBL overview, the results revealed that this unit engaged students in multiple cognitive activity levels including apply, analyze, evaluate, and create, while using procedural and metacognitive knowledge.

The first objective was “the students will build a functional SeaPerch ROV, including electronic control boxes.” To build a functional machine, students would need to analyze the instructions and parts using sequential procedural knowledge. Secondly, they would need to evaluate the functionality to do so they would use strategic knowledge to perform tasks which is classified as RBT metacognitive thinking. The RBT pairs for plotting objective 1 were analyze/procedural and evaluate/metacognitive.

The second unit objective was “the students will use their SeaPerch ROV to execute an underwater obstacle course and complete the rescue challenge using the ROV.” I distilled this objective to *perform underwater tasks remotely*. To perform the tasks, they would need to apply course information and follow a sequential procedure (apply/procedural). Secondly, performing this task with a team would require that they apply the course information and operate the ROV and use metacognition to coordinate this activity with teammates (apply/metacognition).

The third unit objective was “the students will assess the functioning of their SeaPerch ROV and make modifications as needed.” To assess functioning would require them to analyze aspects of how the ROV operated using procedural knowledge (analyze/procedural) and to judge ROV performance (evaluate/procedural). This objective involves another layer of cognitive activity and knowledge use; they would use their evaluation to create strategies for improving the functionality of the ROV which would require using problem-solving skills with their team (create/metacognitive).

For the product description, Teacher 3 stated on the overview, “The students had to fully assemble a SeaPerch ROV and control box and accomplish various underwater tasks. They then participated in a regional SeaPerch competition.” Emergent themes and embedded cognitive verbs were that they would apply instructions and mechanical knowhow to put together the parts of the ROV and connect them in a sequence (apply/procedural). They would need to evaluate how the parts are working together (evaluate/procedural) then use that knowledge to come up with ideas to troubleshoot or improve the function working with teammates (create/metacognitive).

I plotted the cognitive activity verbs and knowledge levels for the learning objectives and the product description using RBT Taxonomy Tables. The results showed strong dominance for both pedagogy and product in the highest quadrant for HOTS. This indicated that Teacher 3 had HOTS in mind when planning the PBL and the outcome or the final product showed evidence of HOTS engagement.

Indicator analysis. To identify levels of HOTS in the three dimensions of PB-LIFTS for the SeaPerch ROV PBL unit, I used indicators from the literature review to analyze data collected from Teacher 3. For each area of analysis, the PB-LIFTS framework contains four levels of embedded thinking skills from level 1 (lower ordered thinking skills) to level 4 (HOTS). The results showed that the teacher's pedagogy type for this PBL unit was social constructive. The student product innovation was at a combination level 3, transform, and level 4, innovate. The data analysis results of the skills used to produce the product were task level 3, thinking level 3-4, teamwork level 3-4, resource tools level 3, and technology tools level 3-4.

Pedagogy indicators. To identify the pedagogy type for the SeaPerch ROV, I studied the language and concepts Teacher 3 used to describe this PBL in reflective journals and semistructured interviews using indicators. By identifying the teacher role, student role, and learning design, the results indicated that the teacher's pedagogy type on the horizontal dimension of PB-LIFTS was social constructive.

Regarding teacher role, Teacher 3 described in interview 1, her "learner-focused" approach to experiential learning. When students have opportunities to be actively engaged, “learning is more meaningful, and they are able to make connections. Positive experiences encourage higher level thinking.” In the debriefing interview, Teacher 3 explained that she and other staff wanted personal firsthand experience building the ROV before attempting to guide their students. With administrative support, “the teachers did it first, and learned together as a team by doing it ourselves.” From this experience, Teacher 3 said, “then we could better teach our students.” This indicated that the teachers were committed to being well prepared to guide the ROV teams and they valued the perspective of the learner.

Teacher 3 explained how she and her team of teachers helped students understand the bigger picture of what they would do by building background knowledge. One strategy was watching videos of SeaPerch competition on the internet. Another example she described in interview 1 was that they “took a trip to see a real ROV” so they would have an idea of “what to expect ahead of time.” Teacher 3 said the ROV was “huge” and added that her students were excited about “making a smaller version.” She challenged them to consider functions of ROVs used in different places such as underwater, on the floor of the ocean, or under ice. She asked students what they thought about the ROV on Mars, “how did they control it from so far away?” Once Teacher 3 was confident that her students had “a true understanding” of the project challenge, she said, “it was their turn to make it happen.”

Teacher 3 described in interview 1 how she encouraged student ownership and reliance on the team’s ability to problem-solve and work interdependently. She shared several incidents that illuminated how she was close by and observant but did not take over when students struggled. In interview 1, she gave the example that if something didn’t work perhaps because they missed a step in the directions they might ask her for help, but she would “gear them back to their group…and say “this isn't my project--this is your project. Ask your friends… what happened and why… then they would look at each other and try to figure it out.”

Teacher 3 also explained in interview 1 that she kept an eye on their progress related to their timeline. If they needed to be working faster, she would say things like, “tomorrow we are going to be testing in the pool, and just give subtle warnings.” Other times she would “do a time check or just point” to a list of goals they generated with a time frame to keep them on track. Other times she might be more direct and say, “it’s your competition” and remind them only two weeks were left. Teacher 3 also described in interview 1 that she was careful to make sure students knew how to do certain things and said, “I would help guide them if for example, they needed to use…a soldering iron or something.” The theme that emerged from the data regarding teacher role in the SeaPerch PBL was that Teacher 3 supported social learning and flexibly served as a guide.

Regarding student role, Teacher 3 in interview 1 described how she consciously empowered her students to take control of the learning experience so they could learn by working as a team to discover their personal skills and strengths. She was careful to make sure they understood the content and what to do, then she handed the task over to them saying, “now you can do this independently.” She was on hand to guide if necessary, but mostly “I let them do it on their own.” Teacher 3 in interview 1explained that having “visual prompts like a chart of the procedures” was a key to setting clear expectations and promoting student driven learning. She added, “posting the list is helpful because I don't have to explain and monitor them; they can keep track on their own." Teacher 3 also explained in interview 1 that an important skill for teammates was learning to watch each other and giving constructive suggestions, "we encouraged them to help each other and observe what was being done or not done to make sure that everything was covered and [learn] how they could help each other best."

In the debriefing interview Teacher 3 emphasized the value of giving students opportunities to engage in student-driven learning for them to discover their personal strengths and find roles that they could do well. In interview 1 she mentioned that some of her students may not go to college but "they need to find where they are productive and what skills they have and where they fit, so projects like this give them a role." She listed simple jobs they could try out like being the recorder, setting up experiments, and using checklists. To illuminate this point, in the debriefing interview she gave the analogy of the scrub nurse in an operating room. That person may not be the surgeon, but the scrub nurse gets everything ready, plugged in, and instruments lined up; those tasks "may be simple but [they are] crucial to the success" of the whole team in the operating room. She implied that through PBL experiences discovering their skills can be empowering for students. She suggested, "give them a role they can do. Experiencing success "boosts their self-esteem." Teacher 3 implied that she saw positive things happen once students developed the courage to try; she remarked during the debriefing interview that there were times when she was "taken aback" seeing what they could do. For example, she recalled, "some students who you think are very delayed… can be awesome problem-solvers." Learning to learn from mistakes is another skill that can promote the courage to succeed. Teacher 3 said in interview 1, "if they made a mistake" she discouraged them from “being critical of themselves saying that they are awful or stupid” she would redirect them by saying, “No, no, you did great! Where can you get help? If you do not know something, you can ask for help or find another strategy, that’s all.” Thus, when mistakes were made students were guided to use team interdependence and navigate the way to a successful outcome.

The theme that emerged from the teacher’s descriptions regarding student role in this PBL unit indicated that developing the collaborative and interdependent mindset progressed with practice. Through PBL engagement, across data sources Teacher 3 described learning as co-constructed, student-led, and social interactive.

Learning design is the last PB-LIFTS pedagogy indicator and Teacher 3 summarized this in the PBL overview as a “multilayered and multileveled project” then she elaborated that students developed STEM knowledge and skills as well as “soft-skills” through participation in the SeaPerch ROV unit. “Construction of a functional SeaPerch ROV was the primary goal, there were a multitude of critical skills that are developed and enhanced.” In interview 1 Teacher 3 stated, “the students had to know the names of the parts [of the ROV]. They had to able to identify them, and the tools that they used.” From a science perspective, they learned about the ROV systems that came together to produce a “functional machine” including structural, mechanical, and electrical. In the debriefing interview Teacher 3 provided examples of “basic physics” they applied for testing and maneuvering the ROV. In interview 2 when I asked Teacher 3 to name some of the science concepts they applied, she listed, “buoyancy, density, volume, speed, distance, resistance, and velocity.” She added that, “maybe they did not use those exact terms, but that is what they were doing.” To help students learn the terminology, the teachers refrained from giving them a sign, “instead of the sign, they would [finger]spell the correct scientific term when doing an experiment.”

Besides the STEM aspect of the learning design, they also developed soft skills. In the comments section of the PBL overview she described what she meant by soft-skills and listed, “communicating, working within a team, troubleshooting, problem solving through trial and error, strategizing, prioritizing tasks, etc...”

In reflective journal 1 Teacher 3 provided a bulleted list that summarized the learning design for the SeaPerch ROV project and showed it was a social interactive design:

- give students the opportunity to build a functional machine
- expose students to “real world” applications of science
- have students work in teams allowing for brainstorming, problem solving, strategizing
- foster hands-on skills (rudimentary electronics, soldering, assembly, design, product modification)
- identify personal skills and aptitudes and roles associated with their teams.

Thus, across the indicators for pedagogy type on the PB-LIFTS, the emergent themes indicated a social constructive pedagogy type characterized as teacher supported, collaborative student engagement, and co-constructed knowledge and products. Further, the product was made from a kit, but its functionality was impossible to predict until the competition day. Aligned with the PB-LIFTS pedagogy types in the horizontal dimension, this PBL unit was social constructive indicating that students were engaged in using HOTS.

Product indicators. To identify the level of innovation for the students' PBL product, I studied the language and concepts Teacher 3 used to describe their SeaPerch ROV in reflective journals and semistructured interviews using indicators. Analyzing excerpts related to product originality, creativity, and content for the two teams indicated that students engaged in HOTS in the vertical dimension of PB-LIFTS at level 3, Transform, and level 4 Innovate to produce the SeaPerch ROV product.

For the first product indicator, product originality, Teacher 3 described in reflective journal 2 that although students used a kit to build and test their ROV, there were opportunities for students to apply original ideas for problem-solving to produce a competitive product. For example, "one team was not satisfied with [the ROV] function, so they took a cast-off piece of PVC pipe, filed an appropriate size notch into it (basic measurement skills), and used duct tape to seal the end." This was a low-tech solution but "it was a far superior tool than the various 3D printed ones we had created." Thus, for this PBL students had opportunities to think of original ways to solve-problems and to test their ideas. Thus, for originality, Teacher 3 and I scored the product as both level 3 for redesigning and level 4, because students were inventive.

For the second product indicator, creativity, in interview 2, Teacher 3 shared how students used their imagination and creativity to solve a problem during competition. "One of the ROVs sank because of gravity, it was just too heavy." Teacher 3 thought they would need to add more flotation but "the students were smarter than me. They cut off weights. There was some metal strapped on, so in two seconds they took it off, and it ran fine." Teacher 3 thought their "simple solution was awesome" and stated she was thinking of something more complicated. Hence, these students under the pressure of competition were able to think quickly and creatively to problem-solve.

The ROV PBL also sparked new creativity beyond the present product. In the debriefing interview Teacher 3 shared that the advanced team discussed plans for another project "they are going to design their own ROV." They are "playing with that idea." Teacher 3 in the debriefing interview reflected on the students discussing ideas for their ROV design, and this discussion illuminates HOTS engagement. Teacher 3 explained that they will need to decide on the number of thrusters "so they are considering issues like the size of the ROV and the physics involved" as well as how they will make it maneuver. The emergent themes for the ROV PBL was that it was creative and unique, and this activity generated even more challenging creative thinking which is HOTS. Therefore, we rated this PBL as both level 3 and level 4 for creativity.

The third indicator for the level of innovation was product content. As stated in the learning design section, Teacher 3 described many physics and engineering concepts students applied to make the product and improve ROV functions which indicated that this PBL was content rich. In the debriefing interview Teacher 3 explained that due to the range of skills and knowledge among students, the content had to be "modified according to many variables" She gave examples of new students joining the program who had no experience with this kind of learning or students whose formal education began late, and "some students never really had formal education." Teacher 3 also stated in interview 1, "you know my students' experiences can be very limited" and in "student-focused learning" it is important that they have "good experiences" so they are able to "visualize and make connections" instead of the content "going over their heads." Hence, she valued working from where the students were, and the level of rigor was adjusted accordingly to keep increasing their content knowledge and ability to synthesize. Thus, an emergent theme describing the product content for some students was at a level 3, for knowledge synthesis and for the more advanced students, the content level was at a level 4 as it was deep and multifaceted. For originality, some students redesigned a novel project and others produced a more inventive and unique project; for creativity some students were clever and creative while others were ingenious; and for product content, some students synthesized knowledge and for others, content was deep and multifaceted. Therefore, across the indicators for the level of product innovation the emergent themes placed at levels 3 and 4 in the vertical dimension of PB-LIFTS.

Process indicators. To gain a deeper understanding of the level of HOTS students used to produce the SeaPerch ROV, I examined the 4T processes that the teacher described in reflective journals and semistructured interviews. The language and concepts Teacher 3 expressed relative to the 4Ts revealed emergent themes for four process skills. Using emergent themes, the level of HOTS for each process could be identified in the third dimension PB-LIFTS. Emergent themes for task, thinking, teamwork, and tool use indicated levels 3 and 4 performance levels.

Regarding task, PB-LIFTS indicators include PBL planning, organization, and accountability. Regarding planning, in interview 1Teacher 3 spoke highly of her team and shared how the teachers planned the PBL:

> We had frequent meetings--you know, a lunchtime meeting, or in the hallway we might share an idea. Teachers had after school meetings to discuss the project

using a more formal process. We wrote out our plan incorporating different ideas that included a timeline, expected outcomes, and goals.

As mentioned in the teacher pedagogy section, the timeline chart was an important visual prompt used consistently. Teacher 3 described her dialog with students and how the chart was used. She said she would ask, “What are doing first, and second and third? What has been made, and who is doing what, and how?” Teacher 3 explained the chart was a way for students and staff to self-check. Teacher 3 said that her students “would inform me of what to put on the chart…then I could double-check and say, hey, did you miss anything? And we could give each other feedback in that way.”

Teacher 3 implied that the kit included specific instructions and procedures to follow so keeping track was important, and over time, students kept track on their own. Regarding organization, Teacher 3 implied in interview 1 that the kit provided structure for what to do and when. Thus, for this type of PBL, perhaps students do not have the opportunity to design their own plan and organization for producing the product. Throughout the school, teachers used thinking maps and with practice, this was a good organizational tool. However, Teacher 3 explained in interview 1 that based on need, she modeled a process for breaking down tasks to help students prioritize and track progress using a structure. She said, “we might discuss three goals for a class” and use a check list to ask students, “if you check this off the list, what’s next?” and perhaps if they ran out of time and didn’t finish all three goals, then she would say, “ok tomorrow we’ll continue working on the third.” This description indicated to me that the students needed help with executive functions such as setting deadlines, meeting goals, and attending to details independently. In the debriefing interview she explained the routine in more depth, “you [the teachers] have structures, you have tasks set, you have the expectations you want to accomplish during the lessons or activity time, and you give that as a guide for the students to know the expectations" for what should be completed by the end of the time period. In addition to an activity timeline, in the debriefing interview Teacher 3 stressed the importance of students having roles. She emphasized that "students need to know that they are going to be doing this, this, and this" and if they don't accomplish the tasks, she asks them, "Did you use your time well? Did you collaborate with your peers? Did you waste time talking too much?" Teacher 3 implied that this routine works because "by the end the students were self-regulating each other."

Regarding accountability, as mentioned in the section on teacher role, Teacher 3 used several strategies that prompted students to stay on task and be accountable. She also stated in interview 1 that if a team finished early, she gave them suggestions for what they could do to support the other team rather than talking. In interview 1, Teacher 3 mentioned that sometimes teams ran into a problem or perhaps a student wasn't working "they would tell me but I would stand back and say 'you work it out' and I would just watch" then they would pull together and get back on task. They also did group and individual performance reflections. In interview 1 Teacher 3 said "most of the time the students and teachers agreed with each other on how they did and what grade they would give themselves . . . and we would also ask, how could you improve next time?"

In interview 1 Teacher 3 raised the importance of students taking ownership for individual responsibilities to the group. She mentioned that if a student realized that they were unsure how to do their role, "it was their responsibility to inform each other of that" and ask for help from teammates. She stated that if something went wrong and the ROV did not work properly students were not to start blaming each other. It was their responsibility to back track, "change it out, or figure out how to fix it." Another issue related to accountability was that each student was responsible for clear communication. She described in interview 1 strategies they had in place for communication repair when a breakdown occurred for example "if someone was unsure of what was signed, they were responsible for asking "what do you mean?....or if one of the team members didn't get it, you have to reexplain it and the person who missed the information had to ask for clarification." Fully understanding each other and clear communication was a value that supported accountability. In sum, for task, emergent themes related to planning was that visual prompts for charting tasks were co-constructed with students and teachers participating; over time students took more ownership. For organization, thinking maps and charts showed logical sequence of tasks and they used systematized strategies for social constructive learning. The teacher monitored accountability and fostered strategies that students used to improve. Overall, the task matched PB-LIFTS Task level 3, systematized with adequate planning, good organization, and they were usually accountable.

Regarding Thinking, PB-LIFTS has four levels ranging from low to high including recall of facts, comprehend, strategic, and extended thinking. Data from interviews 1 and 2 and reflective journal 2 with Teacher 3 revealed several types of thinking and problem-solving that is strategic and extended indicating HOTS. In interview 1 Teacher 3 described the stages of thinking the teams engaged in when they finished putting the ROV together and tested it. If the motor was not working, Teacher 3 described the steps for problem identification. First, they would do a parts check such as “look at the propeller, was it connected right? Was it too tight?” Then they would check the electrical system to see if the wires were connected correctly “maybe their wires were crossed, or they had something in their way.” Once they identified where a problem was then they would decide if the part needed to be “switched out” or if they could improvise and fix the existing part. Once they got the motor running, the next step was to check the control panel and they had a series of tests to complete before immersing the ROV in water. Teacher 3 described “a lot of analyzing had to occur” and she described the case where something was stuck or if the control box had a problem inside, they might “change it out, get a knob, or a control stick.” Once the ROV passed these tests, they studied the ROV obstacle course videos so they could visualize what tasks the ROV had to be able to do underwater.

Last, when they went to the pool, testing took a long time and “they had to communicate well being clear” and “use the vocabulary for parts and tools” through this testing process. Teacher 3 described “a partnership” in interview 1 where one student would slowly “feed the line and another student would operate the control pad. If they went too fast it would get all tangled up” so good communication was critical. After they went through the testing procedures and determined that the ROV could accomplish various tasks on the course, Teacher 3 explained in interview 1 that their thinking shifted to determining “how *well* it worked” and they tried “different theories for how to make it run faster” and more efficiently. Teacher 3 summarized the HOTS she realized her students performed and expressed her pride regarding their thinking processes in reflective journal 3:

> The most gratifying moments are when the students can examine a problem, discuss possible solutions, try out their theories, and come to an agreement/conclusion. They are covering SO many skills, from implementing their technical/mechanical knowledge to sharing their opinions and considering others' perspectives. As melodramatic as it sounds, these are transcendent moments for a teacher!

In interview 2 Teacher 3 remarked how this type of project really ignites students' thinking regardless of their academic level. She explained that many of her students "never really had a chance to be curious….to ask how and why, to disagree, to express themselves, and support their opinion. It's extremely critical that they have that opportunity." She added that they might not always fully understand the depth of what they are learning but the thinking continues and they "need time to incubate, to sync, to chew on ideas." She described the story of a former student who told her that what he had learned in her class "didn't hit him until he was 25 years old." Teacher 3 remarked that giving them "time to process and not pushing them through is critical" to lifelong learning.

During the debriefing interview, when asked which skill she believed contributed most to the final product, without hesitation, Teacher 3 replied, "thinking!" The emergent themes related to levels of thinking included prolonged engagement in working with complex concepts. Hence, the teams achieved the highest level on PB-LIFTS level 4, extended thinking.

Regarding teamwork, PB-LIFTS has four levels of team development including forming, storming, norming, and performing. Teacher 3 stated in interview 2 that one of the teams was especially “awesome”. One team had “two natural leaders …and they were very respectful to their peers which is really nice, but it doesn't always happen.” She implied that the roles students assumed on the team were informally decided and “over time, there was a natural progression where the leader would give up that role and sometimes tasks changed.” In interview 2 she gave the example, “when we were building the ROV, the pit crew used engineering mechanics for building it then when it was time to test the equipment, they would give the controls to other kids to run it.” She described how having flexible roles supported the team as a whole saying, “the pit crew could observe them working the controls or going through the course. So, they changed roles sometimes and it helped problem analysis.”

In interview 2 Teacher 3 added that it is important that students recognize their personal skills that contribute to the team. For example, some students paid more attention to detail and…they helped make sure procedure was followed. Other kids would have more imagination” and the ability to brainstorm and problem-solve.” She reflected that “they recognized each other’s skills and showed each other respect.” Teacher 3 was proud of their development as a team although it was informal, “That wonderful team development takes time to grow and to really get to know each other.” She used another analogy to help students understand the importance of teamwork and what it might look like if they were members of the pit crew at a racetrack,

> You cannot just stand back and not know what to do. When the racecar comes in, you can't just stand there, you have to hurry up, change the tires, get the gas, and help each other out to get that car back on the course fast!”

In interview 2, Teacher 3 emphasized that there is also a time to observe and learn from each other for example, “if one student was really good at welding, by observing [and becoming an apprentice] they could share that task and take turns.” In the debriefing interview Teacher 3 and I agreed that perhaps her less experienced team was at a level 3, Norming, because they were collaborative, clarified roles and goals, and applied interpersonal skills. The more experienced team was at level 4 for team development, performing, because they were interdependent and performed well with constructive synergy.

Regarding resource tools, Teacher 3 in interview 2 believed that resources were some of the ways that students ask for help. She said, “students identified who knows how to help when they're stuck.” Teacher 3 said, “so a person can be a resource and they also used the manual. interview 2, she also mentioned that some of the students had an engineering journal from a previous class and they referred to those notes for help. Another resource was the internet websites they went to such as RoboNation. Teacher 3 explained, “they could see other examples of the ROV on YouTube.” She said students also reached out to staff or teachers who had this type of experience and could help with “problem solving or remembering different techniques like for connecting things soldering, mechanical skills, or maybe a word or a vocabulary term for that the process.” We scored resources this at level 3 because they had multiple resources.

Tools also include technology that students used for their project. In interview 2 Teacher 3 described an engineering design program called SketchUp 3D modeling software. Students used to this program to create a ROV tool to accomplish a lifting task. The advanced team was skilled with using this program and the 3D printer. Teacher 3 described other technology her students us to communicate with each other about the project and said in interview 2, “they text each other all the time …[using] their phones and we use Google classroom and of course, e-mail.” In interview 2, Teacher 3 said that when students had a problem they could not solve, they used “Skype to contact an engineer we know who was very helpful the few times we called him.” Another technology resource was YouTube. Teacher 3 stated in interview 2 that “they could see other teams on the obstacle course and all the hoops they had to go through.” In the debriefing interview, Teacher 3 felt that for both resources and technology use, the less experienced team was at a level 3, but the advanced team was at a level 4

PB-LIFTS. Using pedagogy indicators, the emergent themes across the data aligned with social constructive pedagogy type C on PB-LIFTS and using product indicators, we identified emergent themes at both the transform and innovate levels 3-4. Plotting the pedagogy and product results on the PB-LIFTS matrix of 16 cells, the intersecting cell for this PBL unit was C, 3-4. This finding aligns with the RBT analysis that showed the PBL unit was in the highest quadrant for HOTS shown on Fig. 12 with a box around cells C3, D3, C4, and D4. Teacher 3 agreed that there was a clear relationship between the teacher’s pedagogy type and the level of student product innovation.

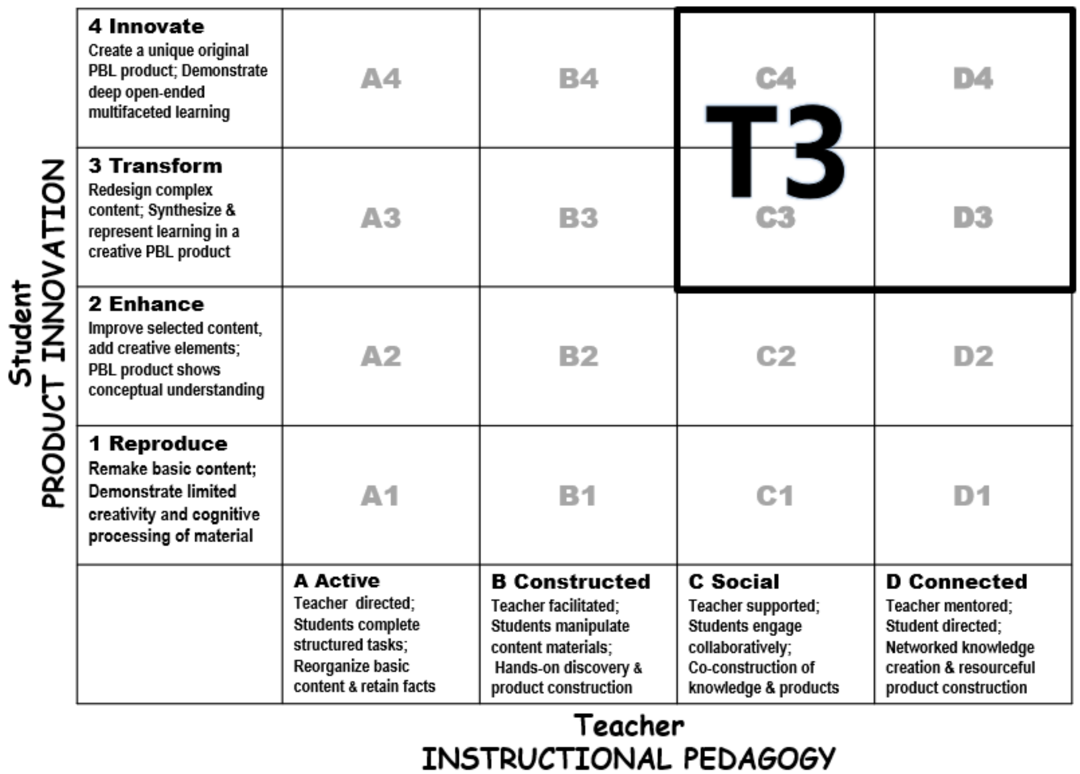


Figure 12. T3 shows where the PBL unit described by Teacher 3 placed on PB-LIFTS. The bold square represents the RBT highest quadrant for HOTS. Note: T3 = Teacher 3

By examining the results of the process skills that were used to produce the product, in the debriefing interview, Teacher 3 and I realized the product innovation level achieved was reflected in the composition of the teams. Teacher 3 had teams of students working together with two levels of experience in robotics, “less experienced rookies” and “advanced or experienced” students. Thus, performance ratings were dependent upon the level of experience of the individual team members and rating the whole group was difficult. The “less experienced” team members were at a level 3 across all of the process skills and the “advanced” team members were most often rated at level 4.

In the debriefing interview when asked which skill she felt was a priority for improvement, she said “task and teamwork.” She said PB-LIFTS made her think of an idea to try in the next project using a thinking map as the basis for task organization, discussion, and reflection following PBL engagement. She said using the tree diagram she would chart the four process skills and have students identify where their strengths were and choose roles accordingly. After team engagement they would return to the chart and review what went well, what did not, and how to improve. This could be visited with individual students and the group to improve both task and teamwork skills.

Teacher 3 identified thinking and technology tool use as contributing most to the product. She stated that next time both levels of students would be challenged in a new way. The less experienced students would do a kit again and now that they knew the process, they would be driving the learning. The advanced students planned to form a team and design their own kit. Teacher 3 looked forward to seeing their continued growth in HOTS.

Teacher 4: Blue People of Kentucky

Teacher 4 described in reflective journal 1, a favorite biology PBL unit he implemented in the spring of 2019 with a small team of deaf high school students. In the debriefing interview he explained that this group of learners had no previous experience with PBL in science; in reflective journal 1, he explained that they “deserved and greatly needed” an opportunity to engage in “the application of real-world data” using scientific procedures. Teacher 4 in interview 1 shared that he spotted a comment in a social media thread about “blue people” that caught his attention and led him to research the Fugate family from Kentucky. He was able to access medical data and decided to use this to engage his class of ninth and tenth grade students in a project to solve an authentic human biology mystery. Teacher 4 added in interview 1, that to prepare himself for making appropriate content modifications to “match the level of the group best,” he completed the case study himself and understood the Fugate family’s blue skin ahead of time.

In the fall of 2018, he announced that his biology class would study blue skinned people and word quickly spread throughout the school. Anticipation for this PBL unit grew as students and parents began asking questions, but Teacher 4 said in his reflective journal 1 that “students had to wait over a semester” while he prepared them “to delve into genetics and the concepts of heredity [needed for] this case study.” In fact, he said students asked about it “at least once a week” and by the time Teacher 4 felt they were prepared, “they were bursting at the seams to dive in and learn more about genetics, heredity, and pedigrees.”

In interview 1, Teacher 4 explained that using PBL, he could differentiate levels of cognitive demand to meet diverse learning needs. With the team of students in this study, he said in interview 1 that he had to “intervene” or “lead a little bit more” than he would with “a higher group,” but implied that this group was very motivated to learn and teacher support needs “shifted over time to where they led.” To learn about levels of thinking in this PBL, I used RBT to analyze HOTS in teacher pedagogy and student product. Secondly, I used indicators to analyze HOTS in each dimension of PB-LIFTS.

Revised Bloom’s taxonomy analysis. Using the cognitive activity verb chart (Figure 7) and RBT to analyze objectives and the product description provided by Teacher 4 in the PBL overview, results revealed that this unit engaged students in multiple cognitive activity levels including understand, analyze, evaluate, and create, while using procedural and metacognitive knowledge levels to produce a pedigree in response to the essential question, “What was the cause of Ella’s blue skin?” I used RBT cognitive activity verbs and knowledge levels to identify levels of thinking embedded in the teacher’s three PBL objectives and product description from the PBL overview.

Teacher 4 had three objectives for the unit. The first objective was “The students will analyze and interpret data that genes are expressed portions of DNA.” To do this, students will apply knowledge of human biology and then interpret genetic data sets. This matched RBT cognitive verb and knowledge level analyze/evaluate. The second unit objective was “The students will depict an accurate pedigree of Ella’s family.” For this objective, students constructed a pedigree based upon scientific data and this matched RBT cognitive verb and knowledge level create/metacognitive. The third unit objective was “The students will use reasoning and analytical skills, in addition to the pedigree they create, to conclude if Ella’s skin condition is hereditary.” For this objective, students would use scientific analysis to draw a conclusion based upon evidence and this matched the RBT cognitive verb and knowledge level, evaluate/metacognitive.

For the product description, Teacher 4 described the students’ final product on the PBL overview as:

> The students read through the case history, analyzed and reasoned through the family’s history of blue skin, researched causes of blue skin (inherited and others), then created a pedigree to show the lineage of the Fugate family, and tried to decipher what type of inheritance pattern the blue skin followed, to determine if that indeed was what caused Ella’s blue skin. They then made their conclusion and presented their findings to a member of the administration team and me.

Seeking emergent themes in the product description to identify RBT pairs, I found that students created a pedigree based upon genetic research (create/metacognitive) and data interpretation (analyze/procedural) to solve an authentic human biology mystery (evaluate/metacognitive). Further, students needed procedural knowledge to know how to produce the pedigree as well as metacognitive knowledge to collaborate with peers to produce the product suitable to present to a variety of audiences.

To identify HOTS, I plotted three pairs of cognitive activity verbs and knowledge levels for the learning objectives and the product description using RBT Taxonomy Tables. The results showed strong dominance for both pedagogy and product in the highest quadrant for HOTS indicating that the PBL was designed by the teacher with HOTS embedded in the objectives and the students produced a product showing evidence of HOTS engagement. Teacher 4 agreed that students performed high levels of thinking skills; however, he added that they applied lower skills as well. In the reflective journal 2, Teacher 4 remarked, “This PBL project really touched on many levels of higher order thinking skills and went up and down, [Bloom’s Taxonomy] and back up again.”

Indicator analysis. To identify levels of HOTS in the three dimensions of PB-LIFTS for the Blue People of Kentucky PBL unit, I used indicators from the literature review to analyze data collected from Teacher 4. For each area of analysis, the PB-LIFTS framework contains four levels of embedded thinking skills from level 1 (lower ordered thinking skills) to level 4 (HOTS). The results showed that the teacher’s pedagogy type for this PBL unit was social constructive and connected learning. The student product innovation was between transform and innovate, level 3-4. The data analysis results of the skills used to produce the product were task level 3, thinking level 3, teamwork level 3, resource tools level 3, and technology tools level 3.

Pedagogy indicators. To identify the pedagogy type for the Blue People PBL unit, I studied the language and concepts Teacher 4 used to describe this PBL in reflective journal entries and semistructured interviews using indicators. By identifying the teacher role, student role, and learning design, the results indicated that the teacher's pedagogy type on the horizontal dimension of PB-LIFTS was a combination of social constructive and connected learning.

Regarding teacher role, in both the reflective journal 2 and interview 1, Teacher 4 described how he prepared students for engagement in the PBL unit related to biology content and fostered the development of "soft-skills" needed for collaborative learning. In interview 1, Teacher 4 shared that he would give students the overall goal of the project and "tried to give them the reins" to pursue the PBL unit. He also described how he guided students to acquire basic scientific knowledge related to the PBL and said, "first we had to do some development for genetics research to study the family and find out "who had …and who didn't have" the blue skin trait; for example, in reflective journal 1, he described that students learned "the symbols that they needed to use" so that they would be able to "synthesize a case study for a specific pedigree to show the Fugate's long line of hereditary traits." In interview 1, he explained that for this type of learning, "it's hard to develop a curriculum beforehand" covering all of the science content they would need "because you can't predict exactly where they're going to go, and where they're going to get, and what path is going to lead them there." In interview 1, he stated that finding the right "balance" of information to give them was challenging because he also tried to "back off" and let them drive their learning. Having his own experience doing the project was helpful because, "I can observe my students and analyze their work and figure out if they are on task or not" and then make informed instructional decisions.

In interview 2, Teacher 4 gave insight regarding how he prepared students to understand the case history and medical terms when the research was particularly challenging. He said he was careful not to "go over their heads and lose them" so for some classes "we spent about thirty minutes in group discussion reviewing the findings to make sure they understood." He also said in interview 2 that having pictures from websites was helpful for clarifying concepts during class discussions. Afterward, Teacher 4 said he would "join in and kind of guide them" when they went back to researching.

Teacher 4 expanded on the concept of knowing when to intervene and when to stand back and observe students in action. In the debriefing interview he said this "can be sticky" because he valued letting them "fail" so they can "realize they were completely off track and learn from their own mistakes." He mentioned the importance of experiencing this in preparation for life beyond high school and implied that he would not be there to rescue them in college so it is important to learn while still in high school that "failure is a part of life…and mistakes are part of the learning process that help you improve." He added that there is a "delicate balance" between knowing when to provide guidance and when to let them figure it out on their own. In making such decisions he said, "it is important for me to… know their individual skills and abilities." Teacher 4 said with that knowledge "I can promote individual development, not only for the class as a whole."

In interview 2 Teacher 4 alluded that part of his role was maintaining high expectations for the students collectively and individually. In this interview he explained that knowing “individual skills and abilities” helped him judge when and how much to “push.” He explained that he was not satisfied seeing students earn a grade of C and emphatically stated, “good enough is not good enough” in his class. He said sometimes he gets the “eye roll” from students when he says the them, “you have to keep pushing…add more information, do more, reach higher for that A.” Teacher 4 added in interview 2 that along with challenging students to do their best, he was careful to “help them recognize how they had improved” as a result. When “they internalize” that they are capable to showing improvement, they get “motivation and ‘grit’ to keep going and give their best effort.” Therefore, Teacher 4 believed part of his role was to nurture a positive mindset for learning and continuous improvement.

In addition to building conceptual knowledge and holding high expectations for researching a genetic trait, Teacher 4 described in interview 1 how he also worked with students to learn about “soft-skills” to increase their understanding of “good communication and collaboration skills…brainstorming, and thinking in depth as a team instead of individually.” The collaborative skills they used were “evidenced throughout the project.” Throughout the data, Teacher 4 consistently described his role as a guide who flexibly provided support and empowered students to drive collaborative social learning.

Regarding student role, Teacher 4 described in reflective journal 2, that students quickly learned collaborative skills such as “communication, responsibility and adaptability” for co-constructed learning. In interview 1, Teacher 4 stated that he "empowered the students to become the researchers and geneticists themselves, so they could solve that mystery" but he admitted in interview 2 that prior to this PBL unit, an area of "weakness was time management skills" for this group of students. In reflective journal 2, Teacher 4 realized his students showed good improvement in this area and expressed pride in how they managed their time, "as the work became more difficult, they fearlessly pushed on to meet deadlines without the night-before stress." Teacher 4 explained that one of his favorite parts of this PBL unit was that "students assumed responsibility for this project" by meeting with each other outside of class using Google Chat when a member of the team was absent; "they were dependent on each other to continue." In sum, themes that emerged from the teacher's descriptions regarding student role in this PBL unit indicated that the learning was student-led, collaborative, and interactive both face-to-face and virtually using technology.

Learning design is the last PB-LIFTS pedagogy indicator. Emergent themes from the data, shared in the preceding sections addressing teacher role and student role indicated that the pedagogy type for this PBL unit was social constructive; however, in interview 2, Teacher 4 described student engagement in networked construction using Google Chat. Teacher 4 said that during "community hour" sometimes he would send students to "different rooms" in the building so they could type to each other using Google Chat "and discuss their project by typing to each other using English." Teacher 4 described two benefits to this approach. In interview 2 and the debriefing interview he stated this is "real-world communication" that students need for future jobs and in interview 2, he identified this as widely recognized in schools for the deaf as a bilingual education strategy for second language development. He asserted that Google Chat is one way to support the development of English skills in reading and writing and “it's really important that students learn to go back and forth between English and ASL” and stressed, “that has to be taught.” Therefore, the learning design for this PBL unit involved face-to-face collaboration and networked construction indicating two pedagogy types on the PB-LIFTS, social constructive and connected learning.

Thus, across the indicators for pedagogy type on the PB-LIFTS, the emergent themes indicated a social constructive pedagogy type characterized as teacher supported, collaborative student engagement, and co-constructed knowledge and products as well as connected learning characterized as teacher mentored, student directed, networked construction of a unique product.

Product indicators. To identify the level of innovation for the students’ PBL product, I studied the language and concepts Teacher 4 used to describe product originality, creativity, and content indicators in reflective journals and semistructured interviews.

For the first product indicator, product originality, Teacher 4 described in interview 1 that scientific data was used to create a novel product for presentation. Teacher 4 shared in interview 1 that trying to prepare students with the information they would need ahead of doing the research was impossible because he couldn’t predict in what direction their case study research would go; this indicated that the final product was original although they used standard scientific procedures. Teacher 4 described some of the steps involved in producing an original product. He said, “They made Google Slides, incorporating their research and they created the pedigree using an internet program they could print. They put everything together and transferred it to their poster.”

For the second indicator, product creativity, in interview 1 Teacher 4 described some of the creative flexibility for knowledge construction that students had. As a result of student-led research, he recalled, “sometimes they would come across a related topic that maybe I didn't know, or the case didn't provide, and they would tie it in to the product.” In interview 2 Teacher 4 said they were able to “make concrete connections between the science content and the case study, as well as their world for example, hereditary deafness.” In reflective journal 2, Teacher 4 described their creativity in producing the final product and said, “they used an online pedigree maker” to create “an attractive pedigree showing the Fugate’s long history with methemoglobinemia.” Thus, the emergent theme for final product was that it was creative and unique.

For the third indicator, product content, Teacher 4 explained in interview 2 that the content of the blue skin case study was complicated and implied that they did not have a model with that degree of complexity to follow. Teacher 4 added that “most of the websites and science books showing pedigrees were rather superficial” and often showed a genetic trait passed down through intermarriage in “royal families trying keep the crown.” Teacher 4 stated in interview 2 that the blue skin pedigree was “much more complicated in the Fugate family” indicating that the content was deep and multifaceted. Teacher 4 implied that the data students used was credible. In interview 2 he explained that although he supplied students with data for their research, they were also required to “find their own and research themselves.” Students showed Teacher 4 information they found, and he helped them determine if websites were “dependable” and the information was “factual and medically sound.” Teacher 4 expressed pride in the “quality of their work" shown in the final presentation. Perhaps seeing the depth of the pedigree and knowing it was based upon credible sources contributed to that assessment.

In sum, the emergent themes related to product indicators for originality and creativity aligned with level 3 on the vertical dimension of PB-LIFTS, transform. The product was redesigned and novel including creative elements. Emergent themes for the third product indicator, content, matched both level 3, transform, and level 4, innovate with respect to project content because the product showed synthesized knowledge that was deep and multifaceted.

Process indicators. To gain a deeper understanding of the level of HOTS students used to produce the pedigree presentation, I examined the 4T processes that the teacher described in reflective journals and semistructured interviews. The language and concepts Teacher 4 expressed relative to the 4T process skills revealed emergent themes that I correlated to levels thinking in the third dimension of PB-LIFTS. Themes associated with task, thinking, teamwork, and tool use indicated high performance levels.

Regarding task, PB-LIFTS indicators include PBL planning, organization, and accountability. Teacher 4 commented that task planning was one of his "favorite parts" and affirmed that his students were "empowered to develop a plan" and added that with some guidance they "developed their timeline and tracked their progress, and they set goals, as well as how they were going to achieve those goals." Teacher 4 stated in interview 2 that students informally organized "roles each person would have and how they were going to progress throughout the project." He also described how he supported task organization by teaching "specific content, such as what the pedigree should look like" and he helped them understand "medical terminology" and what information "needed to be included in their project." From this support, Teacher 4 suggested that they were able to "understand the broader picture" and they were aware of "what criteria they needed" so they could "keep progressing on their own."

Teacher 4 brought out several points regarding task accountability. In interview 2, Teacher 4 credited the team's persistence when he stated "[they] worked their hardest, to create and then re-create, drafts of their work, and sifted through research that on first read, was incomprehensible to them." Teacher 4 also mentioned how students were accountable even when one of the three was absent. They used Google Chat to keep progressing rather than making excuses for falling behind. They were determined to "reach all of their different objectives, until they were met." Thus, emergent themes for task were that planning ranged between adequate and well planned, organization was generally good, and the team was usually accountable to very accountable. These themes indicated task level 3, systematized, and level 4, synchronized on the PB-LIFTS. In the debriefing interview, Teacher 4 said he was hesitant to score their performance at task level 4 as they were not independent with planning, organization, or accountability. He added, "they still have room for improvement. Giving them a level 4 would mean I am satisfied with their [performance]. I want them to keep aiming higher." Teacher 4 and I settled on task level 3 and he remarked that although he was "impressed with their progress" he would expect to see even more independence next time.

Regarding thinking, PB-LIFTS has four levels ranging from low to high including recall of facts, comprehend, strategic, and extended thinking. In reflective journals, interviews, and the debriefing interview Teacher 4 addressed thinking skills. In interview 2, Teacher 4 discussed the many types of critical thinking students performed to learn the science content related to genetics, research medical history, evaluate sources, understand the facts, use the facts to develop the pedigree, and learn to use a pedigree software program. In interview 2 Teacher 4 described critical and strategic thinking students used for problem solving. In order to "figure out if the blue skin was caused by an illness or if it was genetic" they had to ask themselves the right questions and then use the answers to trace the "generational impact."

In addition to the thinking skills students used to work with the content, in reflective journal 2, Teacher 4 illuminated the thinking involved "in applying soft-skills within their team to achieve the final product." Referring to collaborative communication in written English or ASL, Teacher 4 summarized:

> Whether they were communicating in person, or restricted to using Google Chat, they had to find communicative levels and approaches to use, so that the whole team would be on the same page, and able to continue with the project.

Further, in interview 2, Teacher 4 explained that the students presented their project to different audiences and "had to synthesize a visual representation of that pedigree for non-science [audiences] to clearly understand." Teacher 4 implied that when they presented there was evidence of metacognitive thinking skills that enabled them to "cater to and match the needs and levels of the students and staff they presented to."

In sum, because of their involvement in this PBL unit, students engaged in a range of thinking skills. In interview 2 Teacher 4 said, "This project hit many different levels of thinking including lower level skills such as memorization and understanding the facts" as well as HOTS. Emergent themes for the higher levels were structured and procedural thinking to analyze and make generalizations which was thinking level 3, Strategic;

however, they also demonstrated complex reasoning at PB-LIFTS level 4, extended thinking to using complex reasoning to synthesize, design, critique, and collaborate. Once again, in the debriefing interview, Teacher 4 reminded me that “yes, maybe they functioned between Level 3 and Level 4, but they were not one hundred percent independent, I helped them too.” We agreed on level 3 for thinking.

Regarding teamwork, PB-LIFTS has four levels of team development including forming, storming, norming, and performing. Teacher 4 stated in interview 2 that “the other favorite piece of this project [besides planning] was how they got along.” However, he recounted in interview 1, that in the beginning of this project “they would fight more, they would blame each other, and then later they were able to kind of solve problems and work through it….then they were able to guide each other and feel more confident.” Teacher 4 implied that grading was a turning point in interview 2 he said they “realized that they were all working together, and that it's *our* grade, *our* project--not just me, not just you, but that they were all working together” then they were able to refocus and “really go in depth with the project itself.”

Teacher 4 emphasized that communication was a key for successful teamwork and said in interview 2, that this group was “very comfortable” with each other and had “open and honest communication.” He gave an example of how they might get a member of the team who “was off task” to participate more. They might say, “Hey, can you join in more? Can you pay attention…and stop going back and forth to the bathroom?” He said that “as the project continued, problems were discussed and resolved.” In this interview Teacher 4 said he noticed the students began to recognize each other’s skills such as with “technology” and “communication” He also said that “coming together as a team to focus on one goal was really new for some of them.”

Regarding having team roles, In the debriefing interview Teacher 4 explained that they did not need assigned roles. “For this project, the team was flexible” and through “informal” team dynamics “the students naturally picked their roles that matched their strengths.” In reflective journal 2 Teacher 4 commented on what he observed as an outcome of Google Chats regarding team interaction, “they developed their plan, you know, showing roles and responsibilities through the chat. I was proud of them and a little shocked too, that they would set up that time outside of school to have those chats.” In interview 1 Teacher 4 described the importance of having opportunities to work on a project with a team and stated:

> You know it's really a life skill that they're prepping for now with communication skills, critical thinking, problem-solving, and trying to figure out how to get to that end-product, and solving the mystery or the problem, or the experiment we're providing. But we're really practicing getting them ready for life after graduation.”

In the debriefing interview Teacher 4 felt teamwork contributed the most to the final product. Although this team was new to PBL, Teacher 4 was incredibly pleased with their progress and felt they functioned at a PB-LIFTS level 3, norming, for team development and would expect to see continued improvement next time.

Regarding resource tools, Teacher 4 in interview 1, discussed resources students used to do research for this PBL unit and stated that all the students were “required to do research” for this project. “They had to have at least 10 citations and find different resources." In interview 2 he addressed research challenges related to reading skills. He stated that when students in his classes were at grade level for reading, "they could kind of go on their own" but he said the students who participated in the Blue People project "weren't strong readers so I provided most of the resources to help them." He added that for this he had to modify website content to "fit the students' skills." He described strategies he used to help them gather information they could use for the study. He "summarized" the website content, then they could read it, and "we would add pictures. I had to do more teaching to guide them through the process." When they chose their own sites, he described how he helped them "check it if was dependable." Overall, the teacher provided significant support, so in the end, they had multiple resources which matches PB-LIFTS level 3 with guidance.

Regarding technology tools, as described earlier in the product indicator section, students used Google Chat used and Google Slides to collaborate and design the pedigree. To produce the final product Teacher 4 described in interview 2, the software students used to create the pedigree called Progeny Genetics from a rough draft. The students had no experience with this software. For this piece, Teacher 4 implied in interview 2 that he encouraged the students to figure out how to use the pedigree maker themselves; he said, "students had to learn to set it up by watching a video tutorial." He let them "play with it and experiment with the software until they all understood." He said that "at first they struggled, but with more experience and exposure, it became easier for them…. then they had to download the pedigree and save it." Hence, students used technology to redesign or transform a task from one medium to another which matched level 3 on PB-LIFTS for technology tools. In the debriefing interview Teacher 4 agreed with this assessment and he identified tools including resources and technology as an area of skills that would improve most with more PBL practice.

PB-LIFTS. Using pedagogy indicators, the emergent themes across the data aligned with two pedagogy types, social constructive pedagogy type C and connected learning type D on PB-LIFTS. Teacher 4 used social constructive pedagogy in face-to-face learning communicating in ASL, and connected learning pedagogy where students collaborated remotely by typing in English using Google Chat. Regarding product indicators, the emergent themes for product originality and creativity aligned with descriptors at level 3, transform, and product content at level 4, innovate. In the debriefing interview Teacher 4 preferred that the product rating be at a level 3 and reminded me that this was their first PBL and although he made a conscious effort to encourage student driven learning, “they were not 100% independent.” Plotting the pedagogy and product results on the PB-LIFTS matrix of 16 cells, the intersecting cell was C-D,3 for the Blue People of Kentucky PBL unit. This finding aligns with the RBT analysis that showed the PBL unit was in the highest quadrant for HOTS. This quadrant includes C3, D3, C4, and D4 as shown in Figure 13.

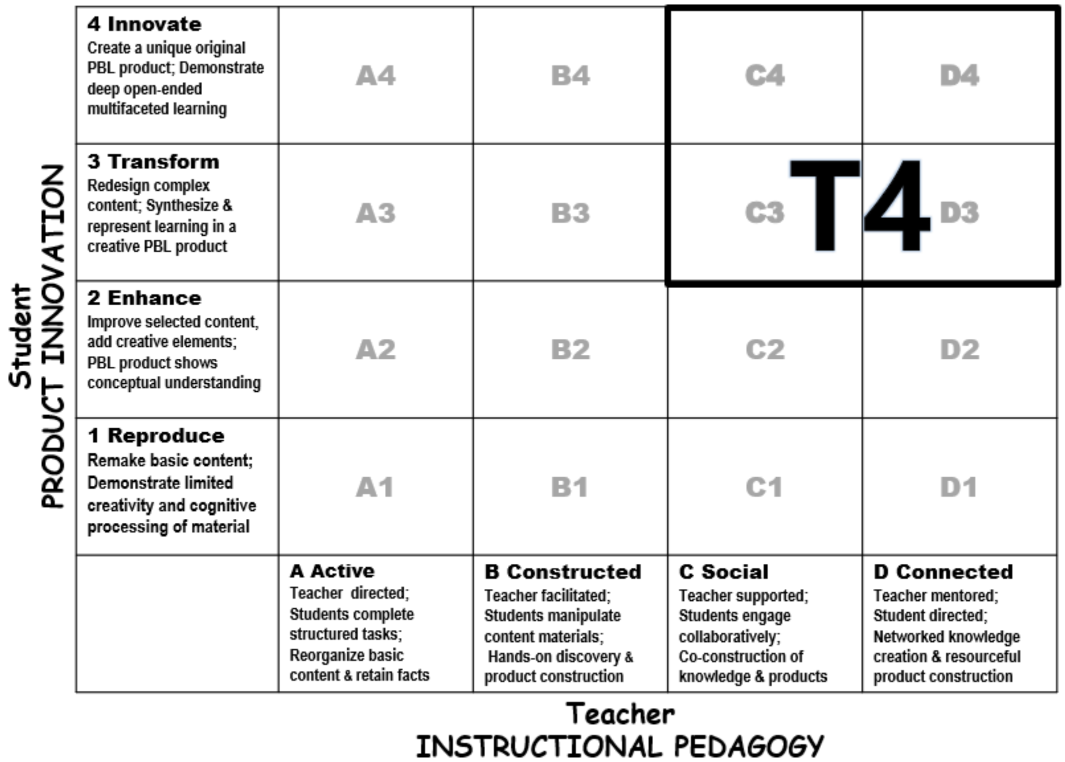


Figure 13. T4 shows where the PBL unit described by Teacher 4 placed on PB-LIFTS and the bold square represents the RBT highest quadrant for HOTS. Note: T4 = Teacher 4.

By examining the results of the process skills that were used to produce the product, indicators for teamwork, task, and thinking were aligned with PB-LIFTS descriptors at level 3 and some level 4. Resources and tool use were rated at level 3. Teacher 4 felt that for the whole team, it would be best to place process skills at level 3 although individual students performed at level 4 for some of the descriptors. He qualified this by saying rating process skills at a level 3 “is not negative, “I want them to keep aiming higher to get that four.” Teacher 4 wanted to see them achieve this without his support the next time. Even with the process skills rated at level three, this still indicated HOTS were used and this supported the product score at level 3, transform as well.

Regarding the RBT score, Teacher 4 said that the cognitive activity verb chart (Figure 7) was helpful for identifying levels of activities and asserted that the students worked at all levels of the taxonomy, “up and down and back again.” He agreed with the RBT result that with support, this team was able to perform at the highest quadrant but using PB-LIFTS was more meaningful. He implied that the RBT result was not descriptive enough or broken down into specific skills for discussion with individual students. He said, “high school students start to become more self-aware of their strengths and weaknesses” and having levels of specific skills delineated would be helpful to “keep them progressing in an upward slope.” Teacher 4 indicated that to prepare students for the next project, he could use PB-LIFTS to have “in-depth discussions one-on-one with students” and set individual goals for the next project.

When asked if he saw a relationship between the pedagogy and product innovation Teacher 4 said, “yes, they are related” and added that “as students’ process skills improve, their executive functioning improves so they can produce a more innovative product.” Teacher 4 saw resource tools as an area needing improvement. He clarified that “the students are learning to research and evaluate the credibility of resources, but they are still dependent on the resources I provide.” Teacher 4 felt that teamwork and thinking contributed most to their product innovation and he believed he would continue to see these improve with more PBL experience.

Results by Research Question

Research question 1. RRQ 1 was, how do teachers of the deaf describe HOTS in their pedagogical approach for PBL? Across all four teacher participants I found their PBL pedagogy to be similar, but one teacher described using two pedagogy types. All four teachers of the deaf created objectives for their PBL that engaged students with a range of skills in higher cognitive activities including analyzing, evaluating, and creating using procedural and metacognitive skills and knowledge. When plotted on the RBT taxonomy, objectives from all four teachers dominated the highest quadrant for HOTS. To better understand this finding, I analyzed each teacher's pedagogy type using three indicators including teacher role, student role, and learning design. I paired emergent themes with the PB-LIFTS pedagogy types, and this revealed that all four teachers engaged students in HOTS using social constructive learning and face-to-face communication. The indicators for this pedagogy type according to PB-LIFTS were as follows: The teachers' role was to support learning; the student role was collaborative, learning was student-led and co-constructed; and the learning design was social interactive. One difference was that Teacher 4 alternated between two pedagogy types, social constructive and connected learning; the latter is the most rigorous of the four PB-LIFTS pedagogy types regarding HOTS. Teacher 4 stated that this strategy strengthened students' second language skills and he believed such an approach was widely used in bilingual programs for the deaf. Using this approach, students were in separate locations and communicated via typing to one another in English. In connected learning pedagogy the teacher serves as a mentor, and students direct the learning process through networked construction of a unique product. Therefore, the key findings for RRQ1 were that teachers of the deaf set high expectations and differentiated PBL units to engage high performing and underperforming DHH students in HOTS using social constructive and to support second language development, connected pedagogy was also used on a limited basis.

Research question 2. RRQ2 was, how do teachers of the deaf describe HOTS in student PBL products? Across all four teachers' descriptions of student products, I found both similarities and differences. Each product was produced in response to an essential question or challenge posed in courses representing different disciplines including theater, history, robotic engineering, and biology. Each product description included higher order cognitive activities synonymous with analyze, evaluate, and create working with procedural and metacognitive knowledge. Using indicators, for product originality, creativity, and content, the levels of HOTS were identified in each teacher's description of the product with level 1 and 2 being lower ordered thinking skills and 3 and 4 being HOTS. Based on the data, all four teachers' PBL product descriptions indicated qualities at levels 3 and 4 for originality, creativity, and content. Level 3, transform, product descriptors were redesigned novel product, synthesized knowledge in a clever and creative PBL product. Level 4, innovate, product descriptors were unique, creatively ingenious, with deep and multifaceted content. In the debriefing interview after teachers evaluated students' PBL process skills, they revisited the data from the product indicators, and I asked if they felt the product rating between levels 3 and 4 was correct or if they recommended changing it. Teacher 1 and 2 felt the rating should be moved up to level 4, innovate, realizing how strong thinking and teamwork skills were. Teacher 3 felt the overall product rating should remain between levels 3 and 4 because the advanced students on the teams contributed to the product at a level 4, and the inexperienced team members contributed to the product at level 3. Teacher 4 preferred to rate the overall product at level 3 because his students were new to PBL, he provided support as needed, and he wanted his students to be more independent the next time. By rating the product at level 3, Teacher 4 believed this provided room for improvement, and promoted a growth mindset. Therefore, key findings for RRQ2 regarding product innovation were that the PBL products showed evidence of student engagement in HOTS and teachers were more confident rating the level of product innovation after evaluating PBL processes and considering the students' skills and abilities.

Research question 3. RRQ 3 was, how do teachers of the deaf describe HOTS in student PBL processes? I found both similarities and differences in the four teacher participants regarding the 4T processes: task, thinking, teamwork, and tools. All four teachers rated the 4Ts between levels 3 and 4 which indicates engagement in HOTS. The first process skill of the 4Ts was task and this included three indicators including planning, organization, and accountability. All four teachers determined that the teams performed at a level 3, systematized. Teachers modeled planning and organization early in the PBL and students took over after routines were established. Regarding task accountability, teachers described how they provided support in a variety of ways throughout the project. The key finding related to task was that students were not independent of teacher involvement in PBL task processes and this was most often due educational disparities among students. See Table 14.

Table 14

Key Findings for 4Ts for Research Question 3

	Key finding
Task	Students were not independent of teacher involvement in PBL task processes and this was most often due educational disparities among students.
Thinking	Teachers saw significant growth in students' thinking skills because of collaborative learning and PBL engagement regardless of students' academic standing.
Teamwork	Teachers were impressed by student growth in collaborative skills because of PBL engagement in teams, and both group and individual reflection on teamwork skills would support continued growth.
Tools	Teachers provided resources and students consulted with individuals for knowledge. One teacher required credible internet resources. Teachers saw use of technology tools as a strength for PBL teams to redesign and transform knowledge in products

Regarding the second of the 4Ts, thinking, Teachers 1, 3, and 4 described higher-level thinking as contributing the most to the success of the PBL unit and Teacher 2 identified teamwork first and thinking as the second most impactful skill. Further, teachers concurred that students of all academic skill levels were able to engage in high levels of thinking over the course of the PBL unit. Teachers 1, 2, and 3 rated thinking at a level 4, extended thinking using complex reasoning. Teacher 4 rated thinking at a level 3, strategic thinking using structured procedures because students were not yet independent and needed teacher support. All four teachers expressed great pride in the array of higher order thinking and teamwork they saw students demonstrate such as problem-solving, collaboration, critical thinking, leadership, persistence, reflection, communication skills, and technology use. Teachers elaborated on thinking skills students applied to effectively communicate such as asking clarifying questions, repairing communication breakdowns, code switching between written English and ASL, using metacognition to communicate with a variety of audiences. Additionally, Teacher 4 described high-level cognitive demands regarding communication in connected learning. The key finding was that all four teachers saw significant growth in students' thinking skills as an outcome of collaborative learning and PBL engagement regardless of students' academic standing. Therefore, deaf students in this study who had language and literacy barriers were able to demonstrate high level thinking skills through PBL engagement.

Regarding the third of the 4T processes, teamwork, all four teachers were exceptionally proud of their teams because they worked hard and showed "grit" as well as team development. Each teacher commented that learning to collaborate in teams is a critical skill and PBL provides the opportunity to develop this. Some of the teachers stated that students had some formal training in teamwork in middle school, but the high school PBL teamwork was informal regarding roles and responsibilities. The teachers rated teamwork at level 3, norming, and level 4, performing, which indicated engagement in HOTS. Each of the four teachers posited that reflecting and reviewing teamwork skills as a whole team and individually with each student would promote continued improvement in teamwork skills. In reviewing teamwork process skills with each teacher, issues of educational disparities influenced the teachers' teamwork rating. Teacher 1 had a team of three advanced students who were "natural leaders" and one student who struggled to find appropriate roles. Due to this imbalance, Teacher 1 rated the teamwork at level 3, norming. Both Teacher 2 and Teacher 3 had advanced students they felt functioned at a level 4 because they showed constructive synergy and leadership; they also had students with lower skills who functioned at level 3 because they were learning how to work together and clarifying their roles. Teacher 4 had a group of three students who were new to PBL and how to collaborate as a team on the same project. He rated this team at level 3. The key finding for teamwork was that teachers were impressed by student growth in collaborative skills as an outcome of PBL engagement in teams, and both group and individual reflection on teamwork skills would support continued growth.

Regarding the fourth of the 4T processes, tools, although all teachers noted that students used multiple resources and therefore rated resources at level 3, overall teachers admitted that the resources were usually provided by the teacher. Teacher 1 provided a documentary film as an example resource for students to create their own, Teacher 2 used a novel as the main resource, and the PBL that Teacher 3 described involved using a kit with instructions. Thus, for these PBL units, students were not expected to find their own credible resources; however, teachers described knowledgeable individuals in the learning environments that students used as resources. Teacher 4 was the only one who required students to find their own resources and to evaluate them for credibility. Teacher 4 indicated that his students were not proficient at this yet but developing this skill is essential "especially when using the internet." Because all the process skills in the third dimension of PB-LIFTS might not apply every PBL, the teachers recommended flexibility in choosing appropriate skills to evaluate for HOTS.

Regarding technology tools, in all the PBLs in this study, students used technology, and the emergent themes matched two levels. Teacher 1 rated technology use at level 4, unique and innovative, because technology allowed the students to create something that was once impossible. Teacher 2 had two levels of technology use at level 3 and 4 because students used technology to redesign and transform and created a unique and innovative product. She added that technology skills would continue to grow if students have access to it, and administrative support to update technology tools available to students is critical. Teacher 3 also rated two levels of technology use based upon the students' experience. The advanced students were at level 4 as "they were skilled in using a 3D printer for example, but the less experienced students were level 3." Teacher 4 described how his students learned to use new software for the project and agreed that technology tools were used to transform a task to another medium; therefore, he decided level 3 was appropriate and he expected to see students' technology skills continue to expand.

The key finding related to tool use was that students engaged in HOTS at levels 3 and 4. Most of the teams used multiple resources but three teachers did not expect students to find their own credible resources; therefore, these teachers did not feel it was appropriate to include resources in the evaluation. Secondly, all teams used technology tools to produce the final products; therefore, teachers agreed that this was appropriate to include as a process skill in the evaluation and alluded that skills using technology are critical to success in college and careers. Teachers made references to students of all ability levels engaging in technology use over the course of the PBL unit and implied that individual technology skills would continue to grow with experience and access.

A discrepant topic emerged in the data that could be considered a process skill. All four teachers addressed communication skills several times, but this skill did not have designated place in in the PB-LIFTS framework. Each teacher described communication skills that they observed students demonstrate or that they believed students needed to master for effective PBL collaboration. Perhaps this would be a good addition to the process skills as communication skills are needed for success in any PBL.

Based on data across all four teachers, I concluded the key findings for RRQ3 related to process skills were that the PBL units engaged students of all ability levels in HOTS, the most impressive areas of growth were thinking and teamwork, and teachers of the deaf suggested adding communication as a process skill. Secondly, teachers should be flexible and selective in choosing appropriate process skills to evaluate whole teams as well as individual students to identify strengths and set goals for future PBL improvement.

Research question 4. RRQ4 was, in what ways could the PB-LIFTS framework be useful to teachers for assessing HOTS? This question was addressed in the debriefing interview with each teacher and I found both similarities and differences across the four teacher participants regarding their thoughts on the usefulness of the PB-LIFTS. They all agreed that the RBT results were not as descriptive as the results using PB-LIFTS indicators to identify HOTS, but they thought the cognitive activity verb chart used for RBT could be useful for planning future PBL units. Teacher 4 stated “that chart is valuable” and said he would use it when writing goals because “verbs are really important” when planning for learning. Teacher 2 considered the indicators for the pedagogy types and stated that “good teachers know this, but to have indicators outlined like student role is a helpful reminder for where individual students are” on the continuum. Teacher 2 added that it would be helpful for novice teachers to use something like PB-LIFTS with indicators and levels. Teacher 3 indicated that having skill levels and indicators is helpful for working with “such diverse learners” for example you can “see who might need support and who is advanced" and it could be "used with a variety of goals or tasks" to track skill development. Teacher 3 said PB-LIFTS could also be used to "generate discussion and share different perspectives" regarding skill levels to identify "what we need to work on…to keep moving up diagonally." Using PB-LIFTS to assess process skills, teachers gained insight regarding the level of product innovation accomplished as a team. For example, after using PB-LIFTS to assess process skills Teachers 1 and 2 realized that thinking and teamwork skills were exceptional, so they decided to move the product innovation level up to 4.

Regarding process skills, Teachers had several ideas for how to increase HOTS using PB-LIFTS to assess skills. Teacher 3 suggested using a thinking map and said, "I would make a tree map with the four process skill categories task, thinking, teamwork, and tools and use it before or after as a review and make this part of the project." Teacher 4 indicated that having levels of skills and allowing students to see how they could improve next time can increase executive function skills and promote a growth mindset. When asked if the PB-LIFTS was useful for identifying HOTS, he replied, "it helps to understand levels of skill development so we can better encourage and empower students." Teachers 2, 3, and 4 noted that the PB-LIFTS helped them realize specific skills students demonstrated. For example, Teacher 2 described how students who were "nonreaders" were able to do technical problem-solving using visual skills and math. Teacher 2 remarked that involvement in project learning can offer opportunities for all students to "shine" even students who struggle due to poor English skills. Although Teacher 1 felt that PB-LIFTS was complicated, after assessing teamwork, he realized the need to help students become more aware of their personal skills and talents as well as those of their teammates. He brainstormed how he would introduce this for the next PBL unit. Instead of “the lower students just following higher students”, he hoped to “balance the work” so everyone had a role and knew what they could do. Teacher 1 also stated that PB-LIFTS would be useful to share with administrators and implied that they would value knowing how the PBL unit engaged students in developing HOTS. He stated that the terminology used in PB-LIFTS may be meaningful to teachers, but not to students. Teacher 3 was enthusiastic about building on PB-LIFTS and making it kid friendly. She also suggested creating a menu of tasks to help students discover what they are good at now and what they would like to work toward doing in the future. A recurring theme was that teamwork was informal and Teacher 3 emphasized that everyone needs to have a job they can do so discovering individual strengths and goals might help every student feel empowered and contributing. Collectively, based on data across all four teachers in the debriefing interview, the key finding for RRQ4 was that using PB-LIFTS indicators to identify HOTS in the dimensions of pedagogy, product, and processes was more informative than using RBT, and the results inspired strategies to support continuous improvement in the next PBL unit.

Central research question. The CRQ was, How do teachers of the deaf describe their lived experiences designing and implementing PBL to build HOTS with DHH students? Although each teacher represented a different discipline, their PBL experiences were more similar than they were different. They all ascribed to student-centered social constructive pedagogy and there were many similarities in the described PBL activities that promoted HOTS and took place before, during, and at the conclusion of PBL engagement. The four teachers planned with the end in mind and had high expectations for critical thinking that challenged students of all ability levels and included gold standard PBL design elements.

Prior to engagement in the PBL, teachers generated enthusiasm and curiosity about authentic topics that were meaningful and motivational for students. For each PBL unit, teachers described ways that students had a voice and ownership in the PBL topic and anticipated activities. Three of the four teachers described students as eager to begin the PBL and asked when they could start. All the teachers pursued activities that helped students understand the “big picture” of the PBL unit and expectations. The teachers were also careful to prepare students with background and content knowledge they would need. All these actions prior to engaging in PBL built students’ confidence and motivation and resulted in students demonstrating HOTS throughout the units.

In the early stages of the PBL units, each teacher modeled methods of planning and organizing the project and set up routines that students later took over. They fostered a culture of support and interdependence for problem-solving. Three of the teachers had mixed ability groups and all the teachers had some students with English literacy challenges. Three of the teachers described ways in which PBL engagement and social constructive pedagogy allowed students with language barriers to take on roles that allowed them to “shine” and use their strengths. The four teachers described group discussion and reflection as critical to social constructive learning, process skill development, and product critique and revision. One teacher periodically added a second pedagogical approach, connected learning, as a bilingual strategy to support English literacy skill development through online collaboration. All the teachers described visual prompts such as white boards used to review progress and promote team agreements, student self-direction, and time management. All four teachers fostered a culture of support with the goal to promote student-driven learning and independence; however, each PBL was rich in complex multilayered content and teacher intervention was needed at times. The PBL pedagogy and processes culminated as a quality product that showed tangible evidence of HOTS.

When the teachers described general outcomes of the PBL unit experience, they all expressed great pride in the “soft skills” and HOTS students demonstrated as an outcome of rigorous and multilayered engagement in PBL. They added that these skills are in great demand and will serve all students well in life beyond high school. Thinking and teamwork skills were the most impressive areas of growth but other forms of HOTS that teachers identified were collaboration, communication, critical thinking, problem solving, technology use, and creativity skills. They all made moving statements regarding how the PBL unit exceeded their expectations and posited that considering the student outcomes, it was well worth the effort. Overall, the key findings for the CRQ were that student engagement in HOTS surpassed the teachers’ expectations; as an outcome of applying evidence-based practices in the PBL units, students who had high language performance skills and students who were underperforming in language relative to their cognitive abilities engaged in rigorous multilayered content learning while developing HOTS in preparation for higher education and careers.

Summary

In Chapter 4, I described the setting for this IPA study, demographic information regarding the four teacher participants, and strategies used to support the trustworthiness of this research. Chapter 4 also contained a description of the data collection procedures over three study phases and the data analysis process. I reported the results of data analysis focusing on each teacher separately and provided the emergent themes that aligned with the three dimensions of the conceptual framework. Secondly, I focused on each of the four RRQs and CRQ focusing on patterns across all four teachers that emerged from data analysis and identified key findings in answer to each research question. The key finding related to RRQ1 addressing teacher pedagogy was that teachers of the deaf set high expectations and differentiated PBL units to engage high performing and underperforming DHH students in HOTS using social constructive pedagogy and one teacher also used connected learning pedagogy to support second language development. Key findings for RRQ2 regarding product innovation were that the PBL products showed evidence of student engagement in HOTS and teachers were more confident rating the level of product innovation after evaluating PBL processes and considering the students' skills and abilities. Key findings for RRQ3 related to PBL process skills were that the PBL units engaged students of all ability levels in HOTS, the most impressive areas of growth were thinking and teamwork, and the teachers suggested adding communication as a process skill. Secondly, teachers should be flexible and selective in choosing appropriate process skills to evaluate whole teams as well as individual students to identify strengths and set goals for future PBL improvement. The key finding for RRQ4 related to the usefulness of PB-LIFTS was that using PB-LIFTS indicators to identify HOTS in the dimensions of pedagogy, product, and processes was more informative than using RBT, and the results inspired strategies to support continuous improvement in the next PBL unit. Overall, the key findings for the CRQ were that student engagement in HOTS surpassed the teachers expectations; as an outcome of applying evidence-based practices in the PBL units, students who had high language performance skills and students who were underperforming in language relative to their cognitive abilities engaged in rigorous multilayered content learning while developing HOTS in preparation for higher education and careers. In Chapter 5, I will discuss interpretations of the findings, limitations of the study, recommendations, implications, and conclusion.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this qualitative study was to explore the lived experiences of teachers of the deaf in using PBL to build HOTS with DHH students in the areas of PBL pedagogy, product, and process. To accomplish this purpose, I developed a conceptual framework called PB-LIFTS aligned with my research questions that guided data collection from multiple sources. I used IPA methodology to gather detailed descriptions of four teachers' experiences implementing a favorite PBL unit with DHH students. Using IPA cycles of data collection and analysis paired with PB-LIFTS, levels of HOTS were identified in three dimensions using PBL indicators and cognitive activity verbs (see Anderson & Krathwohl, 2001). There exists an extensive body of recent scholarly research on using PBL to develop 21st century skills across disciplines, age groups, and learning contexts (Condliffe et al., 2016). However, empirical studies addressing the use of PBL with DHH students were scarce; therefore, little is known about how teachers of the deaf use PBL to build higher order skills needed for college and careers with DHH students. Thus, I addressed this gap in the literature by exploring the experiences of teachers of the deaf in using PBL to build HOTS. This study was conducted to extend the body of PBL research to deaf education and to understand the potential for using PBL to build HOTS with DHH students. This study addressed a second gap in the literature related to PBL assessment and HOTS. Numerous PBL researchers used RBT cognitive activity verbs to identify levels of cognition in PBL; however, recent studies concluded that available methods for assessing HOTS in PBL were not meeting teachers' needs (Alves et al., 2016; Du & Han, 2016; Schulz & FitzPatrick, 2016; Smith, 2016; Williams, 2017; Zhao et al., 2017). Thus, a flexible yet comprehensive method for assessing HOTS in PBL that could be easily adapted and applied in various contexts was lacking. My study was an attempt to fill this gap using the self-designed PB-LIFTS conceptual framework to identify levels of HOTS in three dimensions of cross-disciplinary PBL units to gain insight regarding how levels of HOTS can be identified in multilayered constructive learning using PBL.

The critical phenomenon of interest in this study was how teachers of the deaf used PBL strategies to promote HOTS. Using the PB-LIFTS aligned with my research questions, I explored HOTS in the dimensions of PBL pedagogy, product, and processes described by four teachers of the deaf reflecting on a previously implemented PBL unit. I used RBT and indicators to identify themes and matched them semantically with the four levels of HOTS delineated in the three dimensions of the PB-LIFTS framework. In Chapter 4, I reported the results from each teacher individually. Then I consolidated the results across all four teachers for each research question and stated the key findings. Overall, the key findings for the CRQ were that student engagement in HOTS surpassed the expectations of the teachers of the deaf; as an outcome of applying evidence-based practices in the PBL units, both high performing and underperforming students engaged in rigorous multilayered content learning while developing HOTS in preparation for higher education and careers. In Chapter 5, I interpret the key findings drawing from the literature review to situate the findings from my study in the context of current scholarly research.

Interpretation of the Findings

The literature review for this study was extensive and involved an examination of over 700 scholarly articles with three main areas of interest, including PBL, HOTS, and deaf education. To gain a comprehensive understanding of PBL, I reviewed recent implementation studies focusing on PBL benefits, challenges, teacher perceptions, preparation, and instructional practices. To learn about the relationship between PBL and HOTS, I included studies on cognition and 21st century skills, complex PBL pedagogies and HOTS, claims regarding PBL and HOTS, PBL processes and HOTS, and measuring HOTS in PBL. Lastly, to gain an understanding of pedagogy in classrooms with DHH students, I included historical underpinnings of deaf education pedagogy, deaf education in modern times, and calls for pedagogical change in deaf education. The three threads of this review were constructive for understanding teachers' experiences using PBL from their point of view, interpreting the data related to the research questions, and situating my study's findings within the scholarly literature.

In the next section, I provide the findings of recent research on the three dimensions of the PB-LIFTS conceptual framework and my research questions. I discuss what is known from the body of current scholarly literature regarding how my study confirms, disconfirms, or extends previous findings. Due to the exploratory nature of my study, it is essential to consider the results cautiously. The findings were drawn from data across four experienced teachers of the deaf and are not generalizable, as this small sample is not representative of all DHH learning contexts.

Teacher Pedagogical Approach

RRQ1 asked how teachers of the deaf described HOTS in their PBL pedagogical approach. Key findings from my study related to PBL pedagogy were that the teachers of the deaf set high expectations and used strategies to engage all students in HOTS using social constructive pedagogy, and one teacher supplemented this with connected learning pedagogy. Although scholars in deaf education have asserted that social constructive learning strategies would benefit DHH students (Cawthon et al., 2018; Pagano et al., 2016; Ross et al., 2020), PBL implementation studies with DHH students were not found in the literature review. However, studies with diverse student populations showed that skilled teachers were able to successfully implement social constructive PBL units that engaged students with a range of skills in HOTS (Catapano & Gray, 2015; Chiang & Lee, 2016; Shin, 2018). Therefore, my study fills a gap related to DHH students. The teachers of the deaf in my study used two constructive pedagogy types that dominated the PBL literature. These included face-to-face social constructive pedagogy (e.g., Dole et al., 2016; Martelli & Watson, 2016) and connected learning pedagogy in which learners collaborate online, physically apart from one another (e.g., Rahimi et al., 2015; Shadiev et al., 2015). These two pedagogy types are on the high end of the PB-LIFTS constructive pedagogy continuum for HOTS and are student-centered instructional approaches (cf., Lin et al., 2015; Siemens, 2004). Collaborative learning in both pedagogy types prompts students to use critical thinking skills and engage in metacognitive tasks.

Social constructive pedagogy. In social constructive pedagogy, teachers serve a supportive role as students collaboratively co-construct a product representing their learning (Lin et al., 2015). A large body of research supports the use of social constructive pedagogy in PBL to engage all students in developing 21st century HOTS while working collaboratively (Du & Han, 2016; Habók & Nagy, 2016). Additionally, collaborative learning was found to be motivational for students (Zhao et al., 2017) and supports social-emotional skills (Culclasure et al., 2019). However, studies show that teams are typically heterogeneous, and balancing participation can be difficult for teachers (Ainsworth, 2016; Dole et al., 2016; D. Lee et al., 2015; Moliner et al., 2015). The teachers of the deaf in my study described the challenges of positioning students who were very bright but had poor reading skills to use their hidden talents when collaborating with higher functioning peers. A flurry of research in recent years from the fields of mental health and medicine addressed the topic of language deprivation syndrome and how the lack of language access in the early years can have a cascading effect impacting individuals over the life span (Bergeron, Berland, Demers, & Gobeil, 2020; Cheng et al., 2019; Meinzen-Derr et al., 2018).

Additionally, García-Merino et al. (2020) posited that all team members from struggling to advanced could excel when one goal is to maintain a consistent effort. The teachers of the deaf in my study confirmed these findings when they described surprising and impromptu talents students showed. Often this occurred with students underperforming in language skills, yet they demonstrated high cognitive skills for problem-solving in PBL.

Darling-Aduana and Heinrich (2018) found that PBL can be easily differentiated, and recent studies highlighted evidence-based strategies recommended for engaging mixed ability teams. The teachers of the deaf in my study adapted all the following strategies to prepare DHH students before engagement in social constructive PBL units.

- Plan with students' unique needs in mind (Meinzen-Derr et al., 2018; Mercer et al., 2019).
- Create a culture of thinking together (Mercer et al., 2019).
- Use group dialog (Swanwick, 2017; Webb et al., 2019).
- Scaffold concepts (Chua et al., 2014; Kadir et al., 2019).
- Increase background knowledge to fill gaps (Damsa & Muukkonen, 2020).
- Create incentives for positive interaction (Chen et al., 2019).

The teachers of the deaf in my study set high expectations for learning. By implementing evidence-based strategies, they were able to navigate challenges and support engagement in HOTS throughout the PBL units with high and underperforming students. These talented and committed teachers of the deaf disconfirmed prior studies that concluded DHH students are educationally at risk due to teachers having low expectations and failing to provide access to rigorous learning (Alofi et al., 2019; Salter et al., 2017; Smith, 2013). Using PB-LIFTS to explore the teachers' PBL experiences not only revealed the pedagogy types that the teachers of the deaf used in their PBL units with DHH students, but also extended understanding that when highly effective teachers create PBL learning experiences, DHH students of varying abilities benefit. In relation to having high expectations, my study showed that skilled teachers of the deaf were able to successfully adapt evidence-based social learning strategies in their PBL units with DHH students to engage them in HOTS.

Connected learning. Indicators for connected learning were that teachers serve as mentors and students direct learning through networked construction of a unique product. One teacher in my study supplemented social constructive pedagogy with connected learning as a bilingual strategy for increasing literacy skills during PBL engagement. Students in this class were new to PBL and were not yet ready for full implementation of connected learning pedagogy; however, the point that the teacher considered this type of engagement for DHH students is essential. Research findings suggested that DHH learners are like ELLs (Howerton-Fox & Falk, 2019) and that ELL strategies should be used with DHH students for academic language acquisition (Strassman et al., 2019). Recent studies found that online engagement in English was motivational for ELLs while improving second language and thinking skills (Lamb & Arisandy, 2020; Zhang & Zou, 2020). The findings of Darling-Aduana and Heinrich (2018) and Putri et al. (2017) confirmed that such second language engagement is critical to transforming processes and outcomes for bilingual learners. Further, Eliyasni et al. (2019) found that blending social constructive and connected learning in PBL courses increased HOTS; this implied that using blended learning in PBL units with ELL students may have multiple benefits.

Student Product Innovation

RRQ2 explored how teachers of the deaf described HOTS in student PBL products. One finding from my study was that the products teachers described were original, creative, and sophisticated in content, a high level of PB-LIFTS product innovation. Students used HOTS such as problem-solving, critical thinking, communication, and collaboration to produce PBL products. Studies related to the maker movement (Bell, 2017) and PBL found that when students engage in PBL to produce a product that is meaningful to them, they will negotiate with teammates and engage in HOTS (Georgiou, 2020; Przybysz-Zaremba et al., 2017), and in my study, teachers' overall descriptions of student behaviors confirmed this. While some researchers cautioned that students might rush through projects and produce products that show little effort and lower-level thinking skills (Dole et al., 2017; Rudnitsky, 2013; Smith, 2016), my study disconfirmed this when teachers of the deaf reported that the students genuinely cared about their projects. The teachers of the deaf reflected on the students' perseverance and determination to produce products to the best of their ability. Other studies from the literature showed that when students felt a sense of autonomy and were empowered with a voice and choice regarding their project, this increased ownership, deeper learning, creativity, self-regulation, and engagement in HOTS (Dole et al., 2017; Martin, 2015; Virtue & Hinnant-Crawford, 2019). My study confirmed these findings as well; therefore, my study extends what is known about PBL products and HOTS to DHH students. Studies regarding PBL product assessment found that evaluating a collaboratively produced product without considering individual contributions were challenging for teachers (Nariman & Chrispeels, 2016; Virtue & Hinnant-Crawford, 2019; Williams, 2017) and this was confirmed in my study. The teachers of the deaf were more confident rating the level of student product innovation in the vertical dimension of PB-LIFTS after evaluating the PBL process skills of individual team members. This may confirm Peng et al.'s (2017) contention that every learning context is unique, and assessment methods should consider the learning needs and skills of the students. Therefore, my study may extend what is known about assessing group projects and suggest that the innovativeness of a collectively produced product should be considered in tandem with the individual skills and abilities that created it.

Student Project-Based Learning Processes

RRQ3 explored HOTS in student PBL processes described by teachers of the deaf in my study. In the literature, scholars voiced a persistent need for adaptable methods to assess HOTS in PBL process skills (Schulz & FitzPatrick, 2016; Smith, 2016; Williams, 2017; Zhao et al., 2017). Hence, my study was an attempt to address this gap using indicators embedded in the third dimension of the PB-LIFTS framework to identify HOTS in selected PBL process skills, including task, thinking, teamwork, and tools.

Task. The PBL literature showed that teachers modeled how to organize and plan projects in the early stages of PBL units, but as PBL units progressed, students were given autonomy and took over these process (Dole et al., 2016; Habók & Nagy, 2016; Kokotsaki et al., 2016). This finding was confirmed in my study as the teachers of the deaf reported that once the learning process was transparent, students took over the lead. Next, PBL literature related to task showed that teachers had difficulty letting go of control in student-centered learning (Breunig, 2017; Dole et al., 2016). Teachers in my study confirmed that they had to consciously resist the urge to step in and manage learning processes and admitted they intervened at times, such as when students were overwhelmed by task complexity, or problem-solving efforts took a team too far off track. Thus, my study confirmed that allowing students to manage full responsibility for task processes without teacher intervention was a challenge, but also disconfirmed the finding in the literature that letting go of control and adjusting to the role of the facilitator in PBL was difficult for teachers. The teachers of the deaf in my study were comfortable supporting student-led learning as appropriate. A third issue in the literature related to task accountability and unequal participation among team members. Free riders were a recurring source of conflict on teams (Ainsworth, 2016; Dole et al., 2016; Kim, 2015; D. Lee et al., 2015). In my study, teachers of the deaf reported times when unequal participation occurred, but unlike the free-rider problem, the work imbalance occurred when underperforming students' language barriers limited their job choices. While matching willing learners with suitable tasks posed challenges at times, most often, the teachers described high levels of participation and task accountability, which disconfirmed the finding in the literature related to free riders causing team conflicts.

Thinking. Teachers in my study identified thinking as one of two process skills that contributed the most to the success of the PBL units. My study confirmed other study findings (Hao et al., 2016; Pellegrino, 2017; Perry-Smith & Mannucci, 2017). PBL engagement could foster HOTS as all the teachers in my study described student involvement in similar activities that demonstrated metacognitive thinking skills. Studies have also shown PBL to be an effective strategy for engaging a range of at-risk and marginalized students in higher level thinking (Chiang & Lee, 2016; Holmes & Hwang, 2016) and my study confirmed these findings and extended the value of using PBL to promote thinking skills with DHH students. Students who were underperforming in language were able to apply other skills that contributed to the project, and teachers described the empowering effect of this experience for students and teachers alike.

Teamwork. At the conclusion of my study, teachers of the deaf identified teamwork as the process skill that showed the most growth and contribution to the success of PBL units. Studies on PBL teamwork concluded that positive interdependence was critical for collaborative learning (Chen et al., 2019) and structures for effective collaboration are needed (Ainsworth, 2016; Nariman & Chrispeels, 2016) as well as teamwork training and rubrics that can be reviewed regularly to maintain team productivity (Zhao et al., 2017). In the early phases of my study, teachers indicated that teamwork was an informal process and that a formal structure for teamwork was not needed. Because the PBL units in my study were successful, my study may have disconfirmed the literature supporting formal teamwork structures; however, after using PB-LIFTS to explore team dynamics and process skills, teachers' views regarding the value of collaborative structures may have changed. As evidence of this, two teachers of the deaf shared ideas for future PBL units intended to increase student interdependence by developing a procedure for personal skills discovery and PBL role identification. Their plans were a form of norming at the third level of Tuckman's (1965) team development.

Also related to teamwork, my study confirmed recent research (Hidayati, Zubaidah, Suarsini, & Praherdhiono, 2020) showing that as students gained content knowledge through team collaboration, they also developed communication skills and metacognitive thinking. For example, teachers reflected on students indicating awareness of missing information to teammates, managing interpersonal discourse, asking pertinent questions, negotiating problem-solving strategies, using communication repair strategies, and showing help-seeking behaviors. The positive influence of PBL engagement on students' communication skills in my study confirmed the recommendation that DHH students would benefit from constructivist learning in other studies (Cawthon et al., 2018; Ross et al., 2020).

Tools. While PBL studies from elementary to college levels showed that students struggled with tasks related to finding resources, evaluating credibility, critically analyzing content, and advocating for project resources, they also found that these are critical transferrable skills for higher education and careers (Damsa & Muukkonen, 2020; Nariman & Chrispeels, 2016). In my study, most of the teams used multiple resources, but three teachers did not expect students to find their own credible resources. However, one teacher in my study did require students to research and provide credible sources but admitted this was especially difficult for DHH students with reading challenges. This teacher confirmed the importance of all students developing information searching as a critical skill (Carvalho, 2016) for high school transition readiness.

A second part of the tools process skill is student use of technology. Studies in the literature review revealed that the SAMR model could be used to evaluate levels of innovation in student products (Cherner & Smith, 2017; Hartmann & Weismer, 2016), and this was confirmed in my study. The DHH student products evaluated using SAMR showed high levels of innovation in transforming knowledge and redesigning tasks using multimedia, 3D printers, and science applications. The literature also supports the importance of engaging students of all ability levels in developing digital literacy skills (Israel, Pearson, Tapia, Wherfel, & Reese, 2015) and this was confirmed in my study as all the teachers of the deaf engaged students in using technology as a learning tool.

Usefulness of Project-Based Learning and Innovation for Teachers and Students

Research Question 4 explored teachers' perceptions of the PB-LIFTS framework for assessing HOTS. The literature revealed the need for a method to evaluate HOTS in PBL units (Alves et al., 2016; Georgiou, 2020; Schulz & FitzPatrick, 2016; Smith, 2016). To fill this gap, PB-LIFTS included two methods of assessing HOTS. Teachers indicated the results using RBT were too broad and suggested simplifying the PB-LIFTS assessment process by eliminating RBT. Teachers found the results using indicators to identify HOTS to be more informative with analytic descriptors that could be used to monitor progress.

First, in the pedagogy dimension, teachers commented that as experienced teachers, they were intuitively aware of the pedagogy continuum, but having this in print could be a helpful reference for supporting mixed ability teams and a useful resource for novice teachers and mentors. Second, in the product dimension, teachers recommended clarifying indicators for creativity but felt that the continuum of innovation was helpful for product assessment and discussion with students. Third, the PBL process dimension was most helpful for assessing individual and group HOTS. It also helped confirm the product innovation assessment after considering the students' process skills and effort. Teachers recommended making a kid-friendly version of PB-LIFTS for goal setting. Further, the process skill evaluations sparked ideas to implement in the next PBL unit that would support areas of weakness. Last, the teachers recommended flexibility regarding the selection of process skills to evaluate, which confirmed Zhao et al. (2017) that assessment rubrics must be appropriate to the learning context. For example, they did not feel that evaluating resources would be an appropriate choice in every PBL. They also suggested adding a culturally sensitive communication rubric to PB-LIFTS process skills (see Caggiano, Schleutker, Petrone, & González-Bernal, 2020).

Central Research Question

The CRQ asked how teachers of the deaf described their lived experiences designing and implementing PBL to build HOTS with DHH students. While the teachers in my study described their PBL experiences as challenging, when reflecting on PBL outcomes, they also expressed tremendous pride in student learning and HOTS development that surpassed their expectations. This sentiment was confirmed in the literature as teachers asserted that the benefits of PBL far outweighed the challenges (Dole et al., 2016; Habók & Nagy, 2016). Studies have also found that PBL outcomes positively impacted teacher capacity and self-efficacy (Choi, Lee, & Kim, 2019; Darling-Aduana & Heinrich, 2018), and this was confirmed by teachers in my study who expressed that the student growth was motivational and encouraging for them. Teachers in my study posited that by engaging DHH students in PBL and developing HOTS, they were developing critical skills for life beyond high school. Studies confirmed this by showing that PBL was an effective strategy for developing HOTS needed in higher education and the workplace (Henshon, 2017). Further, researchers in deaf education have shown that soft skills and self-determination are predictors for successful transition outcomes (Cawthon, Wendel, Bond, & Garberoglio, 2016). Thus, the lived experiences of teachers of the deaf in my study who successfully engaged DHH students in developing HOTS underscore the value of extending the use of this strategy to this student population.

Limitations of the Study

Before beginning my study, I identified potential threats to the trustworthiness and developed strategies addressing researcher bias that successfully mitigated these concerns; however, other limitations emerged related to my qualitative study design. First, I limited my study to four high school teachers of the deaf experienced in using PBL. Although the small sample size is a strength in IPA studies (Smith et al., 2009), in deaf education, there are several major educational placement types, and participants in my study represented one of them. Therefore, additional research is needed with other subpopulations of DHH students before assuming that PBL should be extended to all DHH students.

A second study limitation related to time as I did not put restrictions on when each teacher's selected PBL was implemented. Three teachers' favorite unit took place the year before, and one happened several years earlier; however, the latter's product became a social studies curriculum resource viewed annually. The teacher's recollection of the experience was vivid. All teachers received the semistructured interview questions prior to each interview and, therefore, were given time to reflect on their experiences and refresh their memories.

A third limitation related to time and study design was that teachers had to invest time preparing for the debriefing interview conducted using a Zoom conference call rather than in person. The PBL-HOTS packet for applying the results in the PB-LIFTS framework was developed, expecting an in-person debriefing session to explain the process. Further, one finding from the assessment process using PB-LIFTS was that teachers found it complicated and recommended eliminating RBT. Simplifying the framework would increase the transferability of using PB-LIFTS in other studies, which is addressed in my recommendations.

Last, all teachers were invited to provide optional artifacts such as lesson plans, rubrics, photos of products without identifying information. Although teachers wanted to share the PBL products, they could not remove students from the visuals, so to comply with IRB requirements, they were not included. Thus, a limitation to the study was reliance on teachers' descriptions.

Recommendations

This study addressed two gaps in the literature—the first gap related to the absence of PBL implementation studies with DHH students. My study found that teachers of the deaf used PBL to build HOTS with DHH students with a range of skills and abilities. Limitations of this study related to a small number of teachers from separate schools for the deaf. Based upon these limitations and the results of this study about the use of PBL with DHH students, my first recommendation is to replicate this study with other age groups of DHH students and in other program placement types. Secondly, I recommend replication of this study with subgroups DHH students such as academically advanced students, students who are underperforming in language, students with disabilities, and multilingual students to better understand the capacity of PBL strategies to foster HOTS with subgroups of DHH students. Third, concerning PBL pedagogy types and the finding that social constructive pedagogy was used almost exclusively by teachers in my study, I recommend that researchers consider expanding this to study PBL and HOTS in connected and Blended learning. Finally, a long-term recommendation is to study the relationship between using PBL with DHH students and transition outcomes to gain a broader understanding of the potential for using PBL to impact transition trajectories.

The second gap my study addressed was the lack of a flexible method to evaluate HOTS in PBL units. To address this need, I developed the PB-LIFTS framework to identify HOTS in three dimensions of PBL units. One finding from my study was PB-LIFTS could be used to identify HOTS; however, the framework was complex. A second finding related to the PB-LIFTS was that using indicators to identify HOTS in pedagogy and products was more informative than using RBT. Thus, to streamline the PB-LIFTS framework, I recommend eliminating RBT. A third finding related to PB-LIFTS was that teachers should be selective in choosing process skills to evaluate appropriate learning contexts. With these recommendations in place, more research is needed using PB-LIFTS to evaluate HOTS in PBL with a variety of student populations to gain a deeper understanding of the potential for PB-LIFTS to fill the gap related to the lack of a method to evaluate HOTS in PBL units.

Implications

The results of this study have implications for positive social change on the individual level, the organizational level, and the societal level. My study showed that skilled teachers of the deaf successfully implemented motivational PBL units and students engaged in developing HOTS such as communication, collaboration, creativity, and technology use, problem-solving, and critical thinking. These skills are highly valued in the workplace and developing these skills while in school is a step toward preparing students for the transition to adult life. The present study findings extend the use of PBL as an innovative and comprehensive strategy for developing critical skills students need for careers. Thus, on the individual level, the findings of this study support the adoption of PBL with DHH students to improve transition outcomes.

The findings of this study also can support positive social change at the organizational level in deaf education. Kelly et al. (2016) reported that DHH students do not develop the 21st century skills needed for success beyond high school. Recent studies support the need for social constructive instructional strategies to better prepare DHH students for careers and higher education (Millen et al., 2019); further, Cawthon, Wendel, et al. (2016) asserted that interaction with deaf adults and peers is critical to transition outcomes. My study supports implementing PBL with DHH students to develop HOTS for career readiness; however, for teachers of the deaf to do so, they need opportunities to bring students together as teammates. With the high incidence of DHH students receiving one-on-one services from itinerant teachers of the deaf (NCES, 2016), this may require creative systemic changes regarding placement and service delivery. In this regard, my study may advance knowledge in deaf education, drawing attention to the need for social constructive learning opportunities where DHH students can develop the skills they will need to apply in the workforce. Hopefully, my study will prompt additional research on PBL with DHH students, and positive learning outcomes will influence stakeholders and policymakers to assure that DHH students are afforded opportunities to engage as innovators in PBL.

At the societal level, my study also advances knowledge in the field of general education at all levels, including higher education. Studies in the literature review revealed that teachers were not confident in assessing HOTS (Schulz & FitzPatrick, 2016), and a new method was needed (Smith, 2016; Zhao et al., 2017). My study attempted to fill this gap with the PB-LIFTS framework designed to assess HOTS in three dimensions of PBL. Although the PB-LIFTS framework was not perfect, it can be flexibly adapted for any learning environment. The key to using the framework was developing levels of process skills to understand how those skills supported product innovation, coupled with the teacher's pedagogical approach. The findings from my study shed light on how HOTS can be identified and used for reflection and goal setting. Thus, my study bridges theory and practice to support teachers and students using PBL globally.

Conclusion

Deaf education is the oldest branch of special education with a long history of poor academic outcomes (Marschark et al., 2015) and high rates of underemployment and unemployment (Schley et al., 2011). However, studies have shown that DHH students can make academic gains equivalent to hearing peers (Bartlett, 2017). The contemporary drive among general educators to use evidence-based practices sparked an examination of the research base used to inform teaching practices with DHH students. The finding was that deaf education research was based upon beliefs and opinions rather than evidence (J. E. Cannon et al., 2016; Luckner et al., 2016). Recent changes in special education brought a new emphasis on improving transition outcomes. Dammeyer, Crowe, Marschark, and Rosica (2019) posited that the demand for workers with practical communication skills is growing while manual labor jobs are shrinking; hence, deaf individuals preparing for gainful employment may find formidable barriers. The results of this study showed that skilled teachers of the deaf could successfully implement evidence-based practices, set high expectations, and effectively engage DHH students with a range of abilities to develop HOTS. Teachers reported that students showed the most significant areas of improvement in teamwork and collaboration, and these require communication skills. Preparing DHH students to navigate the challenges of joining the workforce in the 21st century, teachers of the deaf must provide opportunities for these young people to develop the skills that will position them for success. I hope that using

PBL with DHH students will grow as well as the evidence base that may trigger systemic changes focused on learning rather than opinions and beliefs.

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Appendix A: Permission from Pearson

Pearson

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Appendix B: Demographic Information

Instructional Setting and Teacher Preferences
Teacher name: ______________________ City _____________ State ____________

Years teaching: _____ Gender: M__ F__ Licensed to teach DHH? Yes No

Type of certification: ____

What degree(s) do you hold? ____

Level of comfort using PBL with DHH students: low 1 2 3 4 5 + high

PBL learning environment where your selected PBL was implemented with DHH students: Please provide level, subject, program type (i.e., public center-based, public itinerant, state residential, charter school), and service delivery model (i.e., self-contained, resource room, pull-out, online, special school)

Level	Subject	Program Type	Service Delivery

Communication accommodation: Your preferred language for interviewing

- □ Spoken English
- □ ASL
- □ Sim-Com
- □ Other ____

Best contact: Cell text ____________ Work Ph.: _______________
Is this a video phone? ____ Do you have access to one? ______

What is your preference for interviewing?
____ in-person interview
____ video conference call

Have you used zoom? ____

Preferred E-mail: Work ________________ Personal ___________________

School Name and Address:

Appendix C: Overview of Selected Project-Based Learning

Please choose a favorite PBL you implemented in the past and provide the information requested. This will be the PBL you will reflect on during interviews. Keep in mind that the purpose of this study is not to compare students, programs, or communication modes. This study is designed to discover how teachers of the deaf use PBL to build higher order thinking skills (HOTS) regardless of student achievement levels.
The information provided will be used for warm up to start our first interview.
Please return this overview to Susan Elliott via attachment: sjsuz@aol.com
or take a picture of the completed form and send the photo to: (720) 300-7255.
Thank you!

Participant: ______________ Course subject: _______________ Grade level ___

Name the PBL____

Last implemented in ____-____school year

Implemented with how many teams of DHH students at one time (circle) 1 2 3 or more

Number of students per team: ______ Have they worked together on a PBL before? ___

What was the essential question or problem students focused on for this study?

____

Please provide the key learning objectives for this PBL that you originally planned:

1. The students will ____

2. The students will ____

3. The students will ____

What did they make for the final product?

____

____

____

____

Comments/questions

Appendix D: Reflective Journal Prompts

Journals will contain information from the PBL overview with the name of the PBL unit, essential question or problem, and the objectives.
Prompts will be sent before the interviews via e-mail. They are intended to prepare participants for the upcoming interview and collect written data related to the research questions for analysis. Upon receiving this, the researcher will send the participant the interview questions to review.

Before interview 1 Reflective Journal Prompt

RJ-1. On the PBL overview, you selected a favorite PBL and provided the learning objectives. In a few sentences, please give some background for choosing them.

Before Interview 2 Reflective Journal Prompt

RJ-2. Describe the 21st century skills or higher order thinking skills you hoped to see students develop when you planned the PBL. How were they evident in the final product?

Before Interview 3 Reflective Journal Prompt

RJ-3. Describe the times you were particularly pleased with student learning and engagement during this PBL. What were they doing? What skills and talents were they showing?

Appendix E: Semistructured Interview Guide

Warm up script for establishing rapport between researcher and participant:
The researcher will review information the teacher provided on the PBL Overview. This included the number of years teaching and how the teacher started using PBL. "You were asked to choose a favorite PBL you implemented with DHH students. This was titled ________________and implemented with a (grade level) (subject) class and there were (number of) students, correct? What was the essential question or problem?
The final collaborative product was ____.

P1-A: You provided learning objectives for this PBL and in your journal response you gave some background regarding how you selected the objectives. Can you elaborate a bit?"

Phase 1 Interview Questions: Planning and Student Product

P1-1. Please *tell me briefly how this favorite PBL came about. What inspired it? What did you hope students would gain?* (Narrative)
Can you tell me a bit more about ______? (Prompt)
What do you mean by _____? (Probe)

P1-2. *What process did you use for planning this PBL? Did the original plan change over time as the PBL progressed? How and why?* (Descriptive)
Can you tell me a bit more about ______? (Prompt)
What do you mean by _____? (Probe)

P1-3. *How did you introduce the PBL and engage students in learning processes? What expectations did you convey to students? How?* (Descriptive)
Can you tell me a bit more about that? (Prompt)
What do you mean by …? (Probe)

P1-4. Over the course of the project what roles and responsibilities did students take on and how were they decided? If you were a bug on the wall how would you describe your role(s)? (Descriptive)
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

P1-5. *Describe the final product students produced. What learning activities did they engage in and what skills did they use to make it?*
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

P1-6. *Tell me about assessment strategies for this PBL. Other than project presentations, how did you decide what to assess and how to assess it?*
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

Phase 2: PBL Processes Interview

P2-1. Tell me how the PBL was managed (by you and/or the students).
How did students know what to do and when?
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

P2-2. Tell me about the resources students used to answer the PBL question or problem.
How were they selected? How did they use resources and information in the product?
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

P2-3. Tell me about your observations of how students functioned in teams.
What was collaboration like? Did it change over time? How?
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

P2-4. If students used technology for this PBL what did they use and for what purpose?
Did it change over time? How?
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

P2-5. Considering both the final product and the processes that produced it, can you identify skills, talents, or awareness that you hope they will continue to develop?
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

P2-6. Is there anything related to PBL and how this unit helped build higher order thinking skills (HOTS) that you didn't have a chance to share?
Can you tell me a bit more about ______? (Prompt)
What do you mean by …? (Probe)

Phase 3: Debriefing Interview

P3-1. We used two methods for identifying HOTS in the PBL pedagogy design. First, we used learning objectives and RBT and secondly, we used pedagogy indicators. Both methods gave us data for placing the PBL in the pedagogy dimension. Can you share your thoughts about using these methods to identify the pedagogical approach? Can you address how the results may or may not be useful to you if you were to plan another PBL unit with this group of students?

P3-2. We used two methods for judging HOTs in the students' final product to identify the level of innovation. First, we used RBT and secondly, we used product indicators. Can you share your thoughts on using these two methods to assess HOTS? What do you think about the results? Can you address how the results may or may not be useful to you if you planned another PBL unit with these students?

P3-3. We examined a third dimension of PBL, student processes. We used several methods to assess HOTS in the areas of task, thinking, teamwork, and tool use (4Ts) using data from the second interview. What are your thoughts regarding the results for this group of students?

Consider any or all the following:

- Which skill do you see as a priority for improvement?
- Which of these skills do you think will improve with more PBL opportunities?
- Which skills do you think contributed the most to the final product?
- Do you think you might use the 4Ts in some way to help students increase HOTS? How?

P3-4. Look at the cell placement for this unit with this group of students on the PB-LIFTS. Please look at the dimensions of instructional pedagogy and student innovation separately. Can you share your thoughts on what you see? The intersecting cell indicates that there is a relationship between the approach and the product outcome. Do you agree or disagree? What are your thoughts about next steps with the group to keep HOTS moving upward diagonally?

P3-5. I want to thank you for helping me learn more about how teachers of the deaf use PBL to build students' HOTS. Do you have any other thoughts to share?

Appendix F: Project-Based Learning-Higher Order Thinking Skills Analysis Packet

PBL Title:
Grade level:

We will use two methods to identify HOTS in Teacher Pedagogy Using:
-Revised Bloom's Taxonomy (RBT): Cognitive Verbs & Knowledge Level
-Pedagogy Indicators: Teacher Role, Student Role, & Learning Design

RBT Objectives
Review the Emergent Themes for Objectives 1-3.
Confirm/edit the associated RBT Cognitive Verbs.
Confirm/edit the associated RBT Knowledge Levels.
****Use RBT reference charts if needed see page 12 & 13.***

PBL OBJECTIVE Analysis Emergent Themes		RBT Cognitive Verbs	RBT Knowledge Level
Objective 1.			
Objective 2.			
Objective 3.			

Plot learning objectives on the RBT Taxonomy Table below
Use cognitive verbs and knowledge levels as X and Y coordinates.
Write: Obj. 1, Obj. 2, Obj. 3 on the RBT chart

The first one is done for you.

Teacher Pedagogy RBT Taxonomy Table
Cognitive Activity Verbs

Knowledge Levels	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
D. Metacognitive						
C. Procedural						
B. Conceptual						
A. Factual						

Anderson and Krathwohl (2001)

(An example PBL is provided on page 12.)

Teacher Pedagogy RBT Taxonomy Table
Cognitive Activity Verbs

Knowledge Levels	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
D. Metacognitive		C			D	
C. Procedural						
B. Conceptual		A			B	
A. Factual						

Anderson and Krathwohl (2001)

Which quadrant was most dominant for these objectives? __________

Next, we will use pedagogy *indicators* to identify HOTS

PEDAGOGY Type Using Indicators
Researcher will copy exploratory comments and emergent themes from the transcript analysis related to pedagogy indicators and insert below.

Pedagogy Indicators
Teacher role
Student role
Learning design

Pease confirm/edit the emergent themes for accuracy

Exploratory Comments	Emergent Themes
Teacher Role	**Teacher Role**
Student Role	**Student Role**
Learning Design	**Learning Design**

Highlight indicators on the chart below that are similar to the emergent themes above.

Pedagogy Indicators	A. Active	B. Constructed	C. Social	D. Connected
Teacher Role	teacher directed	teacher facilitated	teacher supported	teacher mentored
Student Role	follow structure & sequence; process materials	manipulate materials, discover knowledge	student-led collaborative interactive learning	student directed learning
Learning Design	structured task completion; predetermined product	construction activities; predictable product	social interactive co-construction; unpredictable product	networked construction; unique product

Which pedagogy type was most dominant using the indicators? _______________

Did your PBL have some qualities in a secondary pedagogy? _______________

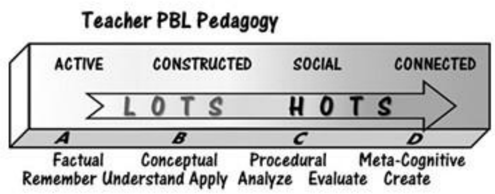
Putting Pedagogy and HOTS together
This section is informational for teachers to consider before responding to debriefing interview question 1.

Here are general descriptions of constructivist pedagogy types commonly used in PBL with students of all ages from elementary through college.

PB-LIFTS Teacher Instructional Pedagogy

A. Active	B. Constructed	C. Social	D. Connected
Teacher directed; students complete structured tasks; reorganize basic content/retain facts	Teacher facilitated; Students manipulate content materials; hands-on discovery & product construction	Teacher supported; students engage collaboratively; co-constructed knowledge/products	Teacher mentored; Student directed; networked knowledge creation & resourceful product construction

The graphic to the right shows the alignment of pedagogy types and RBT to reveal the continuum from lower to higher ordered thinking skills. LOTS to HOTS



Using RBT and objectives the PBL pedagogy type was ________________
Using PBL indicators the pedagogy type was ________________
Was there a secondary pedagogy type? *Describe* __________________________

Debriefing Interview Question 1: Instructional Pedagogy and HOTS
We used two methods to identify HOTS in the PBL pedagogy design. Both methods gave us data for placing the PBL on the constructivist learning continuum of four types. Can you share your thoughts about using these methods to identify the pedagogical approach? Can you address how the results may or may not be useful to you if you were to plan another PBL unit with this group of students?

We are finished with PBL Pedagogy. Next, we will look at HOTS in student products.

To study HOTS in the student product, we will use two methods again:

- **-Revised Bloom's Taxonomy (RBT): Cognitive Verbs & Knowledge Level**
- **-Product Indicators: Originality, Creativity, & Content**

RBT Student Product
Review the Emergent Themes from product descriptions.
Confirm/edit the associated RBT Cognitive verbs.
Confirm/edit the associated RBT Knowledge levels.
****Use RBT reference charts if needed see page 12 & 13.***

PBL Student Product Analysis Emergent Themes	RBT Cognitive Verbs	RBT Knowledge Level
Product description:		

Plot themes for the student product on the RBT Taxonomy Table below
Use cognitive verbs and knowledge levels as X and Y coordinates.
Find the coordinates & write on the RBT chart below: Theme1, Theme2, Theme3

Student Product RBT Taxonomy Table
Cognitive Activity Verbs

Knowledge Levels	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
D. Metacognitive						
C. Procedural						
B. Conceptual						
A. Factual						

Anderson and Krathwohl (2001)

Student Product RBT Taxonomy Table
Cognitive Activity Verbs

Knowledge Levels	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
D. Metacognitive		3			4	
C. Procedural						
B. Conceptual		1			2	
A. Factual						

Which quadrant was most dominant for this product? ________

Next, we will use product innovation indicators to identify HOTS

Product Innovation Indicators
Researcher will copy exploratory comments and emergent themes from the transcript analysis related to product indicators and insert below.

Product Indicators
Originality
Creativity
Content

Please confirm/edit the emergent themes for accuracy

Exploratory Comments	Product INDICATORS **Emergent Themes**
Product Originality:	**Product Originality:**
Product Creativity	**Product Creativity:**
Product Content:	**Product Content:**

Highlight indicators on the chart below that are similar to the emergent themes above

Product Indictors	1. Reproduce	2. Enhance	3. Transform	4. Innovate
Originality	replicated project	improved project	redesigned, novel project	Inventive, unique project
Creativity	imitated	embellished decorated	clever creative	ingenious
Content	basic facts duplicated	conceptualized reworked facts	synthesized knowledge	deep multifaceted

Which product innovation level was most dominant? ___________________

*Did this product have some qualities at another level?*___________________

Comment ____

Next, we will wrap up exploring HOTS in product innovation.

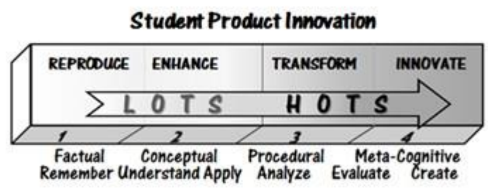
Putting product innovation and HOTS together
This section is informational for teachers to consider before responding to debriefing interview question 2

Here are general descriptions of product innovation levels in student products based upon indicators that have been used in previous studies: originality, creativity, and content.

PB-LIFTS Student Product Innovation

1. Reproduce	2. Enhance	3. Transform	4. Innovate
Remake basic content; demonstrate limited creativity and cognitive processing of material	Improve selected content, add creative elements; PBL product shows conceptual understanding	Redesign complex content; synthesize & represent learning in a creative PBL product	Create a unique original PBL product; demonstrate deep open-ended multifaceted learning

The graphic to the right shows the alignment of product innovation levels and RBT to reveal the continuum from lower to higher ordered thinking skills. LOTS to HOTS

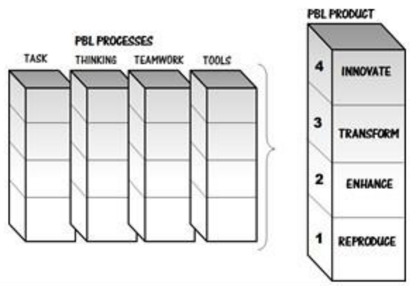


Using RBT and product descriptions the PBL product innovation level was:___________
Using PBL product indicators the level of innovation was: ________________
Was there a secondary innovation level? ____
*Describe*____

Debriefing Interview Question 2: Student Product Innovation and HOTS
We used two methods for judging HOTs in the students' final product to identify the level of innovation. First, we used RBT and secondly, we used product indicators. Can you share your thoughts on using these two methods to assess HOTS? What do you think about the results? Can you address how the results may or may not be useful to you if you planned another PBL unit with these students?

We are finished with PBL Student Product Innovation. Next, we will look at HOTS in PBL Processes

PBL Processes
The Third Dimension of PB-LIFTS



Processes are the skills students used to produce the product.
Using the emergent themes from the transcript analysis we may be able to identify process skill levels and understand the HOTS students demonstrated in this PBL.

PBL Process: TASK

Confirm/edit emergent themes for the task related to planning, organization, and accountability

Task Levels
Synchronized
Systematized
Limited coordination
Uncoordinated

Task Levels Exploratory Comments	Task Indicators Emergent Themes

Highlight task descriptions below that reflect the emergent themes above

Task Levels	
4	**Synchronized:** Well planned Logical organization High accountability
3	**Systematized** Adequate planning Good organization Usually accountable
2	**Limited Coordination:** Marginal planning Limited organization Low accountability
1	**Uncoordinated:** No shared plan Disorganized process No accountability

The Task Level for this PBL was primarily: ____________

PBL Process: Thinking

Confirm/edit emergent themes related to levels of thinking

Thinking Levels
Extended
Strategic
Comprehend
Recall facts

PBL Thinking Emergent Themes

Highlight indicators below that reflect the emergent themes above

Thinking Levels	
4	**Extended** Complex reasoning i.e. synthesize, design, critique, collaborate
3	**Strategic** Structured procedural i.e. analyze, support, generalize, initiate
2	**Comprehend:** Manipulate content i.e. compare, organize, summarize, classify
1	**Recall facts:** Superficial/routine i.e. recite, identify, define, list, rewrite

The Thinking Level
for this PBL
was primarily:
____

PBL Processes: Teamwork

Confirm/edit emergent themes related to teamwork

Teamwork
Performing
Norming
Storming
Forming

Teamwork Emergent Themes

Highlight emergent themes above and associated team development indicators (right).

The Teamwork Level
for this PBL
was primarily:
____

Teamwork Development Levels	
4	**Performing:** Networked collaboration Regulated/interdependent Constructive synergy
3	**Norming:** Collaborative model Clarified roles/goals Interpersonal skills
2	**Storming:** Power struggles Norms/roles lacking Teacher intervention
1	**Forming:** Teacher guided Limited idea sharing Prefer independent work

Tuckman (1965)

PBL Process Tools: Resource Use

Resource Use
Extensive
Multiple
Minimal
Deficient

Confirm/edit the emergent themes related to PBL resources.

Resources Emergent Themes

Highlight emergent themes above and associated Resource Use Levels below

Resource Use	
4	**Extensive:** Credible and selected
3	**Multiple resources:** Vetted selection
2	**Minimal resources** Conventional/textbook
1	**Deficient resources:** Teacher provided

The Resource Use Level for this PBL was primarily:

____

PBL Process Tools: Technology Use

Technology Use
Innovative
Redesign
Functional change
Manual Substitute

Confirm/edit the emergent themes related to PBL technology.

Tools: Technology Emergent Themes

Highlight emergent themes above and associated Technology Use Levels (right

The Technology Use Level for this PBL was primarily:

____

Technology Use Levels	
4	**Unique & innovative** Tech allows for creating products that were once considered impossible
3	**Redesign/transform** Tech enables transformation of a task such as to another medium or form
2	**Functional change** Tech is used to add functional changes, embellishments
1	**Manual substitute** Tech is used as a substitute such as typing rather than writing, no functional change

Putting PBL Process Skills and HOTS Together

Mark the level for each process skill you assessed on pages 7-9

Levels	Task	Thinking	Teamwork	Resources	Technology
4					
3					
2					
1					

Highlight the table below to refine the holistic levels above. This analytic rubric may be helpful for continuing to build students' HOTS in future PBLs.

- Note: resources and technology are combined in 'tools".
- Task, Thinking, Teamwork, & Tools are the 4Ts for PB-LIFTS process skills.

PBL	*PROCESS SKILLS*			
	Task	*Thinking*	*Teamwork*	*Tools*
Level 4 *INNOVATE*	Synchronized: well planned logical organization high accountability	Extended: complex reasoning i.e. synthesize, design, critique, collaborate	Performing: networked collaboration regulated/interdependent constructive synergy	Extensive resources: credible & select Technology use: unique/innovative
Level 3 *TRANSFORM*	Systematized: adequate planning good organization usually accountable	Strategic: structured procedural i.e. analyze, support, generalize, initiate	Norming: collaborative model clarified roles/goals interpersonal skills	Multiple resources: vetted selection Technology use: task redesign
Level 2 *ENHANCE*	Limited coordination: marginal planning limited organization low accountability	Comprehend: manipulate content i.e. compare, organize, summarize, classify	Storming: power struggles norms/roles lacking teacher intervention	Minimal resources: conventional Technology use: functional change
Level 1 *REPRODUCE*	Uncoordinated: no shared plan disorganized process no accountability	Recall facts: superficial/routine i.e. recite, identify, define, list, rewrite	Forming: teacher guided limited idea sharing prefer independent work	Deficient resources: teacher provided Technology use: manual substitute

Debriefing Interview Question 3: PBL Processes and HOTS

We examined a third dimension of PBL, student processes. We used several methods to assess HOTS in the areas of task, thinking, teamwork, and tool use (4Ts) using data from the second interview. What are your thoughts regarding the results for this group of students?

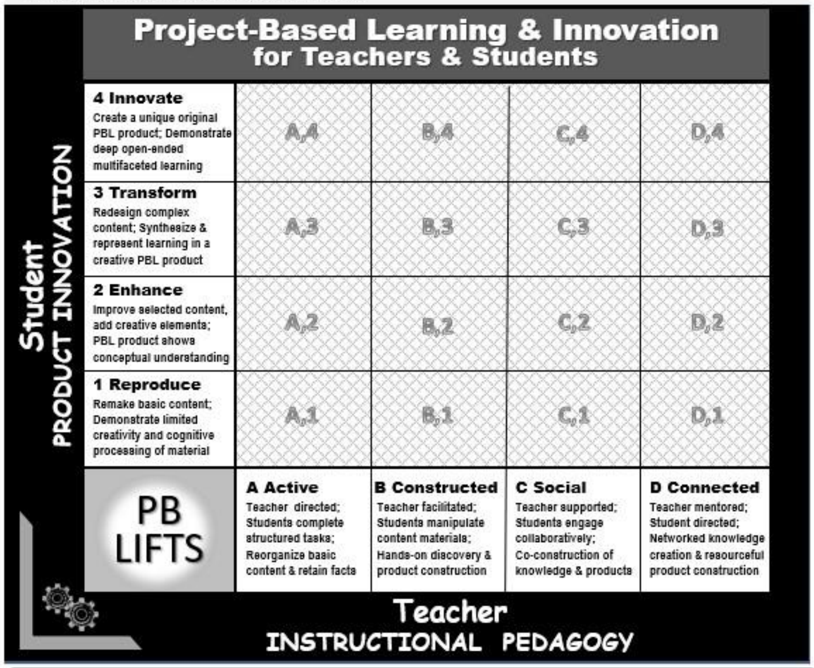
Consider the following:

- Which skill do you see as a priority for improvement?
- Which of these skills do you think will improve with more PBL opportunities?
- Which skills do you think contributed the most to the final product?

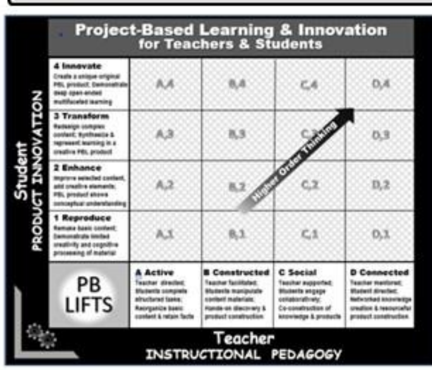
Do you think you might use the 4Ts to help students increase HOTS? How?

Last, you will see the PB-LIFTS framework for PBL the pedagogy and product dimensions. The framework is a tool for showing the relationship between the two dimensions and HOTS.

Average Pedagogy Type from page 2: ________ Average Product Innovation level from page 4: ______
Mark the intersecting cell on PB-LIFTS below.



Debriefing Question 4: PB-LIFTS Teacher Pedagogy and Student Product Innovation
Look at the cell placement for this unit with this group of students on the PB-LIFTS above. Look at the dimensions of instructional pedagogy and student innovation separately. Please share your thoughts on what you see? The intersecting cell indicates that there is a relationship between the approach and the product outcome. Do you agree or disagree? What are your thoughts about next steps to keep HOTS moving upward diagonally?



Debriefing Wrap Up Question 5
Do you have any other thoughts to share? I want to thank you for helping me learn about how TODs use PBL to build students' HOTS. I am so pleased to know that TODs like you value PBL with DHH students. I have a small token of appreciation for you and I'll be happy to share anything from the study you would like me to send.

Thank you!

REFERENCE Materials

Revised Bloom's Taxonomy (RBT)
The two RBT charts, Cognitive Activity Verbs and Knowledge Levels, are used for evaluating HOTS in teacher objectives and student product descriptions.

RBT Cognitive Activity Verbs
Anderson & Krathwohl (2001)

1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
recognizing, recalling	classifying, summarizing	executing, implementing	organizing, attributing	checking, critiquing	planning, producing

***See the Cognitive Activity Verbs chart for more examples next page.*

RBT Knowledge Levels
Anderson & Krathwohl (2001)

A. Factual	B. Conceptual	C. Procedural	D. Metacognitive
Knowledge of discrete content needed to understand subject matter. *i.e. isolated content, definitions, details*	Knowledge of relationships among basic elements of a larger structure. *i.e. classifications and general principles*	Knowing how/when to do something; inquiry method, and criteria for using skills. *i.e. subject specific techniques or methods*	Knowledge of general cognitive processes and one's own cognition. *i.e. strategic knowledge, cognitive tasks*

EXAMPLE Conservation PBL

Objective 1: Students will **state** three benefits of recycling and **propose** a recycling process for the classroom to adopt.
(remember, factual) *(apply, conceptual)*

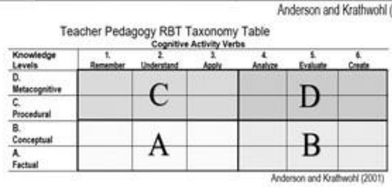
Objective 2: Students will **assess** how many pounds of paper waste the classroom produces in one week.
(analyze, procedural)

Objective 3: Students will **collaboratively produce** a cartoon **teaching** three benefits of the reduce-reuse-recycle approach
(create, procedural/metacognitive)

Teacher Pedagogy RBT Taxonomy Table
Cognitive Activity Verbs

Knowledge Levels	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
D. Metacognitive						*Obj.* 3
C. Procedural				*Obj.* 2		*Obj.* 3
B. Conceptual			*Obj.* 1			
A. Factual	*Obj.* 1					

Anderson and Krathwohl (2001)



These PBL Objectives are most dominant in quadrant D.

REFERENCE

The Cognitive Activity Verbs chart shows an expansion of cognitive and digital activity verbs that may appear in teachers' objectives or descriptions of a student product. This chart is provided to aid the process of judging in which category an activity verb might semantically align. For example if the word 'invent' was used to describe a product, it would be categorized as 'creating'.

THINKING	Cognitive Activity Verbs	
	Cognitive Examples	Digital Examples
	Creating	
HIGHER ORDER	invent, compose, adapt, devise, design, construct, integrate, imagine, produce, formulate, generate, make, assemble	film, animate, blog, vlog, mashup, remix, wiki, publish, videocast, podcast, web 2.0 collaborating, direct/product, programming
	Evaluating	
	critique, check, prioritize, judge, test, detect, monitor, convince, debate, justify, recommend, decide, compare	blog/vlog commenting, review, post, moderate, collaborate, forum, network, doc editing, alpha/beta test, validating
	Analyzing	
	sort, categorize, investigate, subdivide, differentiate, compare/contrast, assess, determine logic	graphing, online polling, linking, surveying, web page design, mind-mapping, mashing, spreadsheets, reverse-engineer, media clipping
	Applying	
	organize, outline, test, use, show, teach, chart, solve, dramatize, report, separate, construct, manipulate, plan	uploading, sharing, editing, gaming, hyperlinking, PowerPoint designing, simulations, screen capture, graphic designing
	Understanding	
LOWER ORDER	explain, paraphrase, predict, relate, convert, classify, identify, translate, rewrite, generalize, summarize, infer	advanced search, annotate, subscribe, blog journal, tagging, categorizing, Boolean search, selecting images
	Remembering	
	name, list, find, memorize, copy, match, recite, draw, underline, write, locate, retell state, label, recognize, recall	word processing, retrieve, quote, copy/paste, drill CD, practice games, google search, clipart, bookmark, texting