An Integrative Review of K-12 Teachers' Strategies and Challenges in Adapting Problem-Based Learning

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Abstract

Problem-based learning has long been recognized as an innovative and effective instructional strategy for enhancing problem-solving and critical skills, which are essential for 21st-century employability. Despite its recognized benefits, PBL adoption in K-12 education remains limited due to significant implementation challenges. This integrative literature review investigates PBL instructional strategies and teachers' experiences, focusing on their challenges and the types of problems used in K12 classrooms, while analyzing empirical studies from 2004 to 2024. The study findings reveal teachers' challenges in terms of problem design and development, scaffolding, technology integration, assessment, and promoting student collaboration, with time availability being a recurring concern. Again, teachers' implementation strategies are flexible but could, however, be summarized into (1) preparing learners for PBL, (2) an iterative cycle of activities, and (3) presentation and evaluation. The findings also revealed that design problems dominate the type of problems that are incorporated into K-12 PBL implementation studies. Beyond setting the foundation for future research in the area, this integrative review offers a deeper understanding related to PBL's application in K-12 settings, providing valuable insight for educational stakeholders.

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General Audience Abstract

Problem-based learning (PBL) is a student-centered teaching method that supports the development of relevant problem-solving and critical-thinking skills which are critical for career success and employability in the 21st century. Although many studies have emphasized its effectiveness, it is not widely used in K-12 education. This limitation is attributed to different implementation challenges. This integrative literature review investigates PBL instructional strategies and teachers' experiences, focusing on their challenges and the types of problems used in K-12 classrooms, while analyzing empirical studies from 2004 to 2024. The study findings reveal teachers' challenges in terms of problem design and development, scaffolding, technology integration, assessment, and promoting student collaboration, with time availability being a recurring concern. Again, teachers' implementation strategies are flexible but could, however, be summarized into (1) preparing learners for PBL, (2) an iterative cycle of activities, and (3) presentation and evaluation. The findings also reveal that design problems dominate the type of problems that are incorporated into K-12 PBL implementation studies. Beyond setting the foundation for future research in this area, this integrative review offers a deeper understanding related to PBL's application in K-12 settings, providing valuable insight for educational stakeholders.

Dedication

This work is dedicated to my beloved mom, Agnes Oduro Senyah, and to the cherished memory of my late father, Peter Oduro Senyah. Thanks for your indescribable love, care, and support. To my brothers and sisters, nephews, and nieces, thank you for the joy you bring into my life.

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Chapter One

Introduction and Need for the Study

Introduction

Education is considered effective when it teaches people how to use their rational powers to think and solve real-life problems (Gagne, 1980). Towards this end, teachers should, "give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results" (John Dewey, 1916, p. 191). At the turn of the 21st century, governments and other stakeholders in education have advocated for high-order thinking and problem-solving skills among their educational institutions as a means of preparing workforces for their nation's development in various industries and commerce (Hara & Schwen, 2006; Jeong et al., 2019; Murray & Savin-Baden, 2000). Problem-Based Learning (PBL) constitutes a learning approach that facilitates students' acquisition of high-order thinking skills, emphasizing the transfer of knowledge from different subject disciplines to solving real-life problems (Barrows, 1986). Proponents in favor of PBL argue that in many professional environments, people are motivated by their ability to use their intellectual capabilities to solve problems (Jonassen & Hung, 2008). Based on such assumptions, there have been efforts to restructure curriculum to focus on problem-solving at many institutions since the early 70s. (Barrows, 1986, 1996; Barrows & Tamblyn, 1980; Dunlap & Grabinger, 1996; Gijbels, Dochy, van den Bossche, & Segers, 2005; Norman & Schmidt, 1992; Savery & Duffy, 1996; Savery 2015; Schmidt, 1983).

Problem-based learning (PBL) is among the popular student-centered instructional approaches to learning in current educational research and practice (Moallem, 2019). PBL within K-12 education has witnessed the emergence of different implementation models. The models rely on authentic problems to promote students' learning. Problems are not all the same; they have different characteristics for the different learning outcomes they intend to promote (Jonassen & Hung, 2008). Although teachers may vary in their approaches to PBL (Erdem, 2022), the goal is always to promote active, self-directed, and lifelong learners with higher-order thinking and problem-solving skills (Hun, Jonassen, & Liu, 2008). Such objectives continue to make the PBL learning approach attractive to many teachers, including K-12 teachers. To be successful, teachers must learn different ways to plan and assess students' performance; most importantly, teachers must learn to relinquish their traditional roles as expert dispensers of knowledge in favor of acting as coaches and facilitators of student learning (Dole et. al., 2016; Mascolo, 2009).

Due to the specific challenges associated with implementing Problem-Based Learning (PBL), such as the need for significant shifts in teaching methodologies (Chen, et. al., 2021), the development of suitable problems that align with curriculum standards (Cho et al., 2015; Savery, 2015), and the provision of adequate support for teachers to transition to a facilitator role, some K12 schools have been cautious or slow in adopting PBL as a pedagogical practice (Ertmer & Simons, 2006; Nurlaily et al., 2019). Additionally, education policies in the past two decades, such as The No Child Left Behind (NCLB) Act, have significantly influenced the education landscape (Ydesen & Dorn, 2022), while placing emphasis on standardized testing rather than problem-solving (Freer-Alvarez, 2016) and other experiential learning approaches. Also, the success of PBL relies heavily on effective collaboration among students, which requires both a supportive classroom environment and the development of students' collaborative skills (Cho et al., 2015). However, despite these challenges, schools that have successfully navigated these barriers have reported enhanced student engagement, improved problem-solving skills, and a deeper understanding of the subject matter among students (Gallagher, 2021).

Problem-based learning (PBL) has remained a relevant and important educational approach despite the challenges posed by the No Child Left Behind (NCLB) act (Anderson, 2012; Nariman & Chrispeels, 2016) and the global pandemic. The need for students who can think critically, solve complex problems, and adapt to changing circumstances has only grown stronger in recent years (Cook-Harvey et al., 2016). PBL provides students with the opportunity to develop these essential skills by engaging them in authentic, real-world problems that require collaboration, creativity, and self-directed learning (Albanese & Hinman, 2019; Hung, 2015). Moreover, teachers who are skilled in facilitating PBL are better equipped to prepare students for the challenges they will face in their future careers and personal lives (Savery, 2015). As such, ongoing research in PBL is crucial to ensure that educators have access to the latest strategies and best practices for implementing this valuable teaching approach. Given these dynamics, the time is apt for an integrative literature review focusing on PBL in K-12 learning environments, particularly exploring PBL problem types, implementation strategies, and teachers' PBL experiences over the last 20 years. This endeavor aims to contribute to general knowledge and the development of a framework that can support instructional design practitioners, researchers, and instructors in advancing research and practice in this field.

The Need for the Study

Problem-based learning developed in response to concerns about the 'fragmented' knowledge of medical students in relation to their clinical preparation (Barrows, 1996; Barrows & Tamblyn, 1980). In an effort to create an integrative and holistic instructional approach where students could synthesize knowledge from various disciplines to focus on patients' conditions, PBL was born. Among medical institutions, PBL has been acknowledged as an effective instructional approach to motivate students' learning of science concepts, and to develop their clinical skills by applying theory to practice (Savery & Duffy, 1995). PBL instructional strategy allows medical students to interact with simulated patients who exhibit various kinds of medical issues (Barrows & Tamblyn, 1976; Torp & Sage, 1998). This approach was intended to equip medical students with the required higher-order thinking and problem-solving skills for practice (Albanese & Mitchell, 1993; Barrows, 1996). The success of this approach at Maastricht University, Canada, where it was first introduced in the 1970s, resulted in its transfer to other medical institutions in Europe and North America (Servant, 2019). Since 1990, interest in PBL as an instructional strategy has increased in various disciplines across K-12 and other non-college level educational facilities (Torp & Sage, 2002; Willian & Hmelo, 1998).

A good PBL lesson usually begins with an ill-structured problem (Barrows, 1996) followed by carefully designed instructional protocols, and it involves teachers' scaffolding at different stages in the implementation process (Davies, 2000; Hmelo-Silver et al., 2007; Nurlaily et al., 2019). However, the type of tutoring required for high-quality PBL is not always provided (Barrows, 1986). The original PBL tutorial process, when successful, involves the following four steps: (a) understand and define the problem, (b) collaborate in managing data sources to solve the problem, (c) find, evaluate, and utilize information as evidence for their solutions, and (d) generate an argument in support of the solution (Kim et al., 2018). The type and nature of the problem are important in setting the stage for the PBL process. This is because "different learning outcomes require different instructional conditions" (Jonassen, 2011, p. 110). Teachers must, therefore, be intentional in the problem they choose or create to implement PBL.

Students in PBL assume the role of active problem-solvers, similar to how professionals engage and solve real-world problems (Barrows, 1996; Savery & Duffy, 1995). Self-directed learning (SDL) is a critical feature in PBL which provides flexibility and autonomy for student learning (Savery, 2006). Collaboration among students in the learning process is also a key component of PBL. In terms of assessment procedures, PBL encourages both self and peer assessment to foster students' metacognition. As students take ownership of their learning, the teachers move towards a more facilitative role (Harper, 2018; Hmelo-Silver & Barrows, 2006; Kim et al., 2019).

Teaching is a complex cognitive activity (Collins et al., 2018; Leinhardt, 1993) where teachers do not just apply procedures, but adapt strategies based on their core beliefs surrounding how learning occurs (Schoenfeld, 1998). Even though teachers' roles change significantly in PBL, they maintain their essential position as guardians of students' learning (Lyberg-Ahlander et al., 2014; Wood et al., 1976). Teachers organize the structure, content, and paths along which student learning must proceed, a role without which the desired learning outcomes will not be achieved (Mascolo, 2009). According to Barrows (1988), however, most teachers are not accustomed to the kind of demands that they are expected to address in a PBL classroom. This is because implementing a PBL lesson requires skills and resources that are very different from those required by more familiar and traditional teaching strategies (Brush & Saye, 2000). Research in the field agrees that adapting to PBL challenges the traditional role of teachers as knowledgeable experts who must impart knowledge. Instead, PBL allows learners to freely explore the content of the curriculum (Achilles & Hoover, 1996; Chan 2016; Lutsenko, 2018; Maxwell et al., 2005). Even though these challenges and associated PBL problems are well recorded, a study by Chen, et al., (2021) found, "however, [that] challenges in PBL implementation was little addressed in the current review works, and even less attention has been paid on how these challenges in implementation are related to the diverse PBL practices" (p. 90).

Different meta-analysis studies have equally reported on the differences in how PBL is implemented within K-12 settings and those in higher education institutions (Condliffe et al., 2015; Goodnough et al., 2006; Kolodner, 1993). Erdem (2022), studying the effects of PBL models on K-12 students, attributed the differences in implementation strategies to how different disciplines approach learning, coupled with the learners' age group and content knowledge. Teachers who are eager to adapt the strategy but face difficulties at certain stages are likely to improvise and adapt to what will suit their needs (Walton, 2014). Considering the typical lack of experience that K-12 teachers have with PBL instructional pedagogy (Land, 2000; Kim et al., 2019), one can understand why, regardless of the effectiveness and benefits of PBL, its adaptation by K-12 teachers has not been extensive (Dole et al., 2016; Hmelo-Silver, 2004; Tawfik et al., 2021).

Different empirical and theoretical studies have revealed and emphasized the challenges and experiences of K-12 teachers in adapting to PBL. For example, even though K-12 teachers have considerable autonomy in their classrooms, they do not control the curriculum from which different PBL instructional decisions are made (Li & Stylianides, 2018; Voet & De Wever, 2017). K-12 teachers who attempt to implement PBL not only have challenges in identifying relevant problems/tasks from the curriculum for their students (Ng et al., 2014; Revelle, 2019), but also lack the mastery skills needed to scaffold and facilitate students' learning (Kim et al., 2018). Again, researchers like David Jonassen discussed the importance of the types of problems being brought into the classroom through PBL and how they matter to student learning and learning outcomes (Jonassen, 2011). He, therefore, called on instructional designers to enhance research in this area. Early research also reveals that teachers lack the skills to effectively assess performance and student learning during the PBL process (Brinkerhoff & Glazewski, 2004). For example, Walton (2014) described teachers' PBL difficulties as the "new demands on teachers for which they may not be prepared" (p. 68). Another early study by Ertmer and Simons (2006) categorized K-12 teachers' PBL challenges as follows: how to create and maintain student independence while at the same time ensuring collaboration, how to adjust their roles and help students do the same, and how to facilitate student learning through scaffolding support during the PBL process. Other studies have also concluded that the amount of time involved in designing and implementing a complete PBL lesson, even for experts in pedagogy, is the most problematic (Nurlaily et al., 2019; Revelle, 2019; Simons et al., 2004). Some have also suggested technology integration issues (lack of time, technical support, access, etc.) and teachers' technology competence as limiting factors impacting the rate of PBL implementation (Lui et al., 2012).

Available meta-analyses and systematic reviews of PBL studies are heavily concentrated on the effectiveness of PBL as an instructional strategy in achieving set learning outcomes (Berkson, 1993; Merrit et al., 2017; Neville, 2009; Norman & Schmidt, 1992). Others have also been focused on comparative studies, making a case for PBL over other traditional pedagogies (Albanese & Mitchell, 1993; Vernon & Blake, 1993). The focus of these previous studies has been investigating PBL in relation to different domains of student learning such as content knowledge, collaborative learning, self-directed learning, etc. PBL studies focusing on teacher issues have been on teachers' self-efficacy, teachers' motivation, implementation (Hmelo-Silver, 2019), and assessment (Albanese & Hinman, 2019; Kolmes et al., 2019). Other studies that have attempted to study K-12 teacher challenges in adapting to PBL have been limited to a particular level of education or a particular subject discipline. Ertmer and Simons (2006), conducted a descriptive study on the possible obstacles that K-12 teachers might face in their attempt to adapt PBL in their classrooms. Their focus was not to highlight the types of problems or models used or teachers' experiences in implementing PBL.

Based on the ongoing research and historical development of PBL and its associated learning environments, now is a good time to analyze data from empirical studies on PBL implementation strategies, the types of problems used, and teachers' adaptation experiences over the past two decades. By synthesizing this information, instructional design practitioners, researchers, and educators can enhance their understanding and utilization of PBL as an instructional tool, leveraging its potential to enhance learning outcomes and performance within K-12 educational contexts. This study can also lay the foundation for continued research in this area.

Purpose Statement

The purpose of this study is to conduct an integrative literature review examining K-12 teachers' PBL implementation strategies as described in the empirical literature. In addition, it investigates the experiences of K-12 teachers, focusing on the challenges they face in implementing PBL, as well as examines the types of problems incorporated within PBL frameworks in these studies.

In achieving this purpose, the researcher focuses on synthesizing available literature on PBL's historical development and the emerging interest of K-12 teachers in this instructional tool. Again, literature on the theoretical and conceptual understanding of PBL, including how PBL has been understood, its characteristics, the role of teachers, the type of problems used, models being implemented, teachers' adaptations, and experiences, among other things are synthesized and presented. This comprehensive study ultimately investigates empirical studies to analyze the different types of problems that K12 teachers adopt to implement PBL, the models of PBL strategies used, and teachers' experiences in adopting PBL.

These processes are in view of updating and informing the insights about effective PBL implementation strategies, the practical challenges faced by K-12 teachers, and the characteristics of problems that have been used to facilitate effective problem-solving skills using PBL. In this way this study contributes to advancing the cause of an instructional strategy which has proven in the past to be a tool with the potential to increase learning and performance in K-12 classrooms.

Research Questions

The following research questions will guide this study:

1. How have PBL implementation strategies/models in K-12 education been described in empirical literature?
2. How have K-12 teachers' experiences/challenges with PBL implementation been described in empirical literature?”
3. How do the types of problems used in PBL within K-12 settings in empirical literature align with Jonassen's (2010) types of problems?

Organization for the Proposed Study

This study is organized into five chapters. Chapter One introduces the study, outlining the need for the study, the purpose of the study, and the research questions. Two presents the literature review, beginning with an exploration of problem-based learning (PBL) and its historical evolution. It also examines the various theoretical foundations of PBL, its implementation in K-12 education, and the strategies employed in this context. Chapter Three presents the methodology for the study with details on the research design and the purpose of the study. This chapter also presents information on the research design, the purpose of the study, and the research questions. This chapter also describes the procedures followed, which include problem identification, systematic literature search, data evaluation, data analysis, discussion, and presentation of findings. Chapter Four focuses on the findings, addressing the three research questions guiding this study. Chapter Five discusses and concludes the findings for each research question. The chapter wraps up with implications for practice, the limitations of the study, and recommendations for further research.

Chapter Two

Literature Review

General Introduction

The purpose of this chapter is to review related literature on PBL to provide a basis for understanding the subject of the study. This will include reviewing a broad range of theoretical and empirical studies involving PBL's historical beginnings and definitions, PBL goals and characteristics, and how PBL has been adopted in various disciplines and at different educational levels, including K-12 educational settings. At this stage, however, it is not the intention of the researcher to offer a critical review resulting in conclusions. Such an effort will be undertaken within the fourth chapter, which will be dedicated to an extensive and critical review of available literature that will help to address the research questions.

The literature review process within an integrative literature study has the advantage of beginning with a conceptual definition search. The researcher is not obliged to present an operational definition and instead searches for different concepts followed by a procedure that evaluates, "the conceptual relevance of different operations" (Cooper, 1984, p. 20) depending on the outcome of the search results. With such an approach, it is not unusual for the researcher to encounter "unanticipated samplings" during the data collection stage (Cooper, 1984, p.20), which supports continuously modifying the research questions.

Introduction to Problem-Based Learning

Problem-based learning (PBL) is a student-centered instructional approach to learning in current educational research. PBL, as defined by Barrows and Tamblyn (1980), refers to, "the learning that results from the process of working toward the understanding or resolution of a problem" (p. 18). PBL enables an innovative learning approach by empowering learners to conduct research and integrate theory and practice to solve real-life problems (Savery, 2015, 2019). This instructional approach guides and supports students' collaborative learning of a given topic through solving complex and ill-structured real-life problems (Barrows & Tamblyn, 1980). At the heart of PBL is emphasizing that learners construct their knowledge by actively engaging with problems in collaborative groups (Hmelo-Silver, 2004). Proponents argue that in many professional environments, people are motivated by their ability to use their intellectual capabilities to solve day-to-day problems (Jonassen & Hung, 2008). In the PBL process, students are guided to solve a given task using research, expert guidance, and personal reflections (Barrows, 2000; Torp & Sage, 2002). The goal of PBL includes supporting students in building a comprehensive and adaptable knowledge foundation, cultivating proficient problem-solving skills, developing self-directed, lifelong learning skills, promoting effective collaborative skills, and nurturing intrinsic motivation for lifelong learning (Barrows & Kelson, 1995, as cited in Hmelo-Silver, 2004, p. 240; Ceker & Ozdamli, 2016; Cindy & Hmelo-Silver, 2014).

Historically, PBL has been predominantly used by medical students across universities in different parts of the world. These medical institutions have adopted PBL as an effective instructional approach to motivate students to learn science concepts and develop their clinical skills through applying theory to practice (Savery & Duffy, 1995). Within medical institutions, it is common for students to interact with simulated patients who exhibit various kinds of medical issues (Barrows & Tamblyn, 1976; Torp & Sage, 1998). The students are expected to analyze and diagnose the underlying medical conditions associated with the simulated patient symptoms. The PBL process provides a multidisciplinary approach for students to apply previous knowledge and generate solutions to the current problem. They do so through practical and hands-on interaction with their peers, while solving ill-structured and real-life problems

(Barrows, 1985, 1986; Hmelo-Silver, 1998). Learners can access research tools like books, articles, and the Internet. Periodically, they can also seek guidance from faculty who assume a facilitator role in the PBL instruction process (Simons & Ertmer, 2005).

Teachers are pivotal in the PBL instructional process. They must select or design problems to align with the curriculum and learning objectives (Hmelo-Silver, 2004). Teachers must develop assessments that are aligned with PBL principles. They must assess content knowledge, problem-solving skills, critical thinking, and collaborative abilities (Schmidt et al., 2015). As students grapple with complex problems, they may encounter challenges and frustration. Maintaining students' motivation and enthusiasm is a crucial responsibility for teachers in PBL (Hung et al., 2008). Unlike the conventional teacher who directly dispenses information, the teacher in PBL has a new role as a facilitator of knowledge (Savery, 2006)

Problem-based learning is currently promoted as an effective tool for assisting students in acquiring high-level competencies and transferrable skills (Murray & Savin-Baden, 2000). Based on such assumptions, governments and institutions are advocating to restructure schools' curricula to focus on problem-solving (Barrows, 1986, 1996; Barrows & Tamblyn, 1980; Dunlap & Grabinger, 1996; Gijbels et al., 2005; Norman & Schmidt, 1992; Savery & Duffy, 1996; Schmidt, 1983). PBL can be used as an instructional strategy to restructure and develop a curriculum at various levels by placing students in the active role of problem-solvers, similar to how professionals solve real-world problems (Barrows, 1996; Savery & Duffy, 1995).

PBL continues to gain popularity as a prominent pedagogical method, not only in medical institutions but across disciplines and levels of educational institutions including K-12 education (Hmelo-Silver, 2004; Hmelo-Silver et al., 2000; Servant, 2020; Torp & Sage, 2002; Willian & Hmelo, 1998). Today, PBL continues to spread to K-12 education institutions as a constructivist approach to learning with the intent to build skills and equip learners with the tools required to solve real-life problems (Tan, 2021). Although problem-based models are used and practiced differently worldwide, they all have a similar theoretical underpinning and uphold the same learning principles (van Der Vleuten & Schuwirth, 2019).

Theoretical and Philosophical Underpinnings of PBL

PBL pedagogy, as practiced today, is rooted in sound educational philosophies and learning theories from the cognitive and social constructivist perspectives (Hung et al., 2019). However, from its historical inception, there was no deliberate intention to construct a pedagogy based on a specific learning theory or educational philosophy. Instead, different intellectual discourses have contributed to shaping its understanding and implementation. Servant et al. (2019) identified sources that explicitly acknowledge the specific theories that directly shaped the application of PBL in the 1970s. Notable among them are the works of Abraham Flexner, John Dewey, Carl Rogers, and the 1956 cognitive revolution.

Abraham Flexner's report on the state of medical education, published in 1910, significantly inspired the development of PBL at McMaster and Maastricht universities (Servant et al., 2019). Flexner's assessment of this comprehensive survey advocated a transformation in medical education, emphasizing the importance of clinical experience and active engagement in learning (Servant et al., 2019). MacAuley (1979) reports that Evans admitted the conclusions of this report as his main motivation in seeking better ways to approach medical education.

One philosopher whose work influenced PBL is John Dewey**,** an American philosopher and educator who advocated for experiential and student-centered learning. Dewey believed that students should learn by doing, and that education should be focused on real-world problems and challenges (Dewey, 1910; 1938). Dewey's work was the main inspiration behind the Case

Method at Harvard Business School. By incorporating this method as a strategy for PBL, the founding fathers were tapping into the ideas of Dewey (Kimball, 1999). Some researchers have hypothesized that Flexner's expectation for medical education was heavily influenced by the prevailing experiential learning and learning-by-doing practices of the time, particularly in John Dewey's circles (Ludmerer, 2010).

The cognitive revolution from 1956 was another intellectual influence on PBL (Servant et al., 2019). The movement shifted the focus of learning from the behaviorist paradigm (a theoretical framework in psychology that focuses on observable behaviors and often ignores internal mental states as a focus of study) that dominated psychology from the 1930s PBL (Servant et al., 2019). Cognitive psychology emerged with the view of understanding the role of mental processes in human behavior and cognition (Bechtel et al., 2001). The revolution resulted in a split from those who viewed the mind's internal process of reasoning and problem-solving as a "content-independent algorithmic process" similar to a computer (referred to as information processing psychology) (Servant et al., 2019, p. 15). From this view, PBL is a systematic diagnostic reasoning tool where the goal of learning is the acquisition of problem-solving skills, while knowledge acquisition is a secondary function produced by the task at hand (Schmidt, 2012). On the other hand, some believe that knowledge is the basis by which reasoning and problem-solving thrive (known as *constructivist psychology*). In this view, PBL becomes a means of actively constructing knowledge by learners within a context, and is never abstract (Schmidt, 2012). It is important to note that these different viewpoints coexisted, leading to a divide between two influential figures. Henk Schmidt (2012) supported constructivist psychology, while Howard Barrows favored information-processing psychology. However, continued research in the field has consistently revealed a dearth of evidence supporting the information-processing theories of learning.

Self-directed learning (SDL), which has become an essential component of PBL, was influenced by the work of Carl Rogers, a prominent figure within the humanistic psychology movement of the 1950s and 1960s (Servant et al., 2019). Rogers believed that individuals possessed the inherent capacity for personal growth and development. According to Rogers, self-directed learning involves individuals assuming responsibility for their learning process. Thus, he advocated for an educational strategy promoting autonomy, freedom, and individuality, permitting students to pursue their interests while learning at their own pace (Servant et al., 2019). He believed that this would position the learner to become more motivated, engaged, and invested in their education, leading to deeper and more meaningful learning experiences. A note from Evans, the founding Dean at McMaster, shared this philosophy of, "a self-directed learner, recognizing personal education needs, selecting appropriate learning resources and evaluating progress" (Evans, 1966; Servant et al., 2019, p. 5)

Karl Popper is another intellectually influential figure whose ideas shaped PBL from the 1970s. His basic assumption was that, since nothing can ever be proven inductively, science only puts forward hypotheses and theories and then attempts to disprove them (Popper, 1963). Subsequently, anything that cannot be subjected to such a falsification test is excluded from science. Popper's influence on PBL was primarily evident in the writings of Henk Schmidt in the 1970s and 1980s. Schmidt positioned PBL as an instructional method capable of tackling any content from any field, not just learning problem-solving skills (Schmidt, 1983, as cited in Servant et al., 2019). The effect was a more content-bound version of PBL, enabling it to break free from its medical roots to other fields such as law, economics, and psychology (Schmidt, 2012).

The emergence of community-oriented healthcare initiatives also gave rise to a different form of PBL (Servant et al., 2019). One of the pioneering programs was established by the University of New Mexico in 1979 (Kaufman, 1985, as cited by Servant et al., 2019). Within this period, the University implemented an outreach medical program designed to cater to its remote and underserved communities. As part of their medical education, a limited number of students were selected to spend the first six months of their studies working directly with family physicians. These students followed a curriculum tailored specifically to address the healthcare needs of the communities they served. The medical issues they observed in these communities formed the foundation of their studies. This community-oriented approach to PBL is now practiced in various cultures worldwide, including countries such as Malaysia and Nigeria (Servant et al., 2019; Forbes et al., 2023).

From the preceding discussion, it can be concluded that the history of PBL has not been linear and seamless; instead, it has evolved. PBL continues to spread to different educational institutions around the world, and is used across a variety of subject disciplines (Hmelo-Silver, 2004; Hmelo et al., 2000; Servant, 2020; Torp & Sage, 2002; Willian & Hmelo, 1998). PBL has since remained a flexible adaptation to different disciplines and levels of students (Schmidt, 1983b, 1993, Schmidt et al. 2019). Schmidt (2012) described PBL experimentation in K-12 education as, "one of the few curriculum-wide educational interventions of the surviving in the 21st century after many decades" (p. 22).

Table 1

Theoretical and Philosophical Influences on PBL

Abraham Flexner (1910)	Flexner's report emphasizing students' clinical experience and active engagement in learning inspired PBL at McMaster and Maastricht universities.
John Dewey (1910, 1938)	Dewey's experiential and student-centered learning influenced the Case Method at Havard Business School which later became foundational to PBL.
The Cognitive Revolution (1956)	A shift from behaviorist to cognitive psychology emphasizes the role of mental processing in knowledge acquisition.
Carl Rogers (1950s-1960s)	Rogers' humanistic psychology, which is characterized mainly by learners assuming greater responsibility for the learning process - self-directed learning (SDL)
Karl Popper (1963)	Popper's falsification test and its influence on Henk Schmidt's writings enabled the adaptation of PBL to different disciplinary contexts beyond medicine.
Community-Oriented Healthcare Initiatives (1979)	Emergence of PBL in community-oriented healthcare initiatives. University of New Mexico's program as a pioneering example. This practice strengthened and positioned PBL as strategy that deals with authentic live situation within the learner's environment

Problem-Based Learning: Historical Milestones

Problem-based learning (PBL) is a student-centered educational approach that focuses on real-world problems and challenges as a means of learning. The development and growth of PBL have resulted from different historical antecedents, which various researchers relate in different ways. According to "When the question of the origin of problem-based learning (PBL) arises in the literature, the consensus tends to be that the method was born at McMaster University in 1969… (Kolmos, Fink, & Krogh, 2004; Schmidt, 1993). From there, speculations abound on the specifics of the history of PBL" (Hillen et al., 2010, p.3). "Despite what has often been stated, PBL was not 'invented' by Dr. Howard Barrows, a mistaken belief likely explained by Barrows' ... Instead, … led by founding Dean John Evans. … William Spaulding, an Associate Professor … William Walsh, an internist … and Fraser Mustard, a world-famous platelets researcher..." (Servant-Miklos, 2019, p. 4).

In 2012, Servant et al. initiated a four-year extensive research endeavor to bring clarity and accuracy to the subject matter. For this, they investigated archival evidence from McMaster University, Maastricht University, and other relevant sources. Comprehensive oral history interviews were conducted with individuals associated with the origins of problem-based learning at various institutions. To maintain coherence and ensure the reliability of their findings, Servant et al. employed Whewell's inductive method of historical analysis as their chosen approach (Servant et al., 2019). The following are some conclusions from their findings, consistent with earlier historical accounts of PBL.

PBL was developed in response to criticisms that conventional teaching and learning methods did not effectively prepare beginning medical students to manage issues in clinical settings (Spaulding, 1969). Despite their initial enthusiasm for studying medicine, students frequently lost interest due to the overwhelming amount of seemingly irrelevant information they were asked to passively absorb. The core principles introduced in PBL resulted from the founding fathers' longstanding experience and connection with existing instructional practices, and not a deliberate effort based on theory or educational philosophy at the time. For example, the core principles of engaging students with real-life clinical problems and in-group discussion were not novel, but influenced by the longstanding 'Case Method' practice from the Harvard School of Business (where Spaulding was affiliated). However, whereas Case Method students were required to prepare selected readings prior to attending a group discussion, PBL students approached new problems relying solely on their prior knowledge (Fraser, 1931).

The PBL concept of integrating themes from multiple disciplines, rather than lecturing topical content, was an experiment from the Western Reserve University School of Medicine (WRU) in Ohio. The concept of teacher-facilitation was also borrowed from the 'Oxbridge Tutorial System' from Oxford and Cambridge universities (Servant et al., 2019).

Early evidence of PBL concepts can be found in the notes of Dr. John Evans, a founding dean of McMaster Medical School (Evans, 1966). Together with his team, they crafted the inaugural PBL outline for the initial cohort of around 20 students admitted in 1969, marking the first implementation of this instructional approach. The new curriculum engaged students through biomedical and clinical problems, which they solved in small groups of five to seven. Summative assessments were avoided during the three-year program. Tutors focused on providing formative feedback to students, aligning with the principles of PBL (Ad Hoc Committee on Undergraduate Education, 1969; Educational Programme Committee, 1968).

Barrows made two significant contributions upon joining the team in 1970. First, he developed a method for training actors to portray patients realistically; second, he coined the term *problem-based learning* in 1974 to characterize this approach to instruction (Barrows & Neufeld, 1974). Servant et al., (2019) noted that some confuse Barrow's role in naming this teaching strategy with his being the founder of PBL.

Another milestone in the history of PBL was its introduction at Maastricht University in the 1970s. Herman Tidan, a friend of Evans, became the first dean of the newly established medical school in Maastricht. He subsequently introduced and implemented problem-based learning in Europe (Knegtmans, 1992 as cited in Servant et al., 2019). However, Maastricht faced unique challenges that required adjustments compared to McMaster's model. The large class sizes, consisting of high school freshmen with limited prior experience in higher education and requiring longer years in medical school, necessitated modifications to suit their needs. In 1976, Schmidt designed a systematic approach known as the *Seven Steps*, ensuring the successful integration of PBL at Maastricht University (Schmidt et al., 1979). This approach involved a summative objective text for all students.

Problem-based learning (PBL) adaptations have continued to undergo various adaptations and implementation in diverse disciplinary contexts and educational institutions, each manifesting its own distinctive approach while upholding its core principles (van Der Vleuten & Schuwirth, 2019). The evolution of PBL has been significantly influenced by findings from cognitive science, enabling scholars to employ rigorous scientific methodologies in understanding the underlying mechanisms that contribute to its efficacy.

Table 2

Timeline to the Development of Problem-Based Learning (PBL)

1966	Dr. John Evans, founding dean of McMaster Medical School, documents early concepts of PBL in his notes, laying the groundwork for its development.
1969	McMaster University implements the inaugural PBL curriculum for a cohort of around 20 medical students, focusing on biomedical and clinical problems solved in small groups.
1970	Dr. Howard Barrows joins the McMaster team, contributing by developing realistic patient portrayals and coining the term "problem-based learning" in 1974.
1976	Herman Tidan, the first dean of Maastricht University's medical school, introduces PBL in Europe, facing unique challenges that led to adaptations in the model.
1979	Schmidt designed the "Seven Steps" approach to successfully integrating PBL at Maastricht University, accommodating larger class sizes and longer medical school durations.
2000's	PBL continues adaptations by different educational institutions beyond medical facilities. And the continues evolution of PBL adaptation to diverse disciplinary context.

Present	Emergence of different strands of PBL across the world, different levels of institutions and disciplines.

Government and Institutional PBL Advocacy

"Education in the 21st century is about dealing with new real-world problems. PBL approaches involve harnessing intelligence from within individuals, from groups of people, and from the environment to solve problems that are meaningful, relevant, and contextualized" (Tan, 2021; p. 2). Tan (2021) has noted that the conventional teaching and learning approach is inadequate to meet these needs. According to Saavedra and Opfer (2012), the traditional instructional approach centers on mastering the curriculum content, and not necessarily preparing students for the workforce. As noted by Binkley et al. (2010), educational reforms in the 21st century should foster a curious, critical, and analytical way of thinking, nurture the ability to work independently and collaboratively, and promote familiarity and proficiency with utilizing technology tools and skills to adapt to new situations.

Governments and policymakers worldwide actively promote and invest in learner-centered and authentic instructional approaches such as problem-based, project-based, and case-based learning (Cho, 2015; Weimer, 2013). In some instances, policymakers have been forthright in emphasizing the need for problem-solving skills across all academic disciplines (Servant, 2020). In 2015, the United States, as demonstrated by enacting the 'Every Student Succeeds Act,' updated and reauthorized the Elementary and Secondary Education Act, emphasizing critical thinking and problem-solving skills across various academic levels (U.S. Department of Education, 2017). In an effort to address the workforce needs of the 21st century, the Singaporean government established the Enterprise Challenge Fund with an allocation of $10 million in 1991 (Tan, 2021). An initiative in a PBL educational project was among the first to win this award in 2000 (Tan, 2021).

Different international frameworks have been developed to identify the competencies and skills necessary for success in the 21st century (Brush & Saye, 2017). For example, the National Research Council's report, "Education for Life and Work," emphasizes the importance of developing transferable knowledge and skills such as problem-solving, critical thinking, and collaboration (National Research Council, 2012). Similarly, the Organization for Economic Co-operation and Development (OECD) created the Programme for International Student Assessment (PISA), to evaluate students' ability to, "think critically and solve complex problems" (OECD, 2019, para. 4). Different studies have consistently concluded that PBL effectively achieves the educational standards being advocated for globally (Festiawan et al., 2021; Seibert, 2021; Strobel & van Barneveld, 2009; Walker & Leary, 2009).

Theoretical Basis for PBL

PBL was developed out of practice and not from a particular educational philosophy or learning theory (De Graaf & Kolmos, 2003). In other words, from its historical inception, there were no deliberate attempts from the founding fathers to construct a pedagogy based on specific learning theories or educational philosophies. Their primary focus was on an instructional strategy that promoted high-order thinking skills (Servant, 2019). Even though different strands of PBL exist, they all agree on six fundamental characteristics: (a) problems as the basis for learning (ill-structured and real-world problems), (b) student collaboration in small groups, (c) flexible guidance from a tutor, (d) minimal lecturing sessions, (e) student-initiated learning, and (f) independent studies and reflection by students (Evensen & Hmelo, 2000; Hmelo-Silver, 2004; Schmidt, 1983b, 1993, Schmidt et al. 2019). In the 1990s, the theoretical foundations of PBL started to gain significant attention (De Graaf & Kolmos, 2003). Researchers have made efforts to connect PBL characteristics to various theoretical frameworks, including constructivism (e.g., Piaget, Vygotsky, Lave, and Wenger), problem-solving, prior-knowledge activation, collaborative learning, scaffolding and ZPD, self-directed learning, activity theory, and situated learning among others (De Graaf & Kolmos, 2003).

Constructivism

PBL pedagogy, as practiced today, is rooted in sound educational philosophies and learning theories from the constructivist perspective (Grant & Tamim, 2019). The core of constructivism is that learners actively construct their own knowledge and meaning from their experiences (Amineh, 2015; Fosnot, 1996; Steffe & Gale, 1995). In other words, the constructivist assumes that learners construct their understanding and knowledge about the world through direct experience while reflecting on those experiences. Fosnot (1989) elaborated on four fundamental principles of the constructivist view of learning. Firstly, learning is influenced by individuals' prior knowledge. Secondly, new ideas emerge as individuals adjust and modify their existing ideas. Thirdly, learning is a process of generating new ideas rather than simply accumulating facts mechanically. Lastly, meaningful learning takes place when individuals reconsider their old ideas and reach new conclusions about conflicting new ideas. Researchers are unanimous that constructivism is both a theory of learning (a psychological theory) and a theory of knowledge (a philosophical, and specifically epistemological, theory). However, it is not a theory of teaching or pedagogy (Matthews, 2012; Golden, 2011).

Constructivism presents learning as a constructive process where the learner constructs an internal representation of knowledge, shaping their interpretation of experiences. This representation is dynamic and subject to modification, serving as the foundation upon which new knowledge structures are built (Kaufman, 2018). In this framework, learning is an active process where experiences and their interpretation play a vital role in comprehension and meaning-making. This perspective acknowledges the existence of the natural world but emphasizes that reality imposes limitations on existing concepts. Additionally, conceptual growth occurs through the interplay of various perspectives and the concurrent adaptation of individuals' internal representations in response to these perspectives (Duffy & Jonassen, 1991).

Over the years, different strands of constructivism have emerged and have been studied in educational philosophy. However, the two dominant perspectives are cognitive constructivism and sociocultural constructivism. Cognitive constructivism, primarily influenced by Piaget's work, emphasizes an individualistic understanding of knowledge. This perspective focuses on an individual's cognitive state as they form their understanding of the world. Piaget proposes that when learners encounter experiences that challenge their existing knowledge and thinking, a state of disequilibrium or imbalance arises (Kaufman, 2018). To restore cognitive equilibrium, learners must adjust their thinking by adapting to the new information. Although Piaget (1970) emphasized the cognitive structuring of the individual, he also favored the influence of society and culture on knowledge construction. In his argument, an individual's knowledge within a specific social or cultural context is a direct outcome of their social interactions, which he referred to as 'social equilibrium'. Building upon the concept of cognitive equilibrium, von Glasersfeld (1987, 1989) describes knowledge acquisition in cognitive constructivism as a process in which individuals make sense of their environment in a manner that is unique to them.

Sociocultural constructivism, on the other hand, is rooted in Vygotsky's work. Vygotsky (1978) emphasizes how the social and cultural environments of the learner influence the individual's knowledge construction and development. Sociocultural constructivism emphasizes knowledge development as a collaborative effort of the learner mediated by their culture and community (Vygotsky, 1978). Within the educational community, learning not only depends on cognitive function, but also on social interactions with peers, teachers, parents, and all others within a specific educational environment (Schunk, 2014). The social constructivist considers learning to be the process by which the learner is assimilated and integrated into a knowledge community (Kaufman, 2018). However, social constructivism acknowledges that while shared meaning can be negotiated through discussions, each person's experiences and interactions will differ as a result of their unique perspectives and interpretations (Willig, 2016). The principles of PBL are more aligned with the sociocultural constructivism theories (Grant & Tamim, 2019; Hmelo-Silver, 2004; Norman & Schmidt, 1992; Schmidt, 1993; Schmidt et al., 1989; Schwartz & Bransford, 1998).

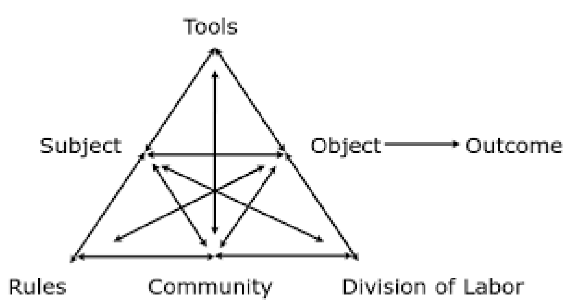
Activity Theory

Activity theory, as a perspective within human science, originated in the Soviet Union during the 1920s and 1930s. Lev Vygotsky played a significant role in its development (Holzman, 2006). Vygotsky emphasized that individuals understand their surroundings deeply and acquire knowledge through meaningful actions, such as collaborative dialogues, interactions, and other social activities. Leont'ev (1978, 1981) further advanced this theory, establishing it as a conceptual framework. Engeström (1987) subsequently expanded on the ideas of Leont'ev and Vygotsky, elucidating how individuals or subgroups adapt their existing frameworks in response to changing situations. Central to activity theory is the notion of an activity system, which is comprised of six essential elements that represent dynamic and complex interactions: the subject (the individual or collective actor), the object (the goal or motive of the activity), the tools and artifacts (mediating instruments used to achieve the goal), the rules and norms (social regulations that govern the activity), the community (the social context within which the activity occurs), and the division of labor (allocation of roles and responsibilities) (Engeström, 1987; Yamazumi, 2021). Activity theory offers insights into how learners engage in activities, interact with peers and teachers, and utilize tools and resources to construct knowledge (Lave & Wenger, 1991; Engeström, 2001).

Activity theory provides a framework for analyzing educational activities, designing pedagogical interventions, and understanding the complex dynamics of teaching and learning in formal and informal settings (Hung et al., 2019). Activity theory provides a theoretical lens through which educators can achieve the goals of problem-based learning. Its emphasis on situated learning, social interaction, mediating tools, goal-oriented learning, and the zone of proximal development (Yamazumi, 2021), aligns with the core principles and practices of problem-based learning. By incorporating activity theory principles, educators can design and facilitate compelling problem-based learning experiences that promote active engagement, collaborative problem-solving, and authentic learning (Chung, 2019).

Figure 1

The Framework of Activity Theory for PBL (Engeström, 2001, p. 135; 2008, p. 257)



Situated Learning

Situated learning is a theoretical framework emphasizing the importance of learning in authentic contexts, where knowledge and skills are acquired through active participation in meaningful tasks and social interactions (Lave & Wenger, 1991; Brown et al., 1989). In other words, learning is situated within specific environments, tasks, and social settings, allowing learners to actively engage with relevant knowledge and skills. Situated learning asserts that individuals learn through experiences in authentic environments (Miner et al., 2021). The concept of situated learning has its origins in the work of Jean Lave and Etienne Wenger (1991), who developed the theory of legitimate peripheral participation (LPP) in communities of practice (CoP). The concept of situated learning has been chiefly associated with a community of learners tackling real-life problems and emphasizing groups' collaborative contributions in informal settings (Brown, 1994). From the various characterizations of this theory, it is evident that learning is a dynamic, social process extending beyond the boundaries of individual cognition to include the sociocultural.

In the field of education, Anderson et al. (1996) outline four fundamental assumptions related to situated learning: (1) action is grounded in the specific situation in which it occurs; (2) knowledge does not readily transfer across different tasks; (3) abstract training yields limited benefits; and (4) instruction should take place within complex, social environments. Learning outcomes are always context-specific (Greeno et al., 1992), encouraging students to address real-world problems and participate in social interactions that arise organically in their environments (Miner et al., 2021).

Self-Directed Learning

Self-directed learning, firmly rooted in constructivism, is a crucial competence for preparing persons for adult life, empowering them to adapt to fluid and complex social and contextual changes (Boyer et al. 2014; Kranzow & Hyland, 2016). Knowles (1975) defined self-directed learning as a, "process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (p.18). It also involves, "conceptualization, design, implementation, and evaluation" by learners as they take control of the learning process (Tekkol & Demirel, 2018, para. 3).

Tough (1967) explained further that individuals have an inherent drive to learn and seek out knowledge and skills that are personally meaningful to them. Self-directed learning often arises in response to life transitions, personal interests, career aspirations, or practical needs (Tough, 1967). The result is the development of active and critical thinking essential in solving authentic real-life problems (Jonassen, 1999; Morris, 2019a). Among the key characteristics of self-directed learners is taking the initiative to identify their learning needs and set their own learning goals. They also actively seek out relevant resources and opportunities for learning such as books, workshops, online courses, or mentors. Self-directed learners are motivated by their internal factors, such as curiosity, autonomy, personal growth, and the desire for satisfaction through self-improvement (Bonk et al., 2015; Knowles, 1975; Knowles, 1977; Jennett, 1992).

Prior Knowledge Activation

"If I had to reduce all educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, 1968, p. vi, as cited in Hattan, 2023). Prior knowledge is any knowledge or information that the individual possesses given their learning situation and includes their world, textual, or personal knowledge (Hattan, 2023). Prior knowledge activation is the cognitive process that involves accessing and bringing forward learners' existing knowledge, experiences, and mental frameworks relevant to a new learning task or topic. It is a fundamental concept in cognitive psychology and educational theory, which emphasizes the importance of connecting new information to learners' prior knowledge to enhance comprehension, retention, and meaningful learning. As Kaufman (2018) noted, learning does not occur in isolation but is instead interconnected with previously acquired knowledge. Therefore, knowledge develops with the integration of pre-existing and new information, broadening the learner's experience and understanding. Activating prior knowledge in a learning situation leads to meaningful learning, a deeper understanding of the context and content, and the long-term retention required for effective learning (Ausubel, 1963).

Collaboration

Collaborative learning has existed for a long time (Johnson & Johnson, 1999, 2021). However, current practices can be credited to the works of Dewey, Vygotsky, and Bruffee (Yang, 2023). Grounded in social constructivism, collaborative learning posits that knowledge is actively constructed through social interaction and dialogue among learners. Smith and MacGregor (1992) proposed five assumptions specific to the collaborative learning viewpoint: "(1) Learning is an active constructive process, (2) Learning depends on rich contexts, (3) Learners are diverse, (4) Learning is inherently social and (5) Learning has affective and subjective dimensions" (Yang, 2023, p. 721). Collaborative learning emphasizes the importance of social interaction, cooperation, and shared knowledge construction among learners.

Through collaborative learning, learners actively engage with others, share perspectives, and engage in joint problem-solving, stimulating cognitive processes such as critical thinking, analysis, and synthesis (Yang, 2023). By working together in groups or teams, learners can access diverse perspectives, challenge their personal assumptions, and construct a deeper understanding of the subject matter (Bruffee, 1984). Social interaction in collaborative learning also provides opportunities for learners to engage in metacognitive activities, reflect on their thinking processes, and monitor their learning (Cockrell, Caplow, & Donaldson, 2000;

Hmelo-Silver, 2004). These cognitive processes, facilitated by collaborative learning, enhance knowledge acquisition by promoting active engagement, deeper understanding, and the application of knowledge in real-world contexts.

Collaborative learning has become a widely adopted concept that encompasses a range of instructional approaches (Laal & Laal, 2012; Smith & MacGregor, 1992; Yang, 2023) aimed at facilitating small group learning, cooperative learning, team-based learning, peer tutoring, study groups, project-based learning, problem-based learning, and learning communities (Yang, 2023). These methodologies recognize and promote learning as a social and active process through meaningful engagement with others.

Scaffolding

The constructivist view of scaffolding is a supportive framework that facilitates learners in actively constructing knowledge and understanding. Wood, Bruner, and Ross (1976) were the first to use the term scaffolding as a metaphor in the learning context. They used the term to describe the nature of parental tutoring in young children's language development. The concept of scaffolding is sometimes linked with the Vygotskian notion of the Zone of Proximal Development (ZPD). The ZPD represents the gap between what a learner can do without assistance, and what a learner can do only with others' (adult) guidance (Hannafin et al., 1999; Jackson et al., 1995; Linn, 1995; Vygotsky, 1978). Scaffolding is described as providing appropriate guidance, resources, tools, and social interactions from a more knowledgeable other to help learners bridge the gap between their current level of understanding and the desired learning outcomes. According to Saye and Brush (2002), these provisions can represent soft or hard scaffolding. What distinguishes soft and hard scaffolding is the timing when each is offered. While soft scaffolding anticipates areas of need and provides them, hard scaffolding, on the other hand, allows the teacher to observe the instructions and provide needed support on the fly (Ertmer, & Glazewski, 2015; Saye & Brush, 2002).

The concept of scaffolding has evolved over the past few decades to include support provided via tools, curricula, and technologies (Reiser & Tabak, 2014) that significant others present to learners in order to bridge the gaps within their ZPD. Puntambekar and Kolodner (1998) designated the term "distributed scaffolding" as an ongoing system of student support through multiple tools, activities, technologies, and environments that increase student learning and performance on a particular task. The amount of assistance is adjusted based on the learner's needs and gradually fades as the learner gains competence (Tabak, 2004).

Tabak (2004) proposed three frameworks for describing distributed scaffolding while referencing the works of Krajcik et al., 2000; Puntambekar & Kolodner, 1998, respectively: (1) "*Differentiated scaffolds* … a way of combining multiple forms of support that are provided through different means to address diverse learning needs (2) *Redundant scaffolds* … involve different means of support that target the same need but are enacted at different points in time in the curriculum to provide titrated levels of support (3) *Synergistic scaffolds*, which refer to multiple co-occurring and interacting supports for the same need" (p. 307).

Problem-Solving

Problem-solving is, "the self-directed cognitive-behavioral process by which a person attempts to identify or discover effective or adaptive solutions for specific problems encountered in everyday living" (D'Zurilla & Nezu, 2001, p. 212). Problem-solving consists of two distinct concepts: the initial problem that prompts the individual's engagement in the process, and the sought-after solution that represents the intended goal or desired outcome. Jonassen (2000) describes a problem as having two critical attributes. First, a problem is an unknown entity in varied situations, from simple to complex. This view of a problem is further elaborated by D'Zurilla and Nezu (2001), who maintained that, "any life situation or task (present or anticipated) that demands a response for adaptive functioning, but for which no effective response is immediately apparent or available to the person, due to the presence of some obstacle(s)" (p. 212-3) could represent a problem. By contrast, a solution is, "a situation-specific coping response or response pattern (cognitive and/or behavioral) which is the product or outcome of the problem-solving process when it is applied to a specific problematic situation" (D'Zurilla & Nezu, 2001, p. 213).

Hesse et al. (2015) present a conceptual framework for problem-solving. The first step is to acknowledge the existence of the problem, the second involves creating a mental presentation of the problem, the third is to formulate a plan that can potentially lead to the intended goal, the fourth is to execute the plan, and the fifth and final step is to monitor the solution process. Hesse et al. (2015) also recognized that this process is not linear. Solving problems requires the individual to engage attention, perception, memory, reasoning, and other cognitive faculties. Research by Mayer (2002) shows that when learners actively engage in problem-solving, they better understand and retain knowledge. In addition, a study by Pollock, Chandler, and Sweller (2002) indicated that problem-solving enhances cognitive load and aids in schema acquisition, contributing to improved long-term information retention.

PBL and other Constructivist Pedagogies

Constructivist learning environments are student-centered, "a place where learners may work together and support each other as they use a variety of tools and information resources in the guided pursuit of learning goals and problem-solving activities" (Rainer et al., 2000, p. 4). Cattaneo (2017) cites a few examples of constructivist learning strategies as: project-based learning (PjBL), inquiry-based learning (IBL), case-based learning (CBL), discovery-based learning (DBL), and problem-based learning (PBL). Others include learning by design (LBD) and design thinking (DT) (Moallem, 2019). All these approaches to learning are student-centered with a constructivist focus. Though these constructivist pedagogies share many common characteristics (Zajda, 2018), each tends to have distinct theory-based features, making them attractive to specific disciplines (Moallem, 2019). Below is a discussion of some of these pedagogies in relation to problem-based learning.

Inquiry-Based Learning (IBL)

Inquiry-based learning is an instructional approach that empowers students to engage in active learning through observations, formulating their own questions, seeking relevant information, analyzing and interpreting data, and drawing conclusions pertaining to real-life or hypothetical problems (Banchi & Bell, 2008; Wale & Bishaw, 2020). Students collaborate in groups to identify the knowledge they need to learn to solve a problem as they investigate and construct knowledge through hands-on exploration and discovery (Avsec & Kocijancic, 2016). Inquiry-based learning shares similarities with PBL as it focuses on student-centered exploration and questioning. However, while PBL often involves the investigation of real-world problems, IBL emphasizes students formulating their own questions and designing their own investigations (Dewey, 1938; Blumenfeld et al., 1991).

Project-Based Learning (PjBL)

Project-based learning is a systematic teaching and learning method where learners work on long-term, interdisciplinary projects that require them to apply knowledge and skills to the projects being undertaken (Chen & Yang, 2019; Larmer et al., 2015). Project-based learning shares similarities with PBL in that both are curriculum-based and use authentic problems as the focus (Savery, 2019). However, PBL is often centered around solving specific ill-structured problems, while PjBL involves the completion of a more extended project or task integrating various subjects and skills to create a tangible product or presentation for a specific audience (Ertmer & Glazewski, 2019; Hung, 2015; Larmer & Mergendoller, 2010).

Case-Based Learning (CBL)

Case-based learning involves using real-life or hypothetical text-based scenarios referred to as "cases" to engage students in problem-solving and critical thinking (Ertmer & Glazewski, 2018). Using case studies as a teaching technique has a similar objective to problem-based learning. The motivation is for learners to analyze issues, exercise judgment, evaluate potentially difficult decisions, and provide solutions (Emblen-Perry, 2022). PBL utilizes cases within a wider scope, with multiple cases across various disciplines (Barrows & Tamblyn, 1980; Thistlethwaite et al., 2012). On the other hand, case-based learning involves one-dimensional and usually independent, noncollaborative analysis of a text-based scenario as a component in understanding the instructor-led discussion for that particular case problem (Emblen-Perry, 2022).

The preceding discussion reveals the existence of competing student-centered instructional strategies that share many themes with PBL. However, Savery (2015, 2019), referencing Barrow's (n.d) set of "Generic PBL Essentials," listed four characteristics that distinguish PBL from other student-centered instructional strategies. The themes discussed were centered around the roles of students, teachers, the curriculum, and the nature of the problem to be solved: (1) The curriculum should have PBL as its fundamental pedagogical approach rather than a component of the teaching plan. (2) PBL should employ ill-structured problem situations, encouraging open-ended exploration and inquiry. (3) Learning should be integrated across diverse disciplines or subjects. (4) The activities conducted in PBL should align with real-world situations.

PBL Implementation Models in K12

Different problem-based learning (PBL) models have been proposed for adaptation in K-12 educational settings (Wijnia et al., 2019). Two popular models are those proposed by Barrows and Myers (1993) for secondary schools, and the Center for Problem-Based Learning (Torp & Sage, 1998, 2002) in the United States. Each of these models has its unique characteristics. The Barrows and Myers model includes a performance presentation activity, where learners can present their solutions to the problem in various forms, such as oral, written, audio, or visual presentation. By contrast, the Center for Problem-Based Learning model includes an optional first stage called "preparing learners." This stage allows facilitators to introduce PBL to students who may be new to the approach (Wijnia et al., 2019; Ertmer & Simons, 2006). Torp and Sage (1998, 2002) noted that these models are flexible and can be adapted to suit the needs of different classrooms and teachers. This model emphasizes prior knowledge activation by thinking through the knowledge they possess (Wijnia et al., 2019). During the initial phase of information acquisition, learners are encouraged to collaborate in small groups comprising three to five individuals, focusing on a predetermined "need-to-know" topic of their choosing (Wijnia et al., 2019). The stage of information gathering is crucial and time consuming for learners, especially when sources of information are scant. In the case of K-12 learners, teachers should be able to guide them to multiple sources of information relevant to the problem (Wijnia et al., 2019). Upon the completion of the information-gathering phase, learners must discern the optimal solution from all other possibilities for their final presentation (Wijnia et al., 2019). Debriefing the problem is also an important step that allows learners to reflect on their proposed solutions (Wijnia et al., 2019).

Table 3

PBL Model for K-12 Education

	Barrows & Myers' model for secondary education	**K-12 model by the Center for Problem-Based Learning**
Author(s)	Barrows and Myers (1993)	Torp and Sage (1998, 2002)
Institution of origin	Southern Illinois University and Lanphier High School	Illinois Mathematics and Science Academy's Center for Problem-Based Learning
Process description	**Starting a new problem:** 1) Set the problem 2) Internalize the problem 3) Describe the product or performance required 4) Assign tasks (e.g., scribe) 5) Reasoning through the problem (hypotheses, facts, learning issues, and action plan) 6) Commitment to a possible outcome 7) Learning issues 8) Resource identification 9) Schedule follow-up Self-study period: 10) Self-directed learning Problem follow-up: 11) Critique used resources 12) Reassess the problem (hypotheses, facts, learning issues, and action plan)	**Teaching and learning events:** 1) Prepare the learner (optional) 2) Meet the problem 3) Iterative cycle of activities: ● Identify what we know, what we need to know, and ideas ● Define the problem statement ● Gather and share information 4) Generate possible solutions 5) Determine the best fitting solution 6) Present the solution (assessment) 7) Debrief the problem Instructions and assessment should be embedded within the teaching and learning events

	Performance presentation after conclusion of the problem: 13) Knowledge abstraction and summary 14) Self-evaluation (and comments from the group)

Note: From, Wijnia et al., 2019 "The problem-Based Learning Process: An overview of Different Models" p. 287.

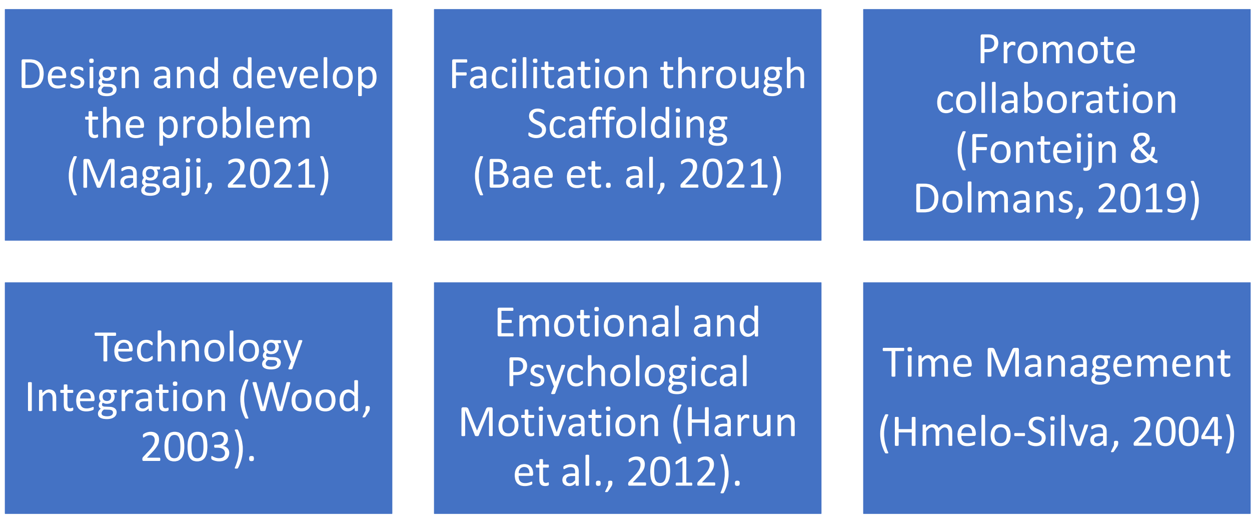
Savery (2019) describes the typical instructional process in PBL as follows: a group of five to eight students is presented with a complex problem that is aligned with the broader curricular objectives in the content domain. This problem does not have a single solution and serves as the motivation for students' learning. The students collaborate to identify the necessary study areas and information required to solve the problem. They then engage in self-directed learning activities to find answers to the identified issues. Finally, the students come together again to share their research findings and engage in further discussions to arrive at a collective solution to the problem (Savery, 2019). After proposing a solution, students are enabled to reflect on the process they underwent and the knowledge they gained. The teacher plays a critical role in designing the problem and facilitating the process while also developing metacognitive thinking skills and helping learners enhance their expertise in the subject domain (Hmelo-Silver et al., 2006). This iterative approach helps learners progressively improve their skills and knowledge in the subject.

Teachers' Role in PBL

Teachers are pivotal in problem-based learning, a student-centered instructional strategy emphasizing active engagement and critical thinking. As facilitators of learning, teachers are responsible for creating and selecting meaningful problems that align with learning objectives, encourage inquiry and exploration, and reflect real-world contexts (Hmelo-Silver, 2004). They guide and support students throughout the problem-solving process, fostering collaboration, metacognition, and self-directed learning skills. Additionally, teachers provide scaffolding and feedback to help students develop deeper understanding, transferable knowledge, and problem-solving abilities. By designing and facilitating PBL experiences, teachers empower students to become active learners, capable of applying their knowledge and skills to solve complex, authentic problems.

Figure 2

Teachers' Roles in PBL Implementation



Time Management

PBL often requires more time for preparation, facilitation, and reflection compared to traditional teaching methods. Teachers need to invest time in creating authentic problems, developing resources, and guiding students through the learning process (Hmelo-Silva, 2004). Teachers might find it challenging to cover the entire curriculum within the allotted time, as PBL often involves an in-depth exploration of fewer topics. This can be a concern in education systems with strict curriculum guidelines and standardized testing (Barrows et al., 1980). While problem-based learning offers valuable benefits, teachers face challenges related to time availability and the inability to cover the entire curriculum. Overcoming these challenges requires a supportive institutional environment, proper training for teachers, and a thoughtful approach to curriculum design that aligns with the principles of PBL. Dolmans et al. (2016) reported in a study that where there is no institutional-wide implementation of PBL, some teachers felt pressured to adhere to traditional teaching methods that cover a large amount of content quickly. This is particularly the situation where teachers do not have the administrative support and understanding of the PBL approach (Nurlaily et al., 2019).

Designing and Developing the Problem

Central to the success of PBL is the role of teachers who design and create the problems or tasks that students must solve (Kim et al., 2022; Parong & Mayer, 2018). Engaging students to solve real-world problems is at the heart of PBL (Bayrak & Gürses, 2020). "Learning to solve problems is the most important skill that students can learn in any setting. In professional contexts, people are paid to solve problems, not to complete exams. In everyday life, we constantly solve problems" (Jonassen, 2004, p. xxi). PBL utilizes problems as the basis through which instructional objectives are realized (Magaji, 2021). According to Sockalingam (2015), the overall, "purpose of a problem is to engage students in problem-solving, rekindle their prior knowledge, spark discussions, encourage collaborative work, promote self-directed learning skills and result in the acquisition of relevant content knowledge" (p. 43). The acquisition of content knowledge and skills is structured around problems rather than being presented in a topical format (Bayrak & Gürses, 2020). The teacher either selects an appropriate problem or designs a problem that aligns with the demands of the curriculum.

Teachers' efforts toward designing a good problem are essential to the success of the PBL process (Hung, 2006). Different studies have demonstrated the correlation between the problem quality and the effectiveness of PBL in realizing its objectives (Hung, 2019). The quality of the problem comparatively contributes more towards achieving learning outcomes than students' prior knowledge and teacher efforts (Coulson & Osborne, 1984; Dolmans et al., 1993; Jonassen & Hung, 2015; O'Neill, 2000; Schmidt & Gijselaers, 1990; van Gessel, Nendaz, Vermeulen, Junod, & Vu, 2003). Van Berkel and Schmidt (2000a) report that the quality of problems significantly contributes to the success of the instruction. A study by Rotgans and Schmidt (2011) revealed that students' situational interest increased when a problem was presented. Other studies have demonstrated a negative impact on students' learning when the problem quality is poor (Sockalingam, 2015). Such adverse effects could include challenges for students in identifying learning objectives (Sockalingam & Schmidt, 2011) and their interest in the instructional approach (Hung et al., 2013b). It is, therefore, essential for the teacher to spend a lot of time and resources on the design and development of the problem.

When designing problems for PBL, teachers need to consider key principles and characteristics to ensure practical learning experiences for students (Houghton, 2023). Authenticity and relevance are crucial, as authentic problems enhance engagement and motivation (Hmelo-Silver, 2004; Suwono et. al., 2023). The problem should be ill-structured to foster critical thinking and the development of expertise (Schmidt & Mamede, 2015). Open-endedness and multiple perspectives encourage exploration and divergent thinking (Hmelo-Silver, 2004). Alignment with learning objectives establishes clear connections between problem-solving and educational goals (Savery, 2006). Problems with interdisciplinary integration also promote teamwork and interdisciplinary thinking (Michaelsen et al., 2004), which contributes to the effectiveness of the learning process.

Different authors have initiated different models and guidelines to assist teachers in designing and developing effective problems. Among the most comprehensive ones include Hung's (2019) "2^{nd} Generation of the 3C3R" approach to designing PBL problems, which is an update from Hung's (2006) 3C3R framework for designing problems and Hung's (2009) 9-step PBL problem design process for PBL educators. In this approach, Hung (2019) presents a systematic method to guide teachers through designing and developing PBL problems. The second generation 3C3R model involves core, processing, and enhancing components. The core components encompass content, context, and connection, which support content/concept learning. Processing components, including researching, reasoning, and reflecting, focus on the learning processes and problem-solving skills. The enhancing components include affect, difficulty, and teamwork, considering the psychological, emotional, and other factors affecting students' motivation, engagement, self-directed learning, and collaborative/cooperative learning (Hung, 2019).

Facilitation Through Scaffolding in PBL

Teachers' facilitation of the PBL process through scaffolding plays another important role in the function and success of effective PBL. According to Hmelo-Silver (2004), "having good problems is a necessary but not sufficient condition for effective PBL" (p. 244). Scaffolding is an essential characteristic of PBL, in which students are supported through difficulties associated with problem-solving (Bae et al., 2021). The idea of a student-centered approach to knowledge acquisition in PBL does not imply that students "must actively construct their skills and understandings by themselves" (Mascolo, 2009, p. 5). In order to solve problems, learners will have to evoke knowledge from different subject disciplines and resources. The process can be complex and difficult (Kim et. al., 2019). Considering the cognitive maturity level and experiences of K-12 students who are accustomed to solving well-structured problems, it is important for teachers to be prepared with the skills to facilitate the PBL process (Kim et. al., 2019). Unlike the traditional instructional approach, where teachers offer the same notes and instruction to all students, PBL places different students with different needs at different stages in the process, but at the same time (Kim et al., 2018). The personal guidance and support for different learners with consideration to their needs at different stages, and without which they might fail to achieve the educational goals, is called scaffolding (Wood et al., 1976). The teacher facilitates the PBL process by engaging and motivating students' thinking and reflections on the problem that they must solve (Tiantong & Teemuangsai, 2013).

Researchers have identified and categorized different types of scaffolding depending on the learning environment, the task being undertaken, the facilitator's experience, and the student's cognitive maturity on the subject (Simons & Ertmer, 2005). Some have suggested that there are four categorizations of scaffolding that teachers provide: conceptual, metacognitive, strategic, and motivational (Collins et al., 1989; Hannafin et al., 1999; Kim et. al., 2019; Tuckman & Schouwenburg, 2004). Hogan and Pressley (1997) maintained that teachers facilitate by scaffolding when they model the desired approach towards solving a problem instead of directly spoon-feeding students. They may also clarify students' questions so they can continue the lesson or invite them to participate in an activity that gives them a sense of direction in the problem they are solving. Alternatively, teachers may pose questions at a different time for students to articulate their understanding or offer clues that help students to think and reflect upon the problem. These strategies may be applied individually or combined in response to the nature of the problem being solved.

Saye and Brush (2002) also classify scaffolding into soft and hard scaffolds. What distinguishes soft and hard scaffolding is the timing for when each is offered to learners. As part of planning for PBL, a teacher may diagnose students' strengths and weaknesses, and anticipate areas where students may need extra information or clues before they can complete a solution; this is hard scaffolding (Saye & Brush, 2002). On the other hand, when a teacher moves around and observes student activities while answering their questions and offering support on the fly, this is soft scaffolding (Saye & Brush, 2002).

Engaging in effective scaffolding involves several factors. Teachers must ensure that educational goals and objectives are understood and valued by students (Korhonen, 2019). Also, scaffolding should be given in relation to students' level of understanding and skills after a careful diagnosis of their actual needs (Korhonen, 2019). Teachers should also vary the type of scaffolding they adopt depending on the task or problem being solved (Dabbagh, 2003). Teachers should also understand the temporary nature of scaffolding (Stone, 1998).
Researchers are generally divided on the extent of scaffolding that should be offered during the PBL process. Kirschner, Sweller, and Clark (2006) maintain that PBL, as an instructional strategy, requires minimal student guidance. However, considering the age and experiences of K-12 students and the cognitive maturity level needed for self-directed learning as required by PBL, others are of the view that scaffolding should be extensive enough to ensure students achieve the learning outcomes (Belland et al., 2008; Schmidt et al., 2007). According to Barrows (1988), most teachers are not accustomed to the scaffolding role that they are expected to play in a PBL classroom. He further explained that this type of facilitation is not always

planned in detail (Barrows, 1986). This is precisely because the teacher cannot anticipate all student responses in an open-ended educational environment (Etmer, 2018).

Collaboration in PBL

Another critical characteristic of PBL revolves around small groups collaborating to solve a given task or problem (Cockrell et al., 2000). PBL uses collaboration among learners as a strategy to build different communication and social skills. Teachers are responsible for orchestrating the optimal grouping dynamics within the class to facilitate and promote effective PBL. A PBL study review by Azer and Azer (2015), concluded that group interaction among students was influenced by various factors, including the perceptions of both students and tutors, the subject-matter expertise of tutors, the tutor's group dynamic skills, and the training that tutors provided to students in group dynamics. While problem-solving is at the heart of PBL, small group interaction provides the context for all activities toward achieving this goal (Fonteijn & Dolmans, 2019). To optimize the performance of each group, the teacher must consider several key factors. According to Fonteijn and Dolmans (2019), there are several key areas that affect group work and group dynamics in PBL, including group size, the resource pool, the learning task and group learning process, and the learning context.

Group Size. Grouping learners to work collaboratively on a problem is essential to the PBL tutorial process (Cockrell et al., 2000). However, scholars are not in agreement about the best number of learners for each PBL group. Several factors may determine the number of learners in a group including the nature of the problem, available class space, instructional materials and resources, and the number of facilitators involved (Duffield & Grabinger, 1997). These notwithstanding, a medium-sized group of five to eight is generally recommended (Chang et al., 1995; Savery & Duffy, 1995). Whereas a smaller group limits the level of diversity and quality of discussions, a larger group prohibits all members from participating fully (Barrows, 1994). For these reasons, a medium-sized group is always preferable for a successful PBL lesson. Membership in groups should be maintained over a long period to build them into student learning communities (Shapiro & Levine, 1999).

Resource Pool. Fonteijn and Dolmans (2019) noted individual differences, cognitive and skill abilities, experience, diversity, the learning task, autonomy, and group climate as the key factors that teachers must consider related to team learning behaviors. In assigning students to groups, teachers must consider their individual differences. Driskell et al., (2006) noted that personality factors like extraversion, conscientiousness, agreeableness, and dominance have the potential to either enhance or impede group work dynamics. Different studies have mixed conclusions relating to the effects that individual cognitive ability and skill levels have on group performance. While Stewart (2006) found a high correlation between excellent students and high group performance, Woolley, Aggarwal, and Malone (2015) found only a moderate correlation to group performance.

The Learning Context. The main themes for teachers' consideration under the learning context are subject discipline, cultural experience, socialization, and training of students. Some subject disciplines like business and psychology tend to attract students who are oriented towards working in groups (Van Lange, Schippers, & Balliet, 2011). Extensive evidence also exists demonstrating the influence of a student's cultural orientation on their engagement in various forms of group work (Frambach et al., 2013; Frambach et al., 2012; Holen et al., 2015; Nanda & Manjunatha, 2013;). For example, Dutch students are more inclined to share academic resources compared to Middle Eastern and Hong Kong students, who appear to be oriented toward competitiveness and personal achievement (Frambach et al., 2012). Fonteijn and Dolmans (2019) highlighted the nature of the problem, the extent of student autonomy in self-directed learning, the group's overall climate, and various team learning behaviors as additional factors that can impact group performance.

Researchers have investigated issues within PBL groups resulting from unbalanced participation or tensions between outspoken and reserved students (De Grave et al., 2002; Dolmans et al., 2015; Hendry et al., 2003). Zajac et. al., (2014) found that group meeting duration affects group performance quality. A limited time for group meetings will likely lead to poor learning outcomes. Other studies also show that teachers' presence has negatively affected student group performance (Nanda & Manjunatha, 2013). Fonteijn and Dolmans (2019) also pointed out the challenges teachers face in distinguishing individual contributions from team contributions and unraveling the interdependencies among individuals and groups.

Motivation in PBL

From its inception, PBL was intended to promote an innovative instructional approach that would promote students' engagement in the teaching and learning process (Spaulding, 1969). However, Harun et al. (2012) noted that "transforming the typical spoon-fed learners to the self-directed learners is a painstaking process. At the very beginning, most students rebel PBL approach as if PBL is the worst teaching mode they encounter" (p. 236). In other words, it takes some effort to abandon the conventional method where the teacher dispenses knowledge in favor of an environment where students are expected to assume full responsibility for their learning. The PBL teacher must, therefore, be familiar with best practices that sustain students' interest in the task at hand. Facilitator motivation, especially at the early stages of their transition, is crucial in alleviating students' frustration and strong emotional reactions (Harun et al., 2012). In planning to support students' motivation, Biggs and Tan (2007) suggested that teachers pay attention to three critical areas: (1) student perceptions of the task's significance, (2) student confidence in their ability to accomplish the task, and (3) student self-esteem and emotional responses to the task.

The conclusions from three different studies, as reported by Harun et al. (2012), underscored six ways that teachers can motivate students in PBL: (1) the course goal, (2) the student’s personal goal, (3) interest and background knowledge, (4) relevant materials, (5) student skills related to independent learning, and (6) feedback. Another study by Bergman et al. (2023) concluded that even though students hated the workload in the learning process, they were happy and satisfied with the solutions they could provide for their tasks. It is, therefore, important for teachers to keep students focused on the goal of their learning.

Assessment in PBL

Designing assessments to evaluate students' learning is another critical role of teachers in the PBL process. Poikela and Poikela (2005) assert that, “the most powerful means for guiding students’ work are assessment procedures” (p. 13). Through assessment, teachers can influence student learning in any environment, including PBL (Gijbels et al., 2005; Wood, 2003). PBL assessment should primarily aim to assess students based on the four key objectives, which include: (1) promoting knowledge recall and transfer to apply to new situations, (2) promoting effective problem-solving skills, (3) promoting self-directed learning, and (4) promoting learner motivation (Barrows & Tamblyn, 1980). Similar to traditional methods in evaluating student learning, assessment in PBL can be categorized into formative and summative. Formative assessment involves diverse techniques teachers employ to evaluate students' understanding and learning needs and provide feedback while lesson instruction is ongoing (Albanese & Hinman, 2019). Summative assessment, on the other hand, is employed by teachers to evaluate students’ learning at the end of an instructional period (Albanese & Hinman, 2019). The teacher uses formative assessment to provide insight to students on their progress while alerting them on areas requiring improvement. Teachers employ summative assessments to gauge the extent to which the curriculum goals have been achieved (Nendeaz & Tekian, 1999). PBL facilitators have various measuring instruments to evaluate student learning in PBL. These span from conventional multiple-choice and essay exams to innovative approaches like case-based assessment, self-assessment, peer assessment, performance-based evaluation, and portfolio assessment (Gijbels et. al., 2005). Many researchers in the field have proposed progressive testing, which involves multiple choice questions administered at different stages to all students, This began in 1997 at Maastricht as a form of assessment for teachers seeking to adopt a PBL curriculum (Albanese & Himan, 2019; McHarg et al., 2005; van der Vleuten, Verwijnen, & Wijnen, 1996; Willoughby et al., 1977). Other researchers have suggested programmatic assessment, which, in addition to the focus on progressive testing, "incorporates all competencies and assessment program as a whole" (Van der Vleuten et al., 2010, p. 911). Irrespective of the assessment technique used, it is the teacher's responsibility to assist learners with perceiving them as an integral component of the learning process rather than some ancillary task (Waters & McCracken, 1997).

A PBL teacher's assessment strategy should align with the curriculum goals and instructional principles (Segers, Dochy, & Cascallar, 2003). The goals of PBL require that teachers design and develop assessments to cover the student knowledge base and problem-solving skills (Segers et al., 2003). Surgrue (1993), maintained that assessment towards problem-solving must focus on three critical areas: firstly, evaluating students' understanding of concepts related to the given task; secondly, appraising students' ability to understand the principles or rules that connect various concepts, thus establishing their interconnections; and finally, assessing students' competence in applying their understanding of these relationships to procedures and conditions essential to solving the problem at hand. The advantage of connecting concepts and principles to conditions and procedures enables the development of skills that students can employ in new and unfamiliar situations (Walker et al., 2009).

The distinguishing features of PBL are the very factors that make any assessment criteria challenging to teachers (Pedersen, 2009). In a student-centered approach, the students determine key learning issues making it difficult for teachers to design a common assessment rubric for the different student groups (Pedersen, 2009). PBL presents students with ill-structured problems, but such problems do not have a direct or a single solution. It is, therefore, difficult for teachers to design generalized assessment materials to evaluate all students simultaneously. Considering that most student engagement in PBL occurs within group settings, separating individual contributions from their collaborative efforts demands careful consideration (Jonassen & Hung, 2006). This is crucial as mismanagement of the process could be counterproductive. Teachers looking forward to adopting PBL must be guided by the proper training and skills to plan and structure assessment criteria that truly evaluate all aspects of the PBL curriculum.

PBL in K-12 Education

Researchers are unanimous about the origins of PBL within medical institutions and higher educational settings from the 1970s (Taylor & Miflin, 2008). However, PBL has since spread to other subject disciplines and educational levels and settings (Savery, 2015). Deliberate efforts have been made to diffuse this instructional method into K-12 education. "K–12 education is the terminology used in the United States to refer to elementary and secondary school grades from kindergarten (age 5–6) through grade 12 (age 17–18)" (Johnson, 2022, p.

354). Different meta-analyses on PBL have proven that this instructional strategy is able to improve learners' problem-solving and higher-order thinking skills (Albanese & Mitchell, 1993; Dochy et al., 2003; Vernon & Blake, 1993; Walker & Leary, 2009), when compared to traditional approaches to learning (Hung et al., 2008). According to Brush and Saye, (2017), problem-solving, critical thinking, etc., are required 21st century skills and competencies that PBL helps to develop. Government and policymakers' efforts to develop these 21st-century skills among learners have contributed to the wide diffusion of PBL in K -12 educational settings (Brush & Saye, 2017). In support of this development, there has been a conscious and gradual effort by researchers in the field to offer the needed theoretical, conceptual, and practical understanding for adopting PBL within K-12 education (Boud & Feletti, 1991; Gijselaers et al., 1995; Wilkerson & Gijselaers, 1996). One example is the development of PBL curricula and other training resources on core subjects for the Illinois Math and Science Academy (http:// www.imsa.edu/center/) by Barrows and Kelson (1993). Another example, the Problem-Based Learning Institute (PBLI), continues to offer resources (http://www.pbli. org/) that facilitate teacher-training courses in PBL (Barrows, 1996; Barrows & Kelson, 1993). Others have used teacher development programs, summer teacher workshops, etc. to facilitate the establishment of a strong presence for PBL in gifted education before its broader adoption (Gallagher et al., 1992; Stepien et al., 1993). The increasing interest in PBL within K-12 education (Grant & Tamim, 2019) is also seen through efforts towards the publication of books on the subject (Barrows, 2000; Duch et al., 2001; Evenson & Hmelo, 2000; Kain, 2003; Torp & Sage, 2002). It is likely that PBL will continue to grow outside the core subjects to other disciplines across K-12 education (Torp & Sage, 2002; Willian & Hmelo, 1998).

"PBL scholars and meta-analysis studies remind us that, due to practical issues, the ways PBL, PjBL, LBD, or IBL are implemented in the K–12 settings are different from those applied in higher education or professional schools" (Condliffe et al., 2015; Jensen, 2015; Kolodner, 1993; Kolodner et al., 2003a, as cited in Moallem, 2019, p. 116). Johnson et al., (2022) have cited in their findings that 7% (19) of the articles they studied indicated that younger K-12 students have different developmental levels that create barriers to effective PBL. A recent study by Kim, Belland, and Walker, (2018) on PBL and other problem-centered educational strategies observed high margins for knowledge gained across the different age groups even though all received similar scaffolding support. Unlike medical students, middle and secondary school students who are used to teacher-led direct instruction generally lack the level of information literacy and argumentation skills that are necessary to maintain PBL's original structure (Barrows, 1996; Buchanan et al., 2016; Torp & Sage, 1998). Even though different strands of PBL exist for various reasons, van Der Vleuten and Shurwirth (2019) emphasize that four core structures must always be in place: (1) problem as the starting point of the process, (2) opportunity for self-directed learning, (3) collaboration on tasks, and (4) the facilitating role of the teacher.

The Problem

PBL requires learners' engagement with ill-structured problems leading to knowledge acquisition and skill development. Learners can then apply these to similar or different situations (Grant & Tamim, 2019). Students' dispositions toward the problem's difficulty and their perceived ability to offer the right solutions contribute to the success of PBL. However, conventional K-12 students are used to solving well-structured problems, with the teacher as an expert who provides all the needed information. A sudden transition where students take control of the learning situation becomes a problem. For this reason, Kim et al. (2019) have argued that optimizing PBL tasks in a K-12 environment based on student level alone may not guarantee success unless other factors such as scaffolding, self-directed learning, etc. are equally considered.

Collaboration

In PBL, students collaborate in groups to construct knowledge and solve problems (Hmelo-Silver, 2004). There are, however, different research outcomes on the impact of collaboration on student performance within K-12 settings. Barron (2003) studied how group interactions among sixth graders impacted problem-solving and concluded that there was a positive correlation. On the other hand, Wirkala and Kuhn (2011) cited no significant differences among individuals and PBL groups among sixth graders. Lee, Huh, and Reigeluth (2015), in examining high school collaborative PjBL, reported that group members experienced three types of intragroup conflicts: how to negotiate on tasks, how to direct the learning process, and how to manage relationship conflict that results from personal attributes and negative feelings between members.

Scaffolding

Scaffolding plays an even more vital role in K–12 educational environments than higher education levels (Kim et al., 2019). The key question revolves around determining the appropriate amount of scaffolding to offer to K–12 students. Given the intricate nature of the challenges they face, it becomes imperative that students at this stage receive substantial guidance (Kim et al., 2019). When students confront a demanding problem, it is essential for the teacher or facilitator to provide enough support in order to sustain their interest, motivation, and self-determination in the learning process (Moallem, 2019).

Self-Directed Learning (SDL)

An important focus of PBL is the development of self-directed learners. Self-directed learning involves "learners' awareness, initiative, and acceptance of personal responsibility for their own learning with the acquisition of resources and skills to enhance their learning experience" (Leary et al., 2019, p. 182). Studies examining SDL in various problem-based learning contexts have produced varying results (English & Kitsantas, 2013; Leary et al., 2019; Lee et al., 2010; Loyens et al., 2008). Efforts to bridge the gap are responsible for the different adaptations ranging from high-fidelity adherence to Barrow's PBL model to integrating diverse hybrid curricula (Lee et al., 2010; Lloyd-Jones & Hak, 2004). Different comparative studies have concluded that K–12 students with PBL backgrounds tend to exhibit higher self-directedness levels than students in traditional lecture-based classes (Abubakar & Arshad, 2015; Azer, 2009; Van Deur & Murray-Harvey, 2005).

Conclusion

Problem-based learning (PBL) is a student-centered instructional approach that encourages learners to actively engage with real-life problems, conduct research, integrate theory and practice, and collaborate with peers to find solutions (Savery, 2015, 2019). Historically, PBL has been widely used in medical education to motivate students to learn scientific concepts and develop clinical skills.

Teachers play a pivotal role in the PBL process, selecting or designing problems aligned with curriculum objectives and developing assessments that align with PBL principles. The teacher's role shifts from a traditional dispenser of knowledge to a facilitator, guiding students through the problem-solving process (Savery, 2006). Maintaining student motivation and enthusiasm is crucial, especially when students face challenges and frustration (Hung et al., 2008).

The principles of PBL are based on different educational philosophies and learning theories, including those from the cognitive and constructivist perspectives. With the evolving needs of the 21^{st} century, governments and institutions globally actively promote learner-centered approaches, including PBL. PBL has transcended its roots in medical education and gained popularity across disciplines and educational levels, including K-12 education (Hmelo-Silver, 2004; Servant, 2020; Torp & Sage, 2002).

Despite its successful integration into higher education, implementing Problem-Based Learning (PBL) in K-12 settings presents distinctive challenges. Numerous empirical studies have identified obstacles faced by K-12 teachers attempting to incorporate PBL into their classrooms. These challenges encompass issues such as time constraints for completing the curriculum, the need for skills in designing realistic problems, the ability to effectively facilitate the PBL process, conducting meaningful assessments, and providing motivation to students, among other complexities. The primary objective of this study is to comprehensively examine various empirical studies, consolidating the identified K-12 teachers' implementation strategies and challenges/experiences to discern patterns or relationships. Such analysis aims to enhance our understanding of the subject, offering insights to inform the development of targeted professional development programs for teachers and other stakeholders seeking to explore and implement PBL within K-12 educational settings.

Chapter Three

Research Methodology

This chapter presents the study's methodology, including the scope, and demonstrates how the study was conducted.

Study Purpose

The purpose of this study was to conduct an integrative literature review examining K-12 teachers' PBL implementation strategies as described in the empirical literature. In addition, it investigated the experiences of K-12 teachers focusing on the challenges they faced in implementing PBL and examining the types of problems incorporated within PBL frameworks. This was intended to update and inform practitioners about effective PBL implementation strategies, the practical challenges faced by teachers, and the problems that have been solved through effective use of PBL. Thus, this study contributes to the literature centered on an instructional strategy that has been proven to increase learning and performance in K-12 classrooms.

Research Questions

The following research questions guided this integrative review:

1. How have PBL implementation strategies/models in K-12 education been described in empirical literature?

2. How have K-12 teachers' experiences/challenges with PBL implementation been described in empirical literature?"

3. How do the types of problems used in PBL within K-12 settings in empirical literature align with Jonassen's (2010) types of problems?

Study Design

An integrative literature review methodology was employed in this study. Integrative review (IR) involves analyzing previous empirical or theoretical literature to better understand a specific problem or phenomenon (Broome, 2000). As indicated by Whittemore and Knafl (2005), Integrative Literature Review grants the researcher the opportunity to draw literature from empirical and theoretical studies, as well as diverse methodologies (experimental and non-experimental) from across disciplines. Torraco (2005) emphasizes the rigorous nature of IR when he describes it as, "a form of research that reviews, critiques, and synthesizes representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated" (p.356). Callahan (2010) expanded on this definition, specifying that an integrative literature review is also characterized by its "concentrated focus" (p. 301) and uses a systematic methodology in the development of the review and the creation of the synthesized information. The approach of an integrative review explores, "the depth of a major topic within a field and systematically traces the selected literature on a topic back to its roots" (Callahan, 2010, p.301).

The integrative review methodology is highly suitable for this study. According to Torraco (2005, 2016), an integrative review is, "a distinctive form of research that generates new knowledge about the topic." This is achieved through a comprehensive examination, critical evaluation, and integration of existing literature in a manner that produces novel frameworks and perspectives on the topic (Torraco, 2005, p. 356; Torraco, 2016, p. 404).

The term "integrative review" has sometimes been confused with "systematic review" (Toronto, 2020). This is because literature reviews generally share the common objective of summarizing existing knowledge about a particular subject (Toronto, 2020). Both integrative and systematic literature reviews aim to convey this synthesized information to a targeted audience, and they each require a well-documented systematic process to accomplish their respective goals (Toronto, 2020). However, an integrative review adopts a broader perspective in its exploration of a subject, encompassing both empirical and theoretical sources to fulfill its objectives (Toronto, 2020). The systematic process employed in an integrative review is used, "to identify, analyze, appraise, and synthesize all selected studies" (Toronto, 2020, p. 2). While statistical analysis methods are not part of the review process, any significant observed patterns are to be recognized and integrated into the findings. Callahan (2010) noted that integrative reviews enable researchers to, "systematically trace much (or maybe even all) of the literature on a selected topic back to its roots" (p. 301).

Torraco (2005) distinguished between two categories of integrative reviews. The first type delves into well-established subjects characterized by extensive and diverse bodies of literature that have developed over time. The second type focuses on new or emerging topics that stand to benefit from a comprehensive literature review. In both cases, the expectation is that the knowledge derived from synthesizing the available literature could lead to a reconceptualization, offering fresh insights and drawing conclusions from a variety of sources (Toronto, 2020; Torraco, 2005). This study is centered on the well-developed subject of PBL, and the roles and challenges K-12 teachers face in their effort to implement this instructional strategy. The study's objective focuses on improving knowledge of PBL strategies, teachers' challenges, and the types of problems while highlighting their implications for research, practice, and education (Toronto, 2020).

Different researchers have suggested different steps when conducting an integrative literature review. Torraco (2005) outlines a five-stage process for conducting an integrative review, which includes: (1) identifying a suitable topic, (2) justifying the chosen literature review methodology, (3) conducting a literature search, (4) analyzing and critiquing the literature, and (5) synthesizing the results. Whittemore and Knafl (2005) also present a five-stage approach, involving: (1) identifying the research problem, (2) searching for and reviewing the relevant literature, (3) evaluating the collected data, (4) analyzing the data (comprised of five distinct steps), and (5) presenting the findings. More recently, Toronto (2020) has expanded and redefined the integrative review process, specifying six essential steps: (1) formulate the purpose and/or review question, (2) conduct a systematic search and selection of literature, (3) quality appraisal of the selected literature, (4) analysis and synthesis, (5) discussion and conclusion, and (6) dissemination of findings.

For the purposes of this study, the methodology outlined by Whittemore and Knafl (2005) was employed. This approach was chosen not only because it provides a comprehensive framework for conducting an integrative review but also synthesizes the methods used in other methodologies. These steps are outlined in Table 4 below.

Table 4

Overview of Study Process

Stage	**Action in Stage**	**Tasks in Stage**
1	Problem identification	Identify a problem in the literature Develop research questions Identify review purpose
2	Systematic literature search	Define search criteria Select appropriate databases Initiate search Develop inclusion and exclusion criteria to determine relevant sources Identify initial variables of interest
3	Data evaluation	Evaluate the quality of primary sources using initial variables Identify potential keywords to aid in filtering Explore themes to refine the approach to the problem

4	Data analysis	Analyze and synthesize the information gathered Data reduction via the overall classification system. Extract and code data Create matrices to enhance pattern visualization Identify patterns, themes, relationships and draw implications
5	Discuss and present findings	Create a concise summary of major findings and key contributions Support conclusions, recommendations, and implications Identify and detail limitations Write results and research agenda

Note. Adapted from Whittemore & Knafl (2005)

Study Process

According to Toronto (2020), a study is considered rigorous when it presents a comprehensive and detailed methodological process and reports findings in a manner that allows for replication. This study maintained rigor by following the five stages already outlined to conduct robust and replicable procedures.

Stage 1: Problem Identification

The first stage of an integrative review is the "description of the problem and content of interest" (Oermann & Knafl, 2021, p. 66). "The initial stage of any review method is a clear identification of the problem that the review is addressing and the review purpose" (Whittemore & Knafl, 2005, p. 548). It is essential to highlight the significance of the problem and demonstrate the reasons for choosing integrative review as a methodology that might address this problem (Torraco, 2005). The researcher undertook an extensive reading of existing literature pertaining to problem-based learning (PBL) within the K-12 educational context. The researcher observed that despite the attractiveness of PBL and many commendable success stories as a student-centered pedagogical approach, its implementation is not widespread. A further review of the literature also revealed that the practical applications of PBL are beset by different implementation strategies and challenges for teachers. However, the nature of these strategies and challenges are disparate across the various literature. This prompted a deeper interest in studying the specific PBL implementation strategies, the types of problems used, and the experiences of teachers with a special focus on their challenges while implementing PBL within K-12 educational settings.

In the first chapter of this paper, the researcher systematically presented the identified problem and elaborated on the purpose of this study. Specifically, the purpose was to examine PBL implementation in K-12 settings, updating knowledge and understanding of how empirical data conceptualizes: (a) the PBL implementation strategies in K-12 educational settings, (b) the types of problems used when implementing PBL, (c) the experiences/challenges of K-12 teachers adapting PBL, (d) and the identification of prevalent patterns and issues within the existing data. This was used to provide a basis for outlining a research agenda, as well as to provide practical recommendations for instructional design practitioners and other stakeholders adapting this instructional strategy. Subsequently, the research questions for the study were formulated and defined, which led to the selection of an integrative review as the most suitable methodology for this study.

Stage 2: Systematic Literature Search

A critical stage in maintaining the rigor of an integrative review involves "well-defined literature search strategies" (Whittemore & Knafl, 2005, p. 548). A systematic literature search and data set selection process for integrative review involves, "defining in detail all databases, search terms, limiters, eligibility (inclusion/ exclusion)" (Toronto & Remington, 2020, p. 22). Additionally, this process involves specifying the selection criteria and any supplementary research tools employed to ensure the creation of a well-documented and comprehensive literature review (Cooper, 1982; Whittemore & Knafl, 2005).

This stage begins with the identification of keywords to inform the direction of a computerized data search. This effort also involves a manual search of databases using the references and bibliographies of articles that are identified for review (Cooper, 1986). The manual screening approach is known as the "ancestry approach," and is useful in ensuring that the most extensive body of literature relevant to the topic is collected (Atkinson et al., 2015). Cooper (2017) describes the ancestry approach as, "using the reference lists at the end of research reports to locate other reports that might be relevant to a search" (p. 14). This systematic literature search phase requires the use of "well-defined literature search strategies" (Whittemore & Knafl, 2005, p. 548). The purpose of using clearly defined search strategies is to reduce the potential for insufficient or biased search results, while increasing the accuracy of the papers that are included in the data set to meet the needs of the study (Cooper, 1998; Whittemore & Knafl, 2005).

To conduct this integrative review, specific search terms were used as keywords from the topic to access data for the study. Although the primary focus of this integrative review pertained to Problem-Based Learning, a variety of related terms were explored, including PBL, problem-based teaching, problem-based education, problem-based, etc. The researcher collaborated with a professional librarian from the Virginia Tech library to fine-tune and adjust the list of keywords. Following the formulation and streamlining of keyword search terms, an extensive search was conducted across a range of academic EBSCOhost databases including ERIC, Education Research Complete, PsychINFO, and Computers & Applied Sciences Complete as well as JSTOR databases including Education, Psychology, and Computer Science.

The Boolean operators AND, OR, and NOT were used to expand or limit the search results (Toronto & Remington, 2020). For example, Problem based learning OR Pbl OR Problem based teaching OR Problem based education "problem based" OR "problem-based"; AND (Elementary OR Grade 1 OR Grade 2 OR Grade 3 OR Grade 4 OR Grade 5 OR Grade 6 OR Grade 7 OR Grade OR Grade 9 OR Kindergarten OR Middle* school OR Secondary School* OR Senior High*). The use of "problem-based learning" and other key terms (Table 5) guided a thorough examination of existing literature reviews (Bittencourt et al., 2016; dos Santos et al., 2018).

Table 5

Keyword Search Terms with Boolean

Topic	**Search Term Set Up for Boolean Searches**
Problem-based learning	(Problem-based learning OR Pbl OR Problem based teaching OR Problem based education "problem based" OR "problem-based")
Adaption	Implementation OR implement OR implementing
Strategies	strategies OR methods OR models OR techniques OR interventions OR best practices OR pedagogical approaches OR instructional methods
K-12	Elementary OR Grade 1 OR Grade 2 OR Grade 3 OR Grade 4 Or Grade 5 OR Grade 6 OR Grade 7 OR Grade * OR Grade 9 OR Grade 10 OR Grade 11 OR Grade 12 OR High School OR Kindergarten OR Middle school* OR Secondary School OR Senior High

The search combination (see Table 5) from the databases resulted in a wide range of literature to review. Limiting the search results to peer-reviewed empirical studies and publications in English from 2004 to 2024 narrowed them down to 1,408 results. The results from the databases were then uploaded to Zotero (citation manager) to track references and curate the search results. They were then uploaded to Covidence (a web-based software tool for managing and streamlining systematic reviews) for screening to eliminate duplicates and irrelevant data.

Following the search of the computerized databases, an "ancestry approach" (Cooper, 1986, p. 41) was applied. Utilizing the ancestry approach, the references cited in the collected studies were used to identify additional articles. This study employed Google Scholar for citation tracking (Mongeon & Paul-Hus, 2016) to access publications that are relevant to PBL implementation strategies and teachers' experiences within K-12 educational settings. A total of 6 articles were found in connection with PBL implementation strategies between 2004 and 2024 which were also uploaded to Zotero and further to Covidence.

To enhance the review of search reports, Moher et al. (2009) have outlined steps in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Appendix A). Data selection was conducted through the PRISMA process (Appendix A) using the Covidence data screening tool. This consisted of multiple levels of screening based on inclusion and exclusion criteria (Table 7). The results of this process are shown in Tables 7 and 8. Methods of inclusion and exclusion criteria were also adopted for this screening. Inclusion criteria are characteristics that literature must have to be included in the review (Cooper, 1998; Whittemore & Knafl, 2005). Exclusion criteria are the characteristics that would make a study ineligible to be included in the review (Cooper, 1998; Whittemore & Knafl, 2005). Because integrative reviews address broad questions, they usually retrieve a large body of literature (Toronto, 2020). The PRISMA approach, aided by Covidence, provided a way to manage the large amount of literature from the various databases, and helped to identify the most relevant papers for the review. According to Moher et al. (2009), the purpose of the PRISMA is to ensure quality and rigor as well as to enhance the reporting of systematic reviews and meta-analyses.

This study was limited to relevant peer-reviewed empirical studies published in the English language in the last 20 years (2004 – 2024). The past 20 years in the United States has witnessed an era of major government legislation on education, with the enactment of the No Child Left Behind (NCLB) Act in 2002 (U. S. Department of Education, 2001). While NCLB sought to ensure accountability and proficiency in core academic subjects, its implementation significantly impacted teaching methodologies, particularly those centered on problem-solving approaches such as PBL (Freer-Alvarez, 2016). "Most K-12 teachers in the United States feel pressure to cover academic standards and to prepare their students for standardized tests (Ertmer, et al., 2009, p. 39). Thus, this study presented the opportunity to observe any related patterns. The examination of article titles and abstracts from potentially relevant papers followed specific inclusion criteria outlined in a checklist (Table 6). To answer the research questions, the search results were limited to only relevant empirical studies (Martin et al., 2014; Pentland et al., 2011). Table 7 presents an overview of the systematic process, its rationale, and the results generated from Covidence. The list of the articles that were ultimately selected for the data set can be found in Appendix C.

Table 6

Basic Filtering Information for Data Set

Criteria
Empirical Study
Study published between 2004 and 2024
Study published in the English language
Study published in a peer-reviewed journal
Study focused on Problem-based learning (PBL)
Study focused on K-12 teachers' implementation of PBL
Study concentration is on K-12 education

Study focused on the intersection of PBL, implementation/strategies and K-12 educational environment

Note: The decision to keep an article at this phase was dependent on a response of "yes" to the inclusion criteria above. All data focusing on similar teaching strategies like project-based learning, case-based learning, etc. in K-12 educational settings were excluded.

Table 2

Summary, Selection Actions, Articles for Data Set

Quantities	Reason for Inclusion / Exclusion
1,408 articles were identified through database searches as potentially relevant; references were uploaded into citation manager (Zotero) and further uploaded to Covidence	
476 references were identified as possibly relevant via examination of article title	
98 duplications identified and removed by Covidence	
378 studies screened against title and abstract	
195 studies excluded	
183 studies assessed for full-text eligibility	
152 studies excluded	
61 Study did not focus on PBL implementation	
26 Study is not empirical	
19 Study focus was not the intersection of PBL implementation and K-12 education	
18 Study focus was not K-12 teachers' implementation of PBL	
15 Study not peer-reviewed article	
13 Study concentration was not on K-12 education	
6 studies added during ancestry review / full-text analysis	
37 studies included in the final data set	

Stage 3: Data Evaluation

Published studies can present different degrees of quality. The inclusion of substandard studies in the review may distort the analysis, while excluding such studies may generate bias within the analysis (Evans, 2007). The significance of each piece of literature to the research questions guides which documents are included or excluded. The purpose of being guided by the research questions is to avoid any digression that may occur (Toronto, 2020). It is important to note that there are different approaches to ensuring the quality of a study (Toronto, 2020).

Researchers should always strive to critically appraise all documents used in an integrative study (Katrak et al., 2004).

Cooper (1998) suggests that the selection of initial codes when conducting an integrative review eases the process and improves the quality of the study. It is important that relevant data be extracted from the data set identified in Stage 2, and that the data be stored in a table to allow for the visualization of themes, patterns, connections, and relationships (Whittemore & Knafl, 2005). The selected data sets were examined to identify variable structures and themes as they had been used by researchers conducting empirical studies on PBL.

The three research questions guided the creation of three sets of tables using Covidence. The first research question looked at implementation strategies that aligned with Torp and Sage (1998, 2002), and considered the following variables for coding: prepare the learner (optional), meet the problem, iterative cycle of activities, generate possible solutions, determine the best fitting solution, present the solution (assessment), and debrief the problem. The second research question, which sought to investigate K-12 teachers' experiences/challenges was guided by variables adopted from the theoretical literature review. These included teachers' experiences with problem design and development, scaffolding, collaboration, assessment, technology integration, and time management among others. Extracting and coding data for the third research question was guided by the problem types as proposed by Jonassen (2010). These included logic problems, story problems, algorithm problems, rule-using/rule-induction problems, decision-making problems, troubleshooting problems, diagnosis-solution problems, strategic performance problems, policy-analysis problems, design problems, and dilemma problems.

Stage 4: Data Analysis

The purpose of the data analysis stage is to generate a "thorough" and "unbiased interpretation" of the primary sources, resulting in an updated knowledge base (Whittemore & Knafl, 2005, p. 550). Integrative literature reviews are focused on a deeper understanding of a specific subject by combining and synthesizing data from several sources (Whittemore & Knafl, 2005). Torraco (2016) stated that generating a new perspective on the topic of interest requires an integrative review to analyze and synthesize the incorporation of a large amount of existing data. These sources must be, "ordered, coded, categorized, and summarized into a unified and integrated conclusion about the research problem" (Whittemore & Knafl, 2005, p. 550, citing Cooper, 1998). The strategies to be used, "should be explicitly identified before undertaking the review" (p. 550). The constant comparison method converts information extracted from sources into, "systematic categories, facilitating the distinction of patterns, themes, variations, and relationships" (Whittemore & Knafl, 2005, p. 550). Cresswell and Poth (2018) describe this iterative process as a "data spiral" (p. 186), during which the researcher examines and revisits the source information to manage, organize, describe, classify codes, classify themes, develop, and assess interpretations of the information, represent and visualize the data, and finally, to create an account of the findings. Whittemore and Knafl, (2005) upheld the four steps suggested by Miles and Huberman (1994) when using the constant comparison method for data analysis: (1) data reduction, (2) data display, (3) data comparison, and (4) conclusion drawing and verification.

Data Reduction. Data reduction involves classifying data from selected primary studies into a reasonable format that allows for clarification, abstraction, concentration, and management. Whittemore and Knafl (2005) noted that data sources should be organized into "subgroups according to some logical system to facilitate analysis" (p. 550). This IR study organized the primary studies into different categories based on the problem identification and research questions. This phase of the research process leveraged the Covidence tool through screening to sample the relevant literature on PBL and K-12 teachers' implementation strategies. The details have been presented in Table 8 above. The result was the selection of n=37 articles for this study.

Data Display. This stage involves extracting, converting, and coding the classified data from their subgroups. In this study, the extracted codes in Covidence were later exported with a 'csv' file to an Excel document (Appendix E). The goal was to simplify, focus, and organize data into a "manageable framework" for further interpretation (Whittemore & Knafl, 2005, p. 550). It further enhanced the interpretation and visualization of the data in a way that reduced the cognitive load of viewing large amounts of information at the same time (Whittemore & Knafl, 2005). The study compiled the abstracted data into charts and tables for further data comparison and analysis.

Data Comparison. This phase includes identifying patterns, themes, or relationships among the displayed data (Toronto & Remington, 2020; Whittemore & Knafl, 2005). The extracted data were organized into matrices using specific variables identified after the data extraction and coding processes. This enabled the categorizations related to each of the research question: K-12 teacher implementation strategies, teachers' experiences and challenges in implementing PBL, and the types of problems incorporated when implementing PBL. Creating matrices to enhance the visualization of data improves "clarity to the empirical support emerging from early interpretive efforts (Whittemore & Knafl, 2005, p. 551).

Conclusion Drawing and Verification. This final step in the data analysis stage involves an iterative process of examining extracted data with the goal of identifying relationships, patterns, or themes across the data display (Whittemore & Knafl, 2005). The researcher used conceptual maps and tables to highlight existing relationships, clustering, and common and unusual patterns to “build a logical chain of evidence” (Whittemore & Knafl, 2005, p. 551). This included highlighting and color-coding the information in the initial graphical displays to enhance readability and understandability. This study arrived at conclusions based on an analysis of the data and reported on its findings.

Stage 5: Discuss and Present Findings

Toronto and Remington (2020) emphasize that “the discussion section is the heart of any scientific paper” (p. 72). Reviewers compare “the findings of the review with the background literature, and work of others” (Toronto & Remington, 2020, p. 8) in the form of a review report. This stage involves a critical examination of the patterns, themes, and relationships identified. Whittemore and Knafl (2005) noted that there were no limits to the methods by which conclusions from integrative reviews may be presented; they instead advocated for presenting findings in a comprehensive framework that, “captures the depth and breadth of the topic and contributes to a new understanding” (p. 552). This process is to facilitate how patterns and relationships identified in the previous stage may be conceptualized at a higher level “of abstraction, subsuming the particulars into the general” (Whittemore & Knafl, 2005, p. 551). Verification for accuracy must also be done to avoid potential biases. Each subgroup is analyzed, and the important observations and conclusions from each subgroup are summarized and integrated into a comprehensive portrayal of the information gathered. A record of all analyzed decisions, hunches, thoughts, and ideas that may be directly related to the interpretation of the data should be documented.

As part of the discussion and present findings phase, implications for practice and future research were also presented and emphasized. The goal is "a holistic understanding" (Whittemore & Knafl, 2005, p. 552) of the topic. Thus, a concise summary of major findings and key contributions was created and all conclusions, recommendations, and implications were supported using evidence generated during the previous stages of this IR. The methodological limitations identified for this study were also presented.

The conclusions of the IR, therefore, aim to inform the different stakeholders in education, including governments, institutions, faculty, and instructional designers, so that they may work together to support effective student-centered instructional strategies like PBL to prepare the workforce for the 21st century and beyond.

Chapter Four

Findings

This chapter presents the findings from the integrative review, describing the iterative comparisons across all studies examined in the data set. These findings were guided by the research questions for the study. The findings identified and categorized K-12 PBL instructional models and the types of problems that teachers adopt for implementation. The study highlights different experiences/challenges and concerns of K-12 teachers while adopting and implementing PBL.

This study proposes to respond to the following questions:

1. How have PBL implementation strategies/models in K-12 education been described in empirical literature?
2. How have K-12 teachers' experiences/challenges with PBL implementation been described in empirical literature?"
3. How do the types of problems used in PBL within K-12 settings in empirical literature align with Jonassen's (2010) types of problems?

The study results are presented in two sections. The initial section provides an analysis of the general characteristics of the studies included in the data set. It employs tables and figures to illustrate the categorical attributes of these studies, such as their distribution by year, methodological designs, geographical locations, and participant demographics. Such an overview facilitates a better contextual understanding of the studies selected for the IR.

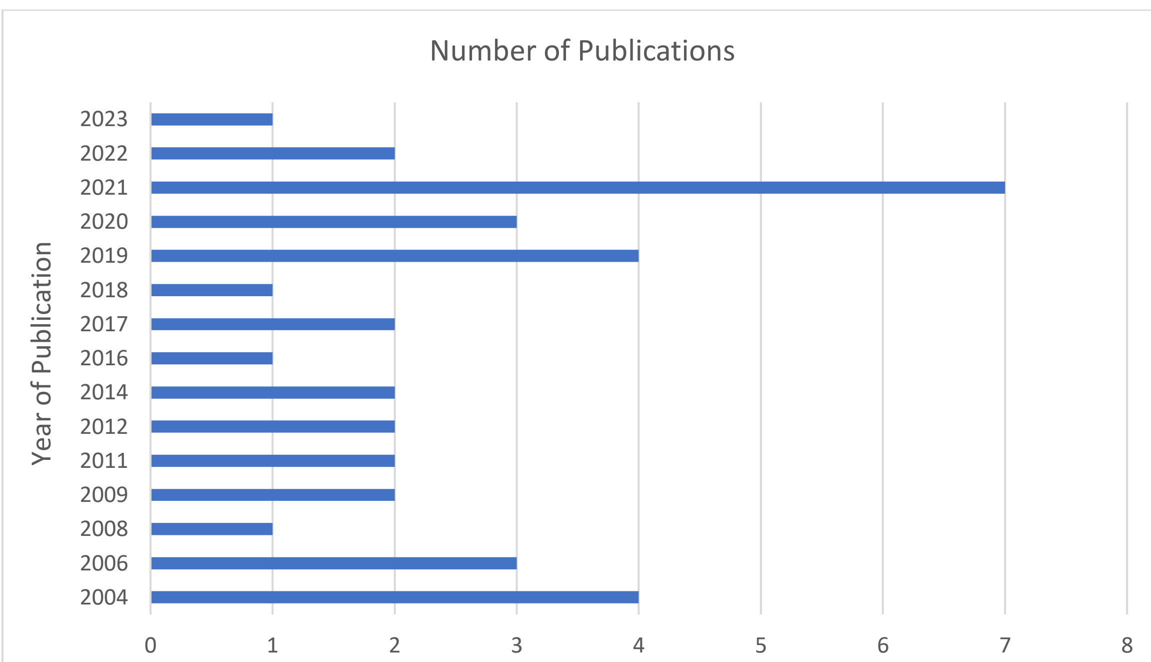
The second section delves into the findings that directly address the three research questions, providing a comprehensive understanding of the empirical literature on instructional strategies, types of problems, and teachers' experiences/challenges in adapting problem-based learning.

Characteristics of the Data Set

There were 37 empirical studies selected for the integrative literature review. These studies took place between the years 2004 to 2024. Figure 3 below provides a visual presentation of this distribution. There was a fluctuating trend in the number of articles published between 2004 and 2023, with some years having higher publication rates than others. There were several years with only one or two publications (e.g., 2008, 2023, etc.) indicating possible periods of lower research activity or other factors influencing publication rates. However, there was a noticeable increase in publications from 2019 onwards, with 2021 having the highest number of publications in this dataset. However, no publications were recorded for 2024 as of the end of March when data was collected.

Figure 3

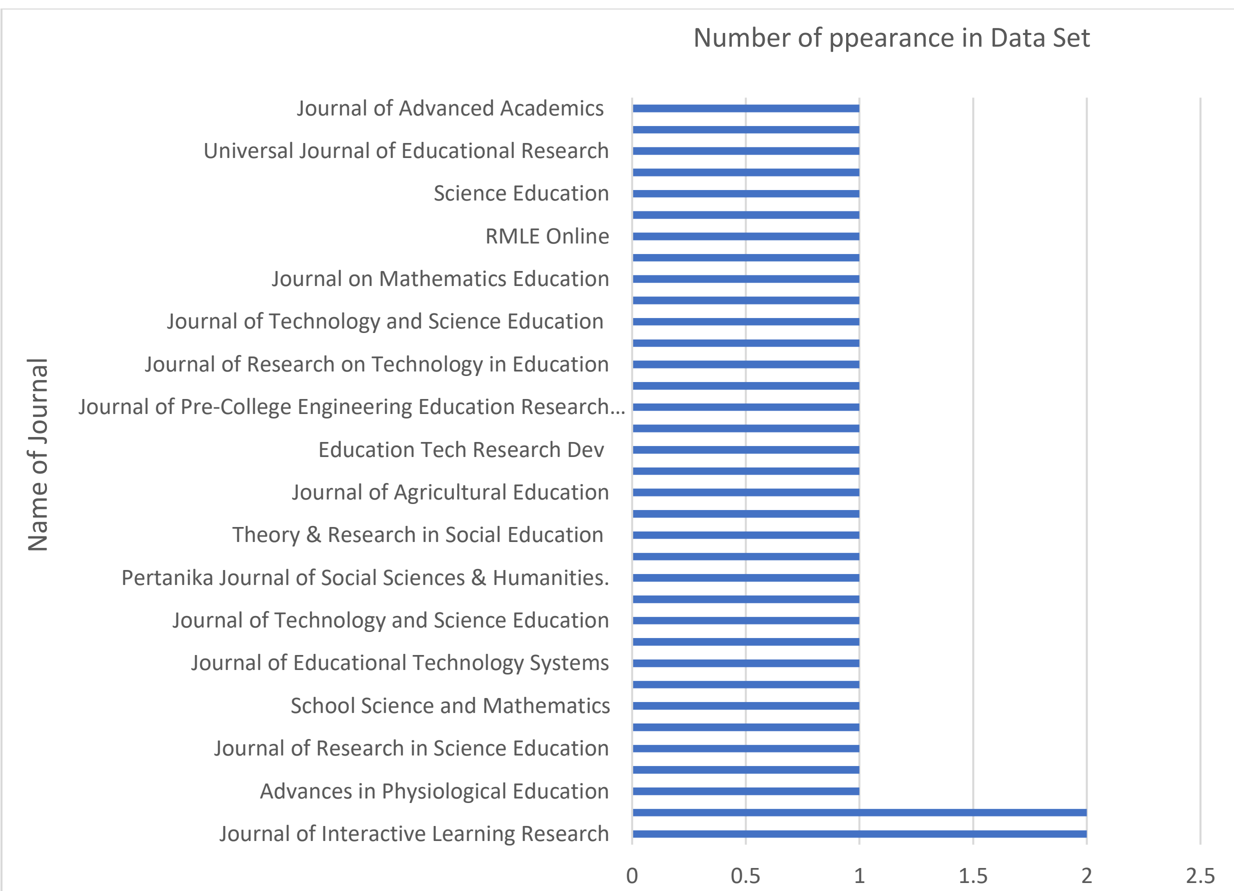
Number of Publications by Year in Data Set



The next analysis examined the journals where empirical articles identified for the data set were published (Figure 4). The distribution across journals was relatively diverse, with each journal having only one or two articles published. Journals like *The Journal of Interactive Learning Research* and *The Interdisciplinary Journal of Problem-Based Learning* published two articles each, making them the most represented in this dataset. The rest only published single articles, indicating a broad dissemination of research across various journals. There was a mix of general educational journals, STEM education-focused journals, and journals focusing on specific educational areas like mathematics education and engineering education. This analysis provides insight into the dissemination of PBL research in education across various journals.

Figure 4

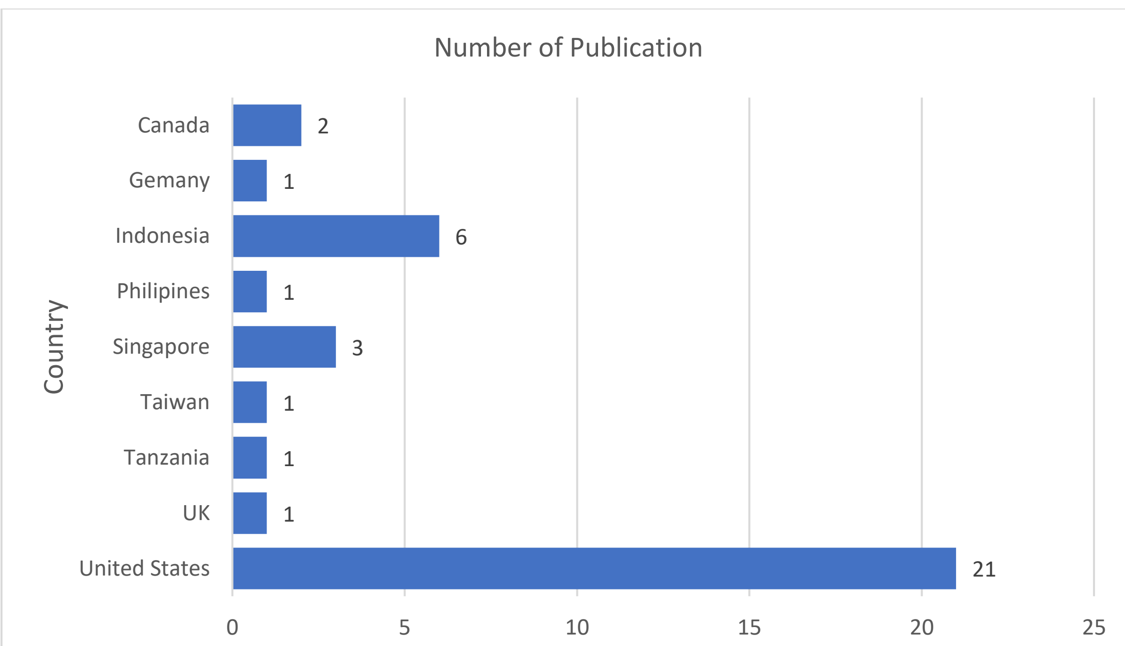
List of Journals in Which Studies Included in Data Set Appeared



Studies included in the review were conducted across different continents in about 10 countries (Figure 5). Most studies were conducted in the United States (21 out of 37), making up approximately 57% of the total studies. Other countries like Indonesia (6 studies), Canada (2 studies), and Singapore (3 studies) also showed notable research activities but to a lesser extent when compared to the US. Countries like Germany, the Philippines, Taiwan, Tanzania, and the UK published one study each. The study from Tanzania (Roy et al., 2014) was a collaboration of researchers from three Finland universities and one Tanzanian university. The spread of studies across different countries indicates a growing trend of PBL awareness and application in various geographical locations.

Figure 5

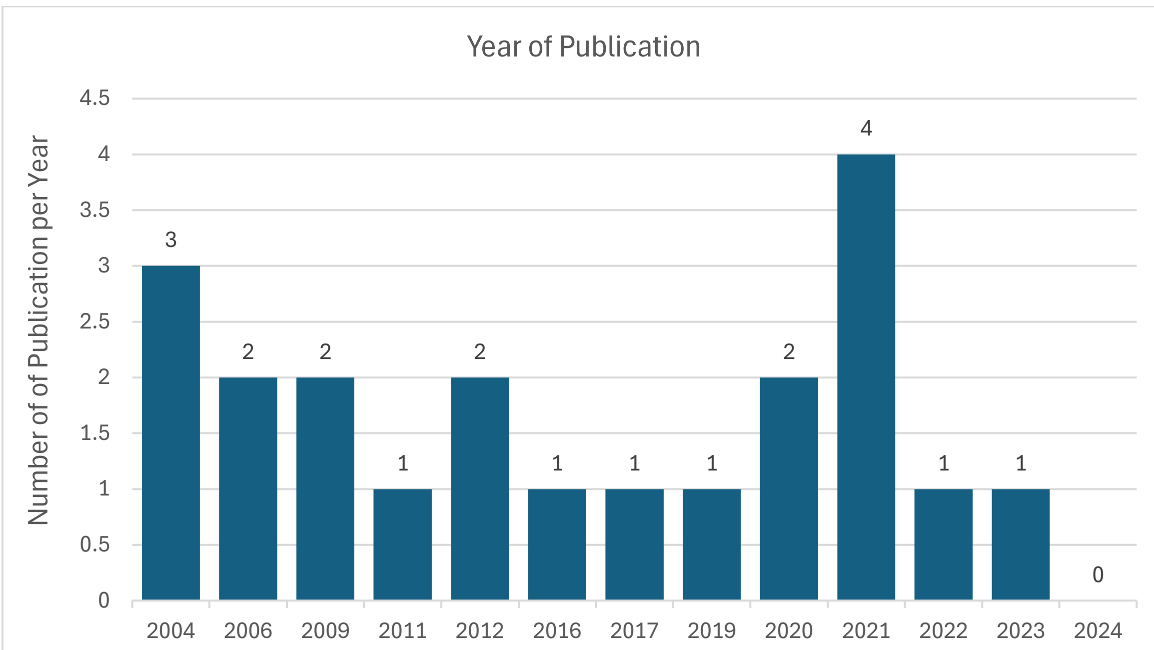
Study Counts Organized by Country of Publication



The data set analyzed from the US within the period 2004 to 2024 did not have any significant variations but rather an inconsistency in the number of publications per year (Figure 6). The highest number of publications in a single year was four, recorded in 2021. Several years, including 2005, 2007, 2008, 2010, 2013-2015, and 2018 showed no publications at all. Years with only one publication included 2011, 2016, 2017, 2019, 2022, and 2023. At the same time, 2006, 2009, 2012, and 2020 each had two publications. It can be observed that apart from 2018 and 2024, there was at least one publication from the US between 2016 and 2023. The data reflects an inconsistent pattern in the number of publications, with certain years demonstrating higher research activity and others showing minimal or no publications.

Figure 6

Number of Studies Published in the US Per Year

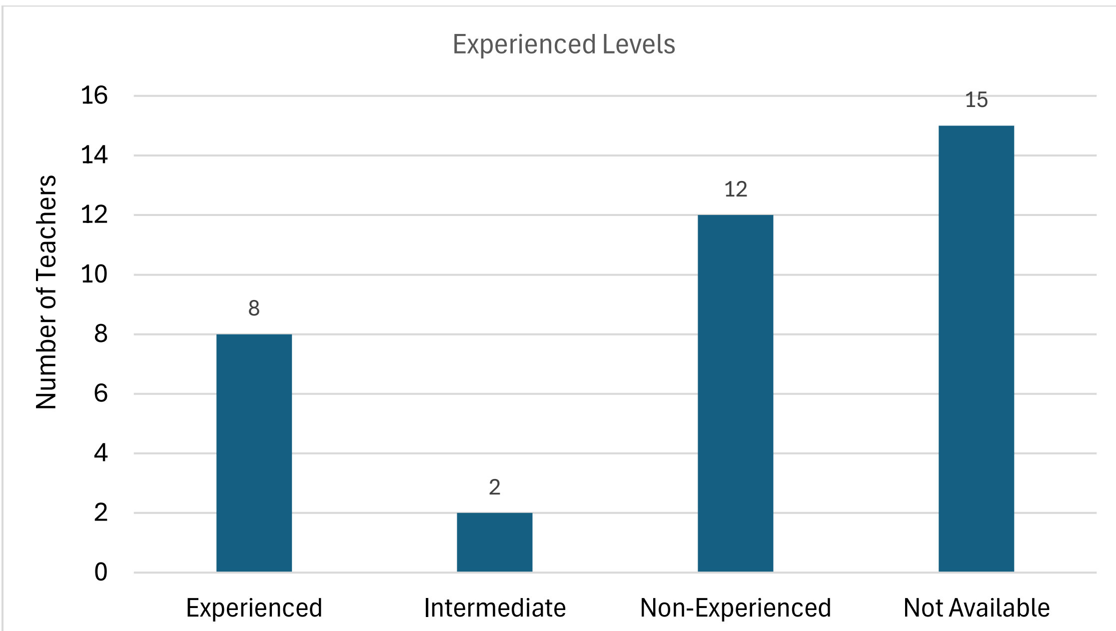


The subsequent analysis focused on assessing the level of teachers' skills and familiarity with Problem-Based Learning (PBL) prior to the study (Figure 7). Teachers were categorized into three groups based on their experience with PBL, with Experienced Teachers having used PBL more than twice, Intermediate Teachers having used PBL once, and Non-experienced Teachers using PBL for the first time. 'Not Available' was used where information about teachers' experience with PBL was not indicated. It was revealed that out of 37 teachers, 8

(21.6%) were experienced, having used PBL more than twice; 2 (5.4%) were intermediate, with one-time PBL experience; and 12 (32.4%) were non-experienced, using PBL for the first time. For 15 (40.5%) teachers, data regarding experience was not available. The data was collected by the end of March 2024, which may explain the absence of publications from the year 2024 in this review.

Figure 7

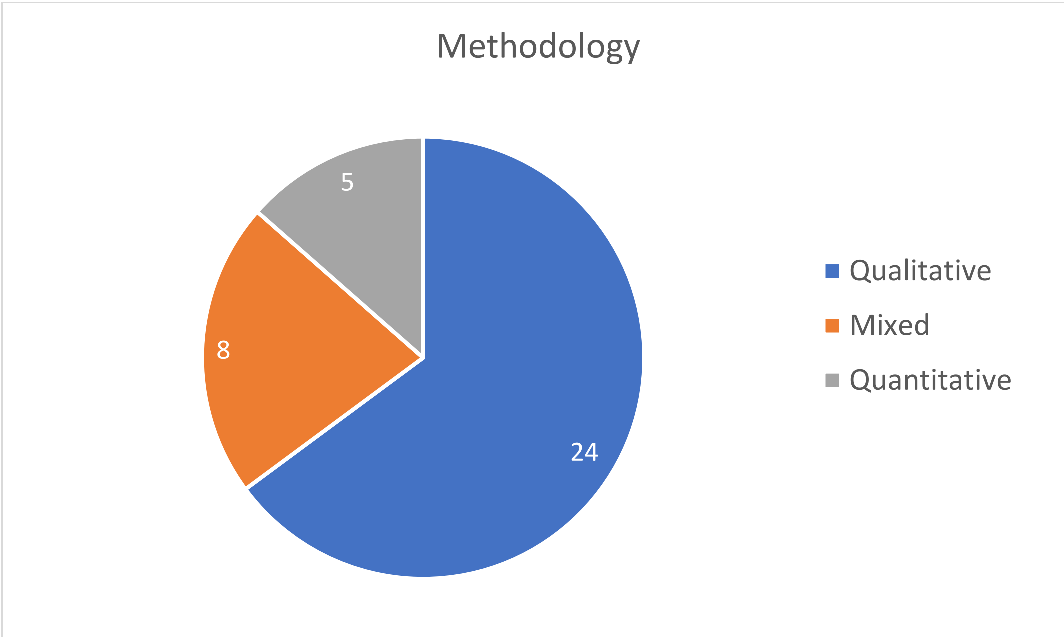
Distribution of Teachers' Experience with PBL



The next set of data was analyzed for the methodology used in the studies. The data set was divided into three methodology design categories based on how data was collected for the study. Studies were categorized as Qualitative, Quantitative, or Mixed Methodology, with 23 (62.2%) studies being Qualitative, 5 (13.5%) studies being Quantitative, and 8 (21.6%) studies being Mixed (Figure 8).

Figure 8

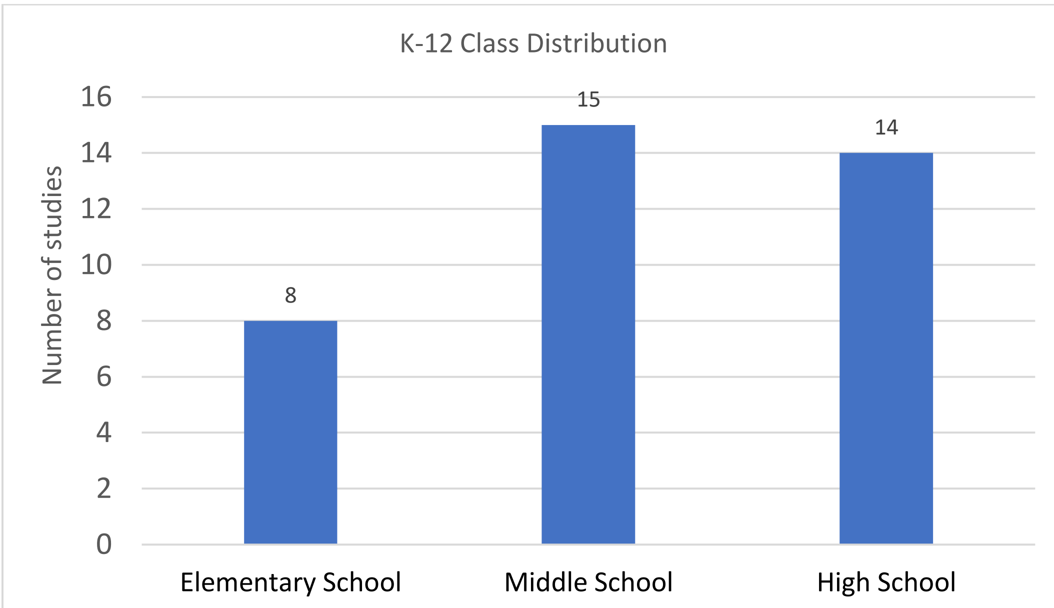
Distribution of Studies by Methodology



Finally, an analysis of the learners who participated in the studies was performed. These were all K-12 Teachers. K–12 is the terminology used in the United States, which generally refers to elementary and secondary school grades from kindergarten (age 5–6) through grade 12 (age 17–18). Data from other countries that use different terminologies, like lower primary and secondary school, were converted to fit this category. Middle school had the most common age range, representing 15 (40.5%) studies from the data set. Studies performed in high school settings also made up a significant proportion of 14 (37.8%) studies conducted. Elementary school ages had the least representation, with only 8 (21.6%) studies in the data set. Out of the 24 PBL studies performed in the US, only 2 (8.3%) (Ding, 2021; Nariman & Chrispeels, 2016) were carried out in elementary school settings. This highlights a lower focus on PBL implementation studies for elementary education in the US compared with middle and high school levels. Most of the middle school PBL studies (86.7%) were conducted in the US. The analysis of middle school studies reveals that 69.2% of these studies focused on 6th-grade students (Kwon et al., 2021; Liu et al., 2021; Pan & Liu,2022; Simons et al.,2004).

Figure 9

Distribution of Studies by Class Level



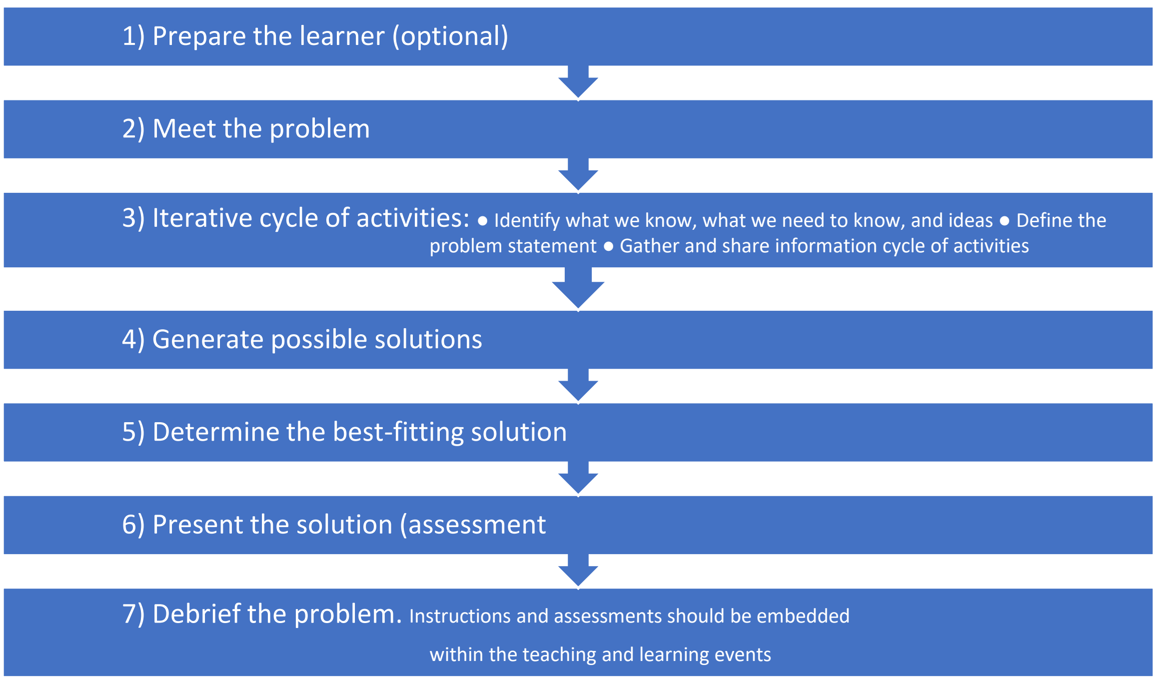
Findings for Research Question 1

Research question 1 stated, "*How have PBL instructional strategies/models in K-12 education been described in empirical literature?"* The purpose of this research question was to investigate the description of PBL instructional strategies and models in K-12 education as documented in the empirical literature. Specifically, it sought to investigate how the PBL instructional strategies used by K-12 teachers aligned with the PBL model for K-12 education proposed by Torp and Sage (1998, 2002), which is supported as a guiding framework by the US Center for Problem-Based Learning. Different studies have acknowledged the flexibility afforded to K-12 teachers in implementing PBL. Examining the extent of alignment or divergence offers valuable insights into the existence of alternative PBL models within K-12 education.

The subsequent paragraphs systematically present findings from approximately 95% (n=35) of the data set (n=37). These findings were organized and aligned to Torp and Sage's (1998, 2002) teaching and learning event; a PBL model for K-12 Education, as adopted by the Center for Problem-Based Learning, USA (Figure 10).

Figure 10

PBL Implementation Model by Torp and Sage (1998, 2002)



PBL Models/Strategies

This section sought to identify other existing PBL models or frameworks that teachers have used to implement PBL. All studies (n=37) involved in this analysis implemented PBL in one way or another. However, only 8 (Table 8), representing approximately 22%, mentioned some form of stages, steps, or models. The remaining 88% of the studies did not indicate the use of any particular model or framework. Of all the studies reporting some form of an outline for their implementation, only one study by Goodnough and Cashion (2006) specifically mentioned adopting Torp and Sage's (1998, 2002) PBL steps.

Table 8

PBL Strategy Alignment with Torp and Sage’s PBL Steps

Torp and Sage (1998, 2002)	Chin & Chia (2006)	Rice & Merrick (2023)	de Pinho et al., (2021)	Century et al., (2020)	Wirkala & Kuhn (2011)	Evendi & Verawati (2021)	Ertmer et al., (2009)	Goodnough & Cashion (2006)
(1) Prepare the Learner (Optional)	(1) identifying the problem to be investigated	(1) Present background knowledge on a topic	(1) Clarify not readily comprehensible terms and concepts	(1) Engage, and assess students' prior knowledge	(1) Problem-formulation and initial analysis	(1) Planning	(1) Planning	(1) Prepare the learner (optional)
(2) Meet the problem	(2) exploring the problem space	2) Provide students with a problem relating to the topic OR Students identify a problem within the subject	(2) Define the problem	(2) Explore, generate questions and new ideas	(2) Problem analysis	(2) Implementation	(2) Implementation	(2) Meet the problem
(3) Iterative cycle of activities	(3) carrying out the scientific inquiry	(3) Students examine the content and identify the parameters of the problem within their content knowledge under teacher supervision and facilitation	(3) Analyze the problem	(3) Explain, Teachers directly introduce new concepts	(3) Problem resolution	(3) Observation	(3) Assessment	(3) Iterative cycle of activities
(4) Generate possible solutions	(4) putting the information together	(4) Students explore and investigate the possible solutions using practical logic	(4) Draw a systematic inventory of the explanations inferred from Step 3	(4) Elaborate, Teachers challenge		4) Reflection as stages		(4) Generate possible solutions
(5) Determine the best-fitting solution	(5) presenting the findings, teacher evaluation, and self-reflection	(5) Students and teachers reflect and analyze the solutions in terms of the previously defined parameters	(5) Formulate learning objectives	(5) Evaluate, Teachers assess students				(5) Determine the best-fitting solution
(6) Present the solution (assessment)		(6) Students engage in a constructive debriefing relating the outcomes of the process to the original problem	(6) Collect additional information outside the group (SDL phase)					(6) Present the solution (assessment)
(7) Debrief the problem			(7) Synthesize and test the newly acquired information (Result presentation and final discussion)					(7) Debrief the problem

Another study that listed implementation steps was by Chin and Chia (2006). Although their steps share some characteristics with Torp and Sage's (1998, 2002), they also differ, especially in terms of structure and emphasis. For example, Torp and Sage (1998, 2002) present an initial optional step, *Prepare the learner*, which is a deliberate effort to set the stage for learning, especially for learners new to PBL. Chin and Chia's (2006) framework dives directly into "identifying the problem to be investigated," placing immediate emphasis on problem engagement. This translates to the second step of Torp and Sage (1998, 2002), and removes a preliminary preparation phase.

Both frameworks prioritize the understanding of the problem as an important step in the PBL process. However, Torp and Sage (1998, 2002) explicitly state an *iterative cycle of activities*. Chin and Chia, (2006) do not specifically mention this iteration, but suggest *exploring the problem space* and *carrying out the scientific inquiry* suggesting a more linear progression through the problem-solving process. Both approaches emphasize the necessity for students to present solutions to the problems. Towards the end of the PBL process, both present feedback, evaluation, and reflection, which Torp and Sage (1998, 2002) refer to as *debriefing the problem*.

The study by Rice and Merrick (2023) presented six steps (see Table 8) in implementing PBL. They began with the first step of *presenting background knowledge on a topic* which aligns with *prepare the learner*, by Torp and Sage (1998, 2002). Both steps equip students with the necessary context or readiness for the problem-solving process, although Torp and Sage make this step optional suggesting flexibility.

Following the initial setup, both models move into problem engagement. Torp and Sage's (1998, 2002) *meet the problem* is closely aligned with Rice and Merrick's (2023) approach, where the problem is either provided by the instructor or identified by the students themselves.

Again, Rice and Merrick (2023) emphasize students *exploring and investigating* and *students examining the content and identifying the parameters of the problem* under teacher supervision. This parallels Torp and Sage's (1998, 2002) *iterative cycle of activities*. Both stress an ongoing, active engagement with the problem, though Rice and Merrick (2023) specify a structured teachers' role in guiding this exploration. Torp and Sage (1998, 2002) conclude with *present the solution* and *debrief the problem* in separate stages. Rice and Merrick integrate these aspects into a 'constructive debriefing,' which relates the outcomes back to the original problem, stressing a synthesis of learning and practical application. The concluding steps in both models underscore reflection and consolidation of learning.

Another study that outlined PBL steps was by de Pinho et al., (2021), who specifically adopted the Maastricht seven-jump process, a well-defined method in medical education that emphasizes a systematic approach to problem-solving. This approach begins with *clarifying not readily comprehensible terms and concepts*, ensuring that all students start with a clear understanding of the necessary terminology and basic concepts. This aligns with a combination of Torp and Sage's (1998, 2002) optional step of preparing the learner and the 'meet the problem' step. However, de Pinho et al., (2021) make it a necessary first step.

The second, third, and fourth steps of de Pinho et al. involve defining the problem, analyzing the problem, and drawing a systematic inventory of explanations inferred from the analysis, which can be seen as an expanded version of Torp and Sage's (1998, 2002) iterative cycle of activities. The formulation of learning objectives by de Pinho et al., (2021) aligns with Torp and Sage's (1998, 2002) steps four and five where possible solutions are generated and the best-fitting solution is determined, but with a specific focus on targeting learning goals as a part of the solution process. A distinct emphasis by de Pinho et al., (2021) is on self-directed learning

(SDL), where students collect additional information outside the group and synthesize and test this newly acquired information. The concluding part of the Maastricht model adopted by de Pinho et al., (2021) emphasizes the synthesizing and testing of information and aligns with Torp and Sage’s (1998, 2002) determining the best-fitting solution and presenting the solution (assessment). What is distinct for Torp and Sage is the last step of debriefing the problem, where reflection is encouraged for learning consolation.

Century et al. (2020) also outlined a five-step process for implementing PBL in their study. Their *engage* step, which focuses on understanding students’ prior knowledge and orienting them toward the lesson goals, could overlap with Torp and Sage’s (1998, 2002) optional stage of preparing the learner to meet the problem. Both frameworks recognized the importance of orienting students for learning. While Torp and Sage continue with *meeting the problem*, Century et al. focus on *exploration to generate questions and ideas*, building a foundation for deeper inquiry.

The iterative cycle of activities in Torp and Sage’s (1998, 2002) model is contrasted by Century et al.’s (2020) *explain* step, where teachers introduce new concepts or skills and provide opportunities for students’ understanding, challenging students understanding and application of these concepts. Torp and Sage’s (1998, 2002) *generate possible solutions* and *determine the best-fitting solution* afford students the opportunity to refine their solutions. This could be compared to the *elaborate* step in Century et al., (2020) because both emphasize the application of knowledge to develop viable solutions to the problem. Both present a period for presentation and assessment. However, Torp and Sage (1998, 2002) further highlight the importance of debriefing as a way of consolidating learning, which is missing from Century et al., (2020).

The PBL implementation steps provided in the studies conducted by Wirkala and Kuhn (2011), Evendi and Verawati (2021), and Ertmer et al. (2009) however, were more generic than specific. This was quite different from the detailed step by step approach to PBL implementation. Wirkala and Kuhn (2011) outlined a three-step process that included *problem-formulation* and *initial analysis, problem analysis,* and *problem resolution*, which simplifies the PBL process. Similarly, Evendi and Verawati (2021) and Ertmer et al. (2009) followed a straightforward three-stage model consisting of *planning, implementation,* and either *observation* and *reflection or assessment*, respectively. While Torp and Sage (1998, 2002) presented a more segmented and detailed approach to PBL, emphasizing iterative activities and other distinct stages, Wirkala and Kuhn (2011), Evendi and Verawati (2021), and Ertmer et al. (2009) outlined simplistic and generalized steps.

These differences may have resulted from the primary purpose and the research questions they used when implementing PBL. It may not have been necessary to present a step-by-step process or stages depending on the study design. This could also be the situation for studies that did not record any specific PBL outline. For example, the study by Ertmer et al. (2009), had the following research questions: 1. *How do teachers characterize the challenges of technology-enhanced PBL? What strategies have they used to address these challenges?* 2. *Why do teachers persist despite the challenges associated with PBL? What rewards are associated with PBL?* (p. 40). The focus of this study was not intended to present a process for implementing PBL.

Although many studies did not present specific models or outlines for implementing PBL, they described their approaches and strategies in various ways and at different levels of detail. An analysis of these studies has revealed various themes and patterns, which are systematically organized in the paragraphs below. The findings are categorized into three broad stages with specific themes associated. These three are: (1) preparing learners for PBL, (2) iterative activities, and (3) presentation and evaluation. (Figure 11).

Figure 11

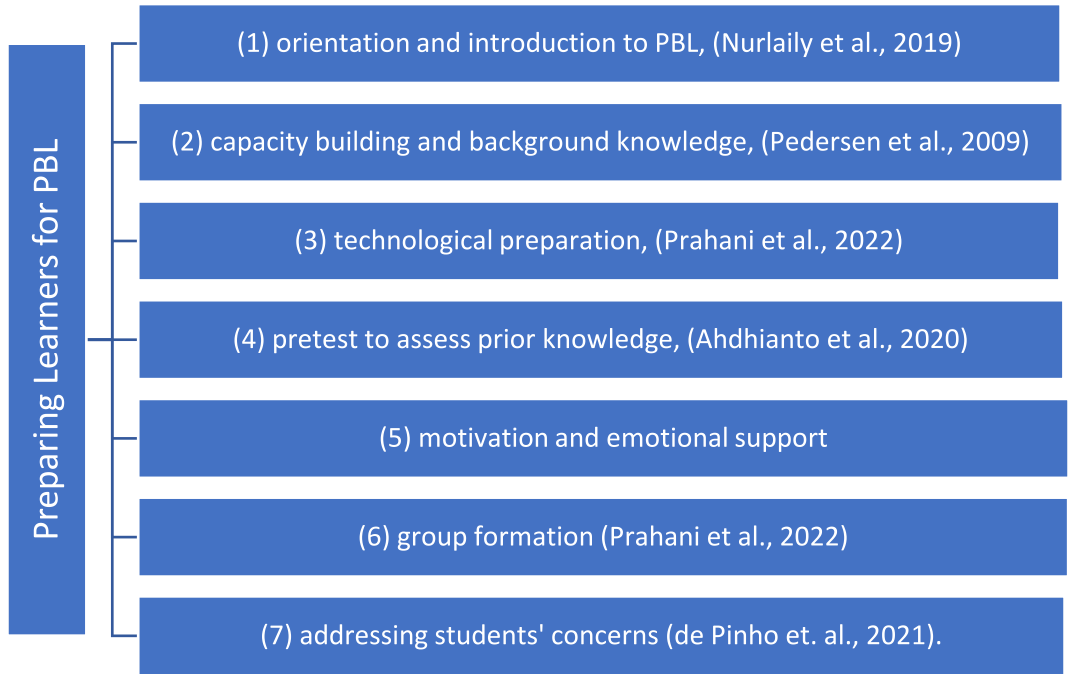
Categorization of PBL Strategies as Identified in the Data Set

Preparing Learners for PBL

This variable focuses on identifying evidence related to the activities or strategies employed by teachers that align with Torp and Sage's (1998, 2002) optional first stage, *prepare the learner*. Approximately 26% of the data set reported that teachers or researchers took extra efforts to prepare students before introducing them to the problem. These were mainly studies where students were experiencing PBL for the first time. The main themes that emerged from the analysis included: (1) orientation and introduction to PBL, (2) capacity building and background knowledge, (3) technological preparation, (4) pretest to assess prior knowledge, (5) motivation and emotional support, (6) group formation, and (7) addressing students' concerns.

Figure 12

Themes Emerging from Preparing Learners for PBL Implementation



Orientation and Introduction to PBL. In the studies where students experienced PBL for the first time, teachers and researchers took time to orient students to the PBL approach. This included explaining the project's aims and objectives and providing an overview of instructional topics and expectations (Chin & Chia, 2006; Nurlaily et al., 2019). The study by de Pinho et al. (2021) reported, "A precycle meeting was carried out on day 1, in which we explained what PBL is and how the activity would be carried out" (p. 751). Some studies also reported teachers using the period to group students and introduce students to materials and resources. (Pedersen et al., 2009; Simons & Klein, 2007; Simons et al., 2004; Valdez et al., 2019)

Pretest to Assess Student Prior Knowledge. Some studies used different means, including pre-tests, to assess student readiness for the problem at hand (Ahdhianto et al., 2020; Pedersen et al., 2009). Some teachers used pretests to identify the gaps they might have to fill before introducing the problem to avoid frustrating and discouraging students (Ding et al., 2021).

Capacity Building and Background Knowledge. Some studies prepared students by providing capacity-building and background knowledge before engaging in the problem. This preparation involved teaching basic concepts, providing extra lessons (including how to conduct research), and ensuring that students had the necessary foundational knowledge for the topic (Ertmer et al., 2009; Liu et al., 2012; Pedersen et al., 2009; Rice & Merrick, 2023;). One study reported, "We give the students a lot of background support. We just don't throw them out there and say, 'Just go and do it...'" (Ertmer et al., 2009, p. 44). Some studies found that preparing students this way eased their anxiety *with a new instructional strategy* (Goodnough & Cashion, 2006).

Technology Preparation. Another important preparation step was ensuring students' familiarity with the technological tools and platforms used in PBL. In studies where technology was used, teachers and researchers used the preparation stage to prepare students accordingly (Prahani et al., 2022; Simons et al., 2004; Simons & Klein, 2007). The study by Prahani et al. (2022) reported that students were given tutorials on how to operate the technology and navigate the software interface for the lesson.

Group Formation. For the purpose of collaboration, group formation is an integral feature of the PBL process. The findings from the data analysis revealed that teachers used different methods to organize and group students for the different learning interventions (Pedersen et al., 2009; Prahani et al., 2022). The findings revealed that groups were formed with an average number of 4-5 students (Chin & Chia, 2006, 2008; Ihsen et al., 2011). The study by Roy et al. (2014) had the highest number per group (9-11 students), while the study by Kwon et al. (2021) had the smallest number per group (2-3 students). Some studies reported that teachers randomly organized and grouped students (Ahdhianto et al., 2020; Saye & Brush, 2004).

However, in other studies teachers selected and grouped students based on their gender (Roy et al., 2014). Some studies also formed groups based on students' interests, abilities, and other characteristics (Buck et al., 2012; Ertmer et al., 2009; Kwon et al., 2021; Wirkala & Kuhn, 2011). The findings about group formation revealed that well-selected groups not only enhanced problem-solving and communication skills (Goodnough & Cashion, 2006; Nariman et al., 2016; Nurlaily et al., 2019) but also supported the diverse needs of all students, including those requiring special education (Liu et al., 2021).

Addressing Students’ Concerns. Critical at this stage was the teacher’s ability to listen and clarify students' questions about the problem. Some common queries pertained to the mode of assessment, technology usage, and unfamiliar terms within the problem (de Pinho et. al., 2021).

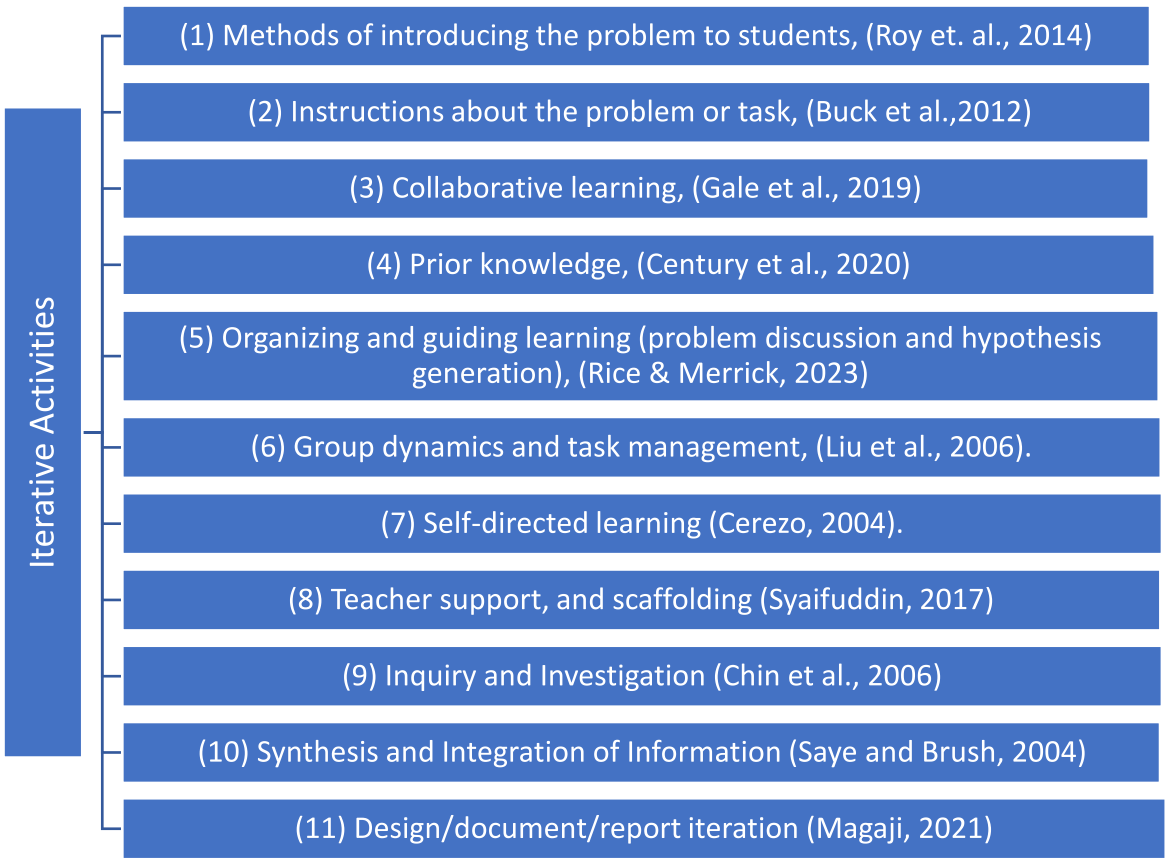
Iterative Activities

This variable sought to investigate the data for PBL strategies involving a continuous process of defining, designing, testing, evaluating, and refining information with the aim of arriving at a solution to the problem. These were parallel to Torp and Sage’s (1998, 2002) second, third, fourth, and fifth steps (see Table 10). Iterative activities foster a hands-on, experiential learning environment where research, trial, and error become valuable components of the learning process. The themes that emerged from analyzing the data set included: (1) methods of introducing the problem to students, (2) instructions about the problem or task, (4) collaborative learning, (5) prior knowledge, (6) organizing and guiding learning (problem discussion and hypothesis generation), (7) group dynamics and task management, (8) Self-directed learning, (6) teacher support and scaffolding, (9) Inquiry and Investigation, (10) Synthesis and Integration of Information, and (11) design/document/report iteration, (Figure 13).

It must be noted that students' collaboration and teachers' scaffolding skills are the underlying themes that support these processes.

Figure 13

Emerging Themes from Iterative Activities Within PBL Implementation



Methods of Introducing the Problem to Students. Teachers used different methods to present the problem to students. In some studies, teachers introduced the problem using multimedia tools. For example, the study by Roy et. al. (2014) reported, "The first step in the study was for the students to watch the three videos" (p. 78). Alternatively, some teachers distributed scripts on paper containing the problem (Chin & Chia., 2008). Some teachers also had the whole problem in a computer file that students had to navigate using the software interface. The study by Simons and Klein (2007) reported, "On the first day, the teacher introduced the project and the central problem to the students by giving a brief overview of the interface" (p. 63). Approximately 33% of studies analyzed mentioned teachers introducing the problem without providing much detail.

Instructions About the Problem or Task. Another theme that emerged across different studies at this stage was the accompanying instructions (either verbal or written) that teachers gave about the problem (Buck et al., 2012; Prahani et al., 2022). In some instances, teachers included a background presentation to contextualize the problem (Ihsen et al., 2011; Mustafa et al., 2019). Teachers' instructions also included where to find study materials and how to use them (Wirkala & Kuhn, 2011).

Collaborative Learning. Collaborative learning is a core component of the PBL process, where students work together to solve complex problems. About 93% of the studies included in the data set highlighted students' collaborative learning efforts from the beginning of the problem to the presentation of their solution. These studies demonstrated different ways that students collaborated towards resolving the problem (Gale et al., 2019; Magaji, 2021; Mustafa et al., 2019; Yeo & Tan, 2014). For instance, a study by Ihsen et al. (2011) described how students manipulated systems to build robots. Similarly, the study by Saye and Brush (2004) reported that students collaborated to gather information on different aspects of their tasks through to the final presentation. The studies by Yeo et al. (2014) illustrated how students collaborated, analyzed evidence, generated hypotheses, and tested them empirically demonstrating a structured approach to inquiry and investigation. Group members were the first to clarify individual questions before teachers' interventions through scaffolding.

Group Dynamics and Task Management. An analysis of the data also revealed that managing group dynamics and role assignments supported effective task management. One study reported that students were allowed to decide upon their tasks and problem-solving approach (Liu et al., 2006). Some studies reported that students selected leaders and scribes to ensure effective collaborative work. The study by Cerezo (2004) reported on the work of the scribe stating that, “They are not to filter or edit these comments recorded" (p. 5).

Self-Directed Learning. As much as PBL promotes collaboration, it also emphasizes self-directed learning, where each student takes responsibility for their learning by setting goals, finding resources, and evaluating their relevance to the task at hand. As part of research and information gathering, it was revealed that students would break from the groups for research before they gathered again to share their findings (Buck et al., 2012; Pan & Liu, 2022; Simons et al., 2004). One study by Cerezo (2004) indicated that group members divided the problem into segments, assigning each student specific tasks to complete at home. Subsequently, students were expected to report their findings and participate in discussions during the next class session (Cerezo, 2004).

Organizing and Guiding Learning (Problem Discussion and Hypothesis Generation). Another important finding at this stage was students' ability to organize and plan their learning in ways that were in alignment with the curriculum goals (Evendi & Verawati, 2021; Chin & Chia, 2008). Rice and Merrick (2023) reported that, “students examine the content and identify the parameters of the problem within their content knowledge …” (p. 98). This process typically involves brainstorming, discussion, and hypothesis formulation to effectively structure learning. In their study, Nurlaily et al. (2019) emphasized the significance of these activities in guiding both individual and group investigations, ensuring alignment with course objectives.

Prior Knowledge. The findings also revealed the role of prior knowledge in connecting what students knew and what they needed to know. Students’ prior knowledge provided a foundation for new information, aiding in problem-solving and deeper understanding. Different studies reported how prior knowledge supported students' brainstorming and discussions towards organizing and planning a solution for their problem. For instance, some reported that students used their prior knowledge to generate questions and new ideas, thereby building an understanding of current concepts (Ahdhianto et al., 2020; Century et al., 2020). The study conducted by Goodnough and Cashion (2006) described how teachers used scaffolding techniques to build on students' prior knowledge by asking guiding questions.

Teacher Support and Scaffolding. The role of the teacher at this stage in teaching and learning events in PBL cannot be overemphasized. Teachers support students' discussions and deliberations through scaffolding, as evidenced in various studies analyzed. Some studies reported on teachers' active soft scaffolding skills in guiding students to ask and research the right topics during their investigations (Anshori, 2021; Nurlaily et al., 2019; Syaifuddin, 2017). The study by Ertmer et al., (2009) reported on the importance of teachers providing greater structure and assistance to struggling students, motivating them, and ensuring that all students could succeed.

Inquiry and Investigation. An important element of the PBL process is the scientific inquiry undertaken by learners to gather information essential for problem-solving. The analyzed studies indicated that some students prepared outlines and formulated hypotheses from their initial discussions and brainstorming, which served as a guide to investigate the problem (Chin & Chia, 2006; Rice & Merrick, 2023; Saye & Brush, 2004). Students accessed various resources, including textbooks and the Internet, to conduct their research (Anshori, 2021). This process varied across studies; in some instances, all group members followed a common outline, while in others each student researched different sections of outlined items (Cerezo, 2004a).

Synthesis and Information Integration. An integral part of the learning process in PBL is the sharing and integration of information among learners (Chin & Chia, 2006, 2008; Ding et al., 2021; de Pinho et al., 2021). Saye and Brush (2004) described how students discussed in order to find the best possible solutions. In another study, the researcher reported that students actively engaged each other to gather information from various book sources and discussed it in groups (Anshori, 2021). Additionally, Cerezo (2004) noted that students divided research tasks to complete at home, and subsequently shared their findings facilitating a collaborative learning environment. During this period, the role of the group's scribe was very important in recording everyone's contribution.

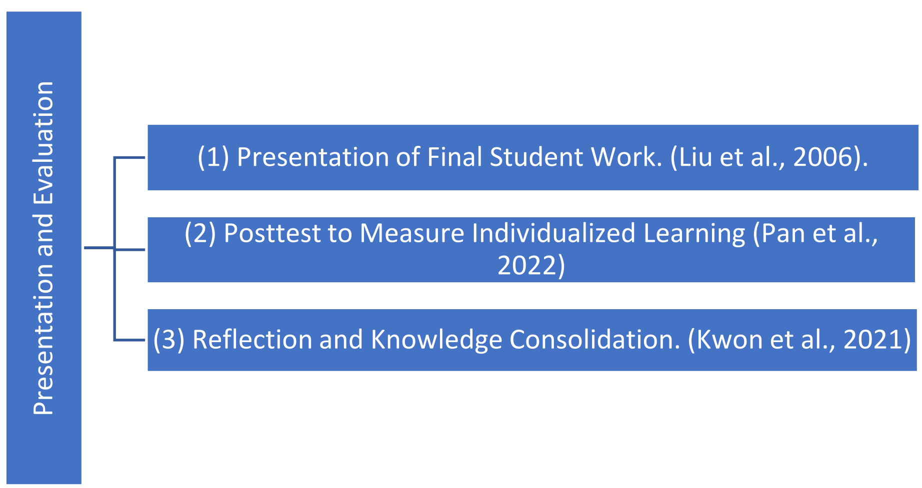
Design/Document Iteration. The analysis of the data set also revealed that students in PBL engaged in an iterative process of conducting research, repeatedly testing, and modifying their designs, and learning from each iteration to enhance their solutions (Liu et al., 2006; Magaji, 2021; Rice & Merrick, 2023; Wirkala & Kuhn, 2011). For instance, Gale et al. (2019) described a scenario where students initially tested a design using a rake/plastic wrap combination that proved unsuccessful. Undeterred, the students re-evaluated their approach, experimenting with a brake/rubber band combination. Despite further challenges, they iteratively refined their design by incorporating the rubber band's advantages. Students must repeatedly review their solutions in line with the curriculum goals for alignment (Century et al., 2020; Gale et al., 2019; Pedersen et al., 2009). Whenever students' solutions did not align with these goals, they were encouraged to make necessary alterations, reinforcing the importance of continuous improvement. For example, the study by Saye and Brush (2004) highlighted how students engaged in discussions to determine how their solutions aligned with the lesson objectives.

Presentation and Evaluation

This section of findings analyzed studies that reported on the sixth and seventh stages of Torp and Sage's (1998, 2002) PBL steps (see Table 10). This latter phase of the PBL process involves students presenting their solutions to the problem to be evaluated. Another important aspect of this phase involves teachers reflecting on the reports or final designs to ensure they align with the learning objectives for the topics. The analysis of the data set has revealed some key themes relevant to this stage, including: (1) Presentation of Final Student Work, (2) Posttest to Measure Individualized Learning, and (3) Reflection and Knowledge Consolidation.

Figure 14

Emerging Themes for Presentation and Evaluation of PBL



Presentation of Final Student Work. Several studies reported that students were required to present their work for evaluation, employing a range of formats to convey their findings. For instance, in about 14% (n=5) of studies analyzed, students worked on the 'Alien Rescue' problem and presented detailed reports on the different ways they would accommodate aliens in particular environments, justifying their decisions based on specific scientific principles. Some students also showcased artifact designs as tangible solutions to the problem, demonstrating their practical application of theoretical concepts (Liu et al., 2006). In some scenarios, students took turns presenting their papers, while in other cases one student presented on behalf of the group reflecting different approaches to collaborative presentations (Saye & Brush, 2004; Simons & Klein, 2007). Although various methods of presentation were used, such as verbal reports, artifacts, and group presentations, one study explicitly mentioned the use of PowerPoint for presenting solutions, highlighting the integration of technology in student presentations (Prahani et al., 2022). This diversity of formats reinforces the use of different PBL presentation methods noted in both theoretical and empirical literature.

Posttest to Measure Individualized Learning. Torp and Sage (1998, 2002) suggested that assessment in PBL should be embedded throughout the process to ensure a comprehensive evaluation of students' abilities. However, findings from approximately 17% (n=6) of the studies revealed that some teachers were not convinced of their students' ability to perform well on standardized tests. To address these concerns, some teachers conducted post-tests to confirm whether students attained the curriculum goals (Pan et al., 2022; Pedersen et al., 2009; Saye & Brush, 2004). Teachers reported positive outcomes from these post-tests, indicating that students were indeed learning effectively. This practice helps to align PBL assessments with familiar standardized testing formats, providing reassurance to both teachers and students about the validity of PBL as an effective instructional strategy (Horak & Galluzzo, 2017; Kwon et al., 2021; Magaji, 2021; Syaifuddin & Mohammed, 2017). Another reason why some teachers used post-tests was to address the challenges posed by group grading, thereby offering a more individualized assessment approach (Magaji, 2021).

Reflection and Knowledge Consolidation. Reflecting on the problem-solving process is an important step in the PBL process. Torp and Sage (1998, 2002) referred to this practice as debriefing. Helping students to reflect on their problem-solving skills enables them to critically assess their methods and align their solutions with learning objectives, fostering deeper understanding and consolidation (Liu et al., 2006; Magaji, 2021; Rice & Merrick, 2023; Roy et al., 2014; Wirkala & Kuhn, 2011). Approximately 49% (n=18) of the studies reported that teachers helped students reflect on their learning and aligned their solutions with the learning objectives. For instance, teachers often closed the PBL sessions with a review, allowing students to report their progress and reflect on their presentations (Simons et al., 2004; Simons & Klein, 2007). Teachers encouraged students to analyze and evaluate their problem-solving processes, assisting them in understanding how their thinking aligned with the objectives of the lesson (Ahdhianto et al., 2020; Nurlaily et al., 2019). Teachers also provided opportunities for students to ask questions about the process, fostering a deeper understanding and encouraging critical thinking (Valdez & Bungihan, 2019). Additionally, Century et al. (2020) reported that this period of reflection supported the transfer of knowledge to new contexts through understanding new concepts and guiding students in applying their newfound knowledge.

Summary of Research Question 1

This section investigated the alignment of PBL strategies used in the data set with the model proposed by Torp and Sage (1998, 2002). Through a comprehensive analysis, various themes emerged, which were subsequently categorized into three broad domains: Learners Preparation, Iterative Activities, and Presentation and Evaluation. Under each of these domains, specific themes were meticulously examined. The findings indicated that only one study explicitly utilized the Torp and Sage (1998, 2002) PBL model, while others employed different implementation stages and steps. However, activities in these studies could closely align with Torp and Sage's (1998, 2002) steps of PBL teaching events. Table 9 below provides a summary overview of the seven steps of teaching and learning events as outlined by Torp and Sage (1998, 2002), juxtaposed with the three categorizations and the corresponding themes that emerged from the data analysis.

Table 9

Categorization of PBL Implementation Strategies and Their Alignment to Torp and Sages' (1998, 2002) Steps

Torp & Sage (1998, 2002)	Categorization	Themes	References
1) Prepare the learner (optional)	Learners Preparation	(1) orientation and introduction to PBL, (2) capacity building and background knowledge, (3) technological preparation, (4) pretest to assess prior knowledge, (5) motivation and emotional support (6) group formation (7) addressing student's concerns	(de Pinho et al., 2021; Nurlaily et al., 2019) (Liu et al., 2012; Pedersen et al., 2009;) (Prahani et al., 2022; Simons et al., 2004) (Ahdhianto et al., 2020; Pedersen et al., 2009) (Goodnough & Cashion, 2006) (Prahani et al., 2022) (de Pinho et al., 2021)
2) Meet the problem 3) Iterative cycle of activities: ● Identify what we know, what we need to know, and ideas ● Define the problem statement ● Gather and share information 4) Generate possible solutions 5) Determine the best-fitting solution	Iterative Activities	(1) methods of introducing the problem to students, (2) instructions about the problem or task, (3) collaborative learning, (Gale et al., 2019) (4) prior knowledge, (Century et al., 2020) (5) organizing and guiding learning (problem discussion and hypothesis generation), (6) group dynamics and task management, (7) Self-directed learning (8) teacher support, and scaffolding (9) Inquiry and Investigation (10) Synthesis and Integration of Information (11) design/document/report iteration	(Roy et al., 2014; Simons & Klein, 2007) (Buck et al., 2012; Ihsen et al., 2011) (Gale et al., 2019; Magaji, 2021; Mustafa et al., 2019) (Ahdhianto et al., 2020; Century et al., 2020) (Rice & Merrick, 2023) (Liu et al., 2006). (Cerezo, 2004). (Syaifuddin, 2017) (Chin et al., 2006) (Saye and Brush, 2004) (Magaji, 2021)
6) Present the solution (assessment) 7) Debrief the problem.	Presentation and Evaluation	(1) Presentation of Final Student Work. (2) Posttest to Measure Individualized Learning (3) Reflection and Knowledge Consolidation.	(Liu et al., 2006). (Pan et al., 2022) (Kwon et al., 2021)

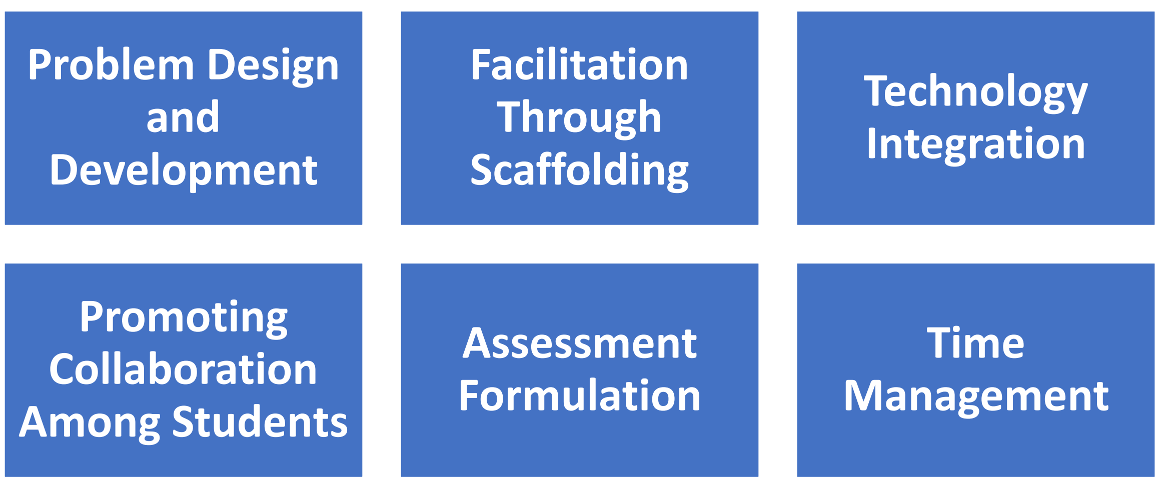
Findings for Research Question 2

The second research question stated, **"***How have K-12 teachers' experiences/challenges with PBL implementation been described in empirical literature?"* This research question aimed to collect empirical data detailing teachers' experiences, with a particular focus on the challenges encountered during their implementation of Problem-Based Learning (PBL) in the K-12 setting. The variables used to gather information to answer this question were carefully selected from the reviewed literature for this study. These variables reflected teachers' experiences/challenges in diverse roles when planning, implementing, and evaluating PBL in a K-12 environment.

The study identified six broad areas reflecting teachers' experiences/challenges: (1) *problem design and development,* (2) *facilitation through scaffolding, (3) use of technology, (4) promoting collaboration among students, (5) assessment formulation, and (6) time management.*

Figure 15

Focus Areas of Teachers Experiences/Challenges in PBL Implementation



Problem Design and Development

This variable aimed to examine teachers' experiences and challenges in formulating problems for PBL. It also gathered information on teachers’ considerations and approaches to creating or selecting appropriate problems for their classes.

The analysis revealed that 57% (n=21) of studies reported several considerations and challenges/experiences of teachers in relation to formulating problems for problem-based learning (PBL) implementation (see Table 11). The general themes that emerged included: (1) the problem’s alignment with curriculum standards and learning, (2) problems relevant to students' situations and interests, (3) the availability of study materials (especially for artifact design), (4) strategies in settling on a problem (such as accessing preexisting problems, collaborating with experts and researchers, or creating the problem by following the 3C3R model), and (5) Time constraints in problem development.

Different studies reported that designing problems for PBL comes with significant responsibility for teachers. Teachers engaged in extensive planning and consideration including the problem’s alignment with curriculum standards and learning outcomes, problems relevant to students' situations and interests, and availability of study materials when completing tasks (Buck et al., 2012; Cerezo, 2004; Chin & Chia, 2008; Ding et al., 2021; Nurlaily et al., 2019; Rice & Merrick, 2023). Some teachers struggled with choosing a problem that aligned with the curriculum goals and learning outcomes (Goodnough & Cashion, 2006). Another challenge teachers encountered was the complexity involved in designing multidisciplinary problems, particularly in science education (Chin & Chia, 2006). Teachers noted that creating such problems requires appreciable background knowledge from other subject disciplines. This complexity is exacerbated for teachers who are implementing PBL for the first time. Teachers also reported difficulties in obtaining resources for students to work with in cases where product designs were involved. Teachers also perceived that the problem design process took more time than they would normally use for their lessons. One teacher's frustration is captured as, "What was I going to plan for? That probably is the most challenging, is figuring out: Are they going to go in this direction, … or this direction? And do I have materials to cover all of the above?" (Ertmer et al., 2009, p. 43).

Teachers employed a variety of approaches in selecting problems. Some teachers collaborated with experts and researchers to design the problems they implemented (Li & Stylianides 2018; Saye & Brush, 2004; Valdez et al., 2019). Many teachers, particularly those with intermediate or no prior experience with PBL, relied heavily on the few pre-existing problems for their studies (Chin & Chia, 2008; Liu et al.,2006; Nariman et al., 2016; Simons & Klein, 2007). The most widely used pre-existing problem in middle school studies in the US was 'Alien Rescue (AR).' 'AR' comes with readily adaptable teaching materials. Another study highlighted teachers' dependence on pre-existing problems in that, despite recognizing that the existing problem did not meet all the new curriculum requirements, they were reluctant to make any modifications to align it with the new standards. Only two studies (de Pinho et al., 2021; Magaji, 2021) reported teachers utilizing the 3C3R model (Hung, 2009) for designing tasks in PBL lessons. This revealed how challenging it was for teachers to independently create problems from the curriculum. Some teachers designed problems by first interviewing and assessing student interests (Buck et al., 2012). Some teachers were worried about students' reactions if asked to engage in more cognitive activities than they were used to.

Researchers made recommendations that could support teachers' design of PBL problems: (1) professional development for teachers, (2) interdisciplinary collaboration among teachers, (3) school support in providing necessary resources, and more importantly, (4) ongoing support from instructional designers and researchers. This would allow teachers to design more problems and develop models like the 3C3R to refine problem-design skills and ensure alignment with curriculum standards.

Facilitation Through Scaffolding

This variable focused on capturing teachers' experiences/challenges related to providing scaffolding during the PBL process. Scaffolding can be described as soft or hard. Hard scaffolding refers to pre-planned support structures provided by the teacher, such as templates or checklists, whereas soft scaffolding involves dynamic, adaptive assistance given in response to students' immediate needs during the learning process. Information was gathered on teachers' experiences, strategies, and methods for supporting student learning within K-12 PBL implementation settings. Approximately 60% (n=22) of the total data set recorded teachers' experiences/challenges with scaffolding in PBL implementation (see Appendix C). Among the themes that emerged were: (1) managing students' questions, (2) balancing guidance and autonomy in view of course objectives, (3) the physical and emotional demands of scaffolding, (4) role transition challenges, (5) extensive preparation requirements, (6) teacher scaffolding skills increase while student scaffolding needs decrease over time, and (7) resource availability issues.

Teachers consistently reported that the level of scaffolding they provided was heavily influenced by the nature of students' questioning. Aligning students' inquiries with the broader objectives of the course was found to be particularly challenging. Teachers expressed difficulty in responding to students' questions while at the same time aligning them to the objectives of the course (Chin & Chia, 2006; Wirkala & Kuhn, 2011). One teacher noted the constant challenge of redirecting students to the lesson's demands, "I always had to bring students back to the demands of the lesson" (Saye & Brush, 2004, p. 365). In some instances, teachers' efforts to keep students in line created a more restricted and structured PBL process (Evendi, & Verawati, 2021; Goodnough & Cashion, 2006; Pedersen et al., 2009; Simons et al., 2004).

Teachers hard scaffolding involved providing structured support through tools such as information sheets and planning forms (Chin & Chia, 2006; Ertmer et al., 2009; Liu et al., 2006; Pedersen et al., 2009). Teachers anticipated students' needs and requirements, presenting them with a file containing necessary information and planning. Instructions guiding students on where to find information and resources to complete tasks were also a significant part of hard scaffolding. Teachers formulated questions to guide students’ discussion (Cerezo, 2004; Li & Stylianides, 2018; Liu et al., 2006; Simons et al., 2004; Wirkala & Kuhn, 2011; Yeo et al., 2014). For example, questions like, "What facts are provided in the scenario? What questions do you have about the problem?" (Goodnough & Cashion, 2006, p. 286) were used to help students focus on learning objectives. Some teachers believed that providing sufficient hard scaffolding enabled them to allocate more time to assist struggling students, as many high-achieving students could independently progress with the support of hard scaffolding (Pan et al., 2022).

Soft scaffolding provided by teachers involved offering fluid, responsive support through the use of guiding questions and feedback. Teachers were sometimes challenged with what feedback to offer and what to withhold. One teacher commented, "I guess every year I sort of struggle with how much do I guide them? Do I push them into a certain way of thinking?" (Rice & Merrick, 2023, p. 104). One teacher commented, “I have this terrible tendency to direct the questions in a way that predicts the outcome” (Goodnough & Cashion, 2006, p. 288). However, many studies reported that students' scaffolding should be diminished over time as they become more adept and independent in their learning (Li & Stylianides, 2018; Pan et al., 2022; Simons & Klein, 2007). Another teacher observed, "It got to the point where the kids didn't need me as much" (Pan et al., 2022, p. 135).

Transitioning from a traditional teaching role to a facilitator of student-led inquiry posed significant challenges. Teachers found it difficult to relinquish control and allow students to explore independently. One teacher commented, “The hardest thing was: being able to let go . . . as a teacher and let the students explore because we're so used to having exactly what we want the students to know and understand” (Nariman et al., 2016). Another teacher remarked, “From what I understand … You’re not supposed to really tell them anything, but the teacher in me wants to mold them and direct them” (Pedersen et al., 2009, p. 241).

Teachers highlighted their struggles with more extensive preparation for PBL compared to traditional teaching methods. They reported having to read more to support students' questions effectively (Saye & Brush, 2004). Different studies also noted the continuous learning process for teachers, "I think every time I do [PBL], I learn how to do it" (Saye & Brush, 2004, p. 104).

Some studies revealed that teacher scaffolding techniques became a source of student motivation or frustration (Evendi & Verawati, 2021; Magaji, 2021). Also, the physical and emotional demands of scaffolding PBL were significant. Teachers were constantly on the move, monitoring students and providing support (Cerezo, 2004), which was physically demanding. One teacher expressed their frustration, “How was I going to find the information that these kids desperately needed out there … That was my biggest fear” (Ertmer et al., 2009, p. 46). Another method of soft scaffolding employed by teachers was 'peer scaffolding,' which encouraged students to seek assistance from their peers before approaching the teacher for support (Li & Stylianides, 2018; Liu et al., 2012; Magaji, 2021; Simons et al., 2004; Wirkala & Kuhn, 2011).

This approach provided some relief for teachers by reducing their immediate workload and allowing them to focus on other needs.

Technology Integration

This variable assessed teachers' experiences/challenges in integrating technology into the PBL framework. The information analyzed was from 24% (n=9) of the studies in the data set. These were the only studies that recorded teachers' experiences/challenges with using technology in the instructional process (see Table 11). The themes from the analysis were: (1) engagement and motivation, (2) providing instructional support, (3) technical and malfunction issues, (4) extra effort towards preparation.

The findings from these studies revealed that teachers had varied experiences integrating technology as part of the instructional process. Teachers generally reported positive experiences with the integration of technology while implementing PBL. They recognized the value of technology in engaging students and supporting their efforts using tools such as videos (Liu et al., 2012; Roy et al., 2014). Some teachers also expressed satisfaction with using technology to provide hard scaffolding, which supported their efforts by structuring tasks and providing guidance. In some studies, teachers remarked on feeling motivated by students' level of engagement and participation using technology in the instructional process (Buck et al., 2012; Nariman et al., 2016).

Despite teachers' positive experiences in some studies, other studies reported significant challenges when integrating technology with PBL. One of the main issues was the additional preparation required. Teachers needed to learn and master the technology before they could effectively use it in their lessons, adding to the demands of lesson preparation (Saye & Brush, 2004). As one teacher noted, "Make sure you know your technology... Know your stuff before you get into it because that just wastes time as far as I'm concerned" (Ertmer et al., 2009; p. 46).

Technical issues were also identified, disrupting the learning process. In the study by Ding et al. (2021), some students reported losing their iPads or missing applications which derailed the PBL activities during the first week of a course. In response, teachers had to reduce the number of devices per student and shift from a 1:1 to a 1:3 device-to-student ratio. Teachers acknowledged that preparing a problem based on technology requires extra care and attention to what might go wrong.

Assessment Formulation

The focus of the assessment variable was to analyze studies in the data set that reported on teachers' experiences/challenges with designing effective assessments to evaluate students' performance in PBL lessons (see Table 11). Approximately 35% (n=13) of the studies reported on teachers' experiences/challenges with PBL assessment. Both formative and summative assessments were adopted for different reasons. A general finding was that teachers did not find the formulation of assessments particularly challenging. However, concerns were noted regarding: (1) the fairness of group assessments, (2) post-tests as a necessity for effective evaluation, and (3) designing a rubric for formative assessment.

Some teachers were concerned about the fairness and accuracy of group assessments. One teacher expressed a common worry, "How will I know everyone does the same amount of work and is addressing the same learning outcomes?" (Goodnough & Cashion, 2006, p. 286). Additionally, some teachers felt that group assessments were unfair to students who contributed more significantly to the project. The findings indicated that many studies employed post-tests to ensure students' readiness for summative assessments, which were standardized across various locations (Horak & Galluzzo, 2017; Kwon et al., 2021; Magaji, 2021; Pan et al., 2022; Pedersen et al., 2009; Saye & Brush, 2004; Syaifuddin & Mohammed, 2017). These were factual recall and objective tests at the end of sessions (Saye & Brush, 2004). Teachers often resorted to post-tests for other reasons such as avoiding the complexities of group grading and selecting assessment strategies that were consistent with what students were familiar with across other disciplines (Liu et al., 2021)

Teachers utilized various formative assessment tools, usually by first designing rubrics, to evaluate specific areas of student performance. These areas included communication skills, critical thinking, note-taking, collaborative work, question formulation for further study, knowledge transfer, etc. (Gale et al., 2019; Liu et al., 2012; Pedersen et al., 2009; Rice & Merrick, 2023). One teacher highlighted the importance of planning assessments that observed students' cognitive processes calling it, “just good teaching” (Pedersen et al., 2009, p. 238).

Only one study reported teachers' views on peer and self-assessment. Generally, teachers did not favor these methods for evaluating the quality of students' work. (Pedersen et al., 2009). This may be due to students lacking the necessary judgment and experience to evaluate their peers or themselves accurately, potentially leading to biased or inaccurate assessments.

Some teachers employed assessments for compliance and motivation purposes (Pedersen et al., 2009). Some teachers also expressed the view that focusing on grading might undermine the quality of the PBL process. Some studies, however, abandoned assessment altogether, emphasizing students’ attention to the PBL process (Rice & Merrick, 2023).

Teachers were generally flexible, combining different assessment strategies at various times to suit their needs (Kwon et al., 2021; Saye & Brush, 2004). By exploring various assessment strategies, teachers aimed to balance the need for fair evaluations with fostering a detailed learning process.

Time Management

The IR conducted an analysis of multiple studies examining teachers' experiences and challenges related to time management during the implementation of (PBL). A recurring theme across these studies was the constraint of time faced by teachers at various stages. Key themes that emerged from the findings centered on: (1) *planning,* (2) *preparation, and* (3) *implementation*. The results had several implications for teachers: (1) an increased workload, (2) the omission of lesson components or skipping processes, and (3) a tendency for teachers to maintain teacher-centeredness. Teachers also reported frustration over the limited time available to both guide students through the complex problem-solving process and provide adequate feedback (Chin & Chia, 2006; Nurlaily et al., 2019). Different studies noted that the structured time frame common in traditional classrooms did not accommodate the exploratory work necessary in PBL (Ihsen et al., 2011).

The findings also revealed that some teachers were concerned about the significant amount of planning and preparation time needed for a PBL lesson (Magaji, 2021; Saye & Brush, 2004). This involves creating realistic and engaging problems, developing appropriate materials and assessment methods, planning hard scaffolding, and getting students settled in their groups among other things. One teacher remarked, "Making a good learning tool takes a long time" (Saye & Brus, 2004, p. 232).

Teachers also reported that the actual implementation of PBL in the classroom is time-intensive, often leading to stress and frustration. Teachers expressed that the structured time frame common in traditional classrooms did not accommodate the exploration necessary in PBL

(Ihsen et al., 2011). The study by Chin and Chia (2008) emphasized that the time taken to conduct PBL activities often exceeded the allocated periods, disrupting the overall course schedule. One teacher noted, "if we had two months I could let them be free-flowing and work at their own pace, but I feel like I've got to give them direction" (Pedersen et al., 2009, p. 241). Some teachers responded to pressures from time constraints by omitting essential lesson components or skipping some instructional activities to adhere to time schedules (Simons et al., 2004).

These extensive demands often lead to teachers feeling overburdened and stressed, which impacts their other responsibilities. A teacher who suddenly realized how much time had passed already remarked, "… I was in panic mode at that point …" (Gale et al., 2019, p. 25).

The general implications of teachers' experiences/challenges with Time could be summarized in the words of one teacher, "Well, I don't know if I have time for this" (Liu et al., 2021, p. 288). The analysis has shown that time constraints pose significant challenges for teachers implementing PBL, impacting planning, preparation, and implementation processes.

Promoting Collaboration Among Students

This variable analyzed 72% of studies within the data set that focused on teachers' experiences/challenges. The main themes that emerged from this analysis were: (1) extended time for group formation, (2) group size (criteria for selection and composition), (3) managing individual dominance and participation issues, and (4) strategies in promoting collaboration.

Group formation whether random or strategic, was reported to require significant time, impacting overall classroom management (Nurlaily et al., 2019; Rice & Merrick, 2023). Group sizes ranged from 2 to 12 students. However, out of the 10 studies that reported the number of students, groups of 4 to 6 students were the most common (Chin & Chia, 2006; Goodnough &

Cashion, 2006; Ihsen et al., 2011; Liu et al., 2012; Magaji, 2021; Simons & Klein, 2007; Valdez et al., 2019)

Group composition varied, with some teachers assigning groups randomly based on gender, ability, or common interests (Cerezo, 2004; Ertmer et al., 2009; Liu et al., 2012; Wirkala & Kuhn, 2011). Other studies reported teachers allowing students to form their own groups according to their interests (Buck et al., 2012; Kwon et al., 2021; Roy et al., 2014). It should be noted that many studies in this category were conducted with 9th to 12th grade students.

Another major concern for teachers centered around dominant students and disengaged groups. Some studies reported teachers' challenges with dominant students taking over tasks and less engaged students not participating effectively (Nariman et al., 2016; Liu et al., 2012; Pedersen et al., 2009). In some studies, teachers adopted strategies that limited such occurrences. For example, teachers assigned specific roles within groups with clear instructions about proceedings (Pan et al., 2022; Nariman et al., 2016). It was observed from the analyses that teachers who provided instructions (hard scaffolding) for their groups received comparatively fewer complaints and questions. While some teachers tried to support students' collaboration, some also expressed concerns about students' capacity for collaboration. A teacher remarked, "They have to collaborate on their own, but unfortunately, some of our kiddos just don't have that skill yet" (Liu et al., 2021, p. 287). Peer support enabled many questions to be answered at the group level, relieving teachers to support other aspects of the PBL process (Simons et al., 2004).

Regardless of these challenges, many teachers expressed satisfaction with their role in organizing and promoting collaboration among students, particularly when roles were assigned, and clear expectations were set (Liu et al., 2012; Magaji, 2021; Wirkala & Kuhn 2011). Teachers observed that assigning roles facilitated effective collaboration among students, reducing the frequency of teacher intervention. Consequently, many of the students' questions were resolved through peer interactions within the group (Liu et al., 2012; Magaji, 2021).

Summary of Research Question 2

The IR explored the multifaceted experiences of teachers implementing problem-based learning (PBL) in a K-12 environment, focusing on five critical variables: problem design and development, facilitation through scaffolding, use of technology, promoting collaboration among students, and time requirements. The analysis highlighted diverse findings across these variables, what makes PBL attractive to teachers, and what prevents others from signing on.

A central theme across almost all other variables was the significant time constraints faced by teachers throughout the PBL process. From the initial stages of planning and problem design to the final phases of development and evaluation, teachers consistently reported that the time required to effectively implement PBL was a major hurdle. However, teachers were generally optimistic about the opportunities that PBL offered despite the associated challenges.

Table 10

Examples of Comments That Express Teachers' Experiences/Challenges with PBL

Areas of Teacher Experience/Challenges	**Example**	**Author**
(1) Problem Design and Development	"Usually, the problem for learning is only taken from the book. It is due to the difficulty in determining the problems in problem-based learning that needs to pay attention to certain criteria."	(Nurlaily et al., 2019, p. 233)
	"I'll just stop and think about an easy way for them to experience the concept Or maybe not easy, but a simpler way."	(Rice & Merrick, 2023, p. 103)
(2) Facilitation through Scaffolding	"You're not supposed to really tell them anything, but the teacher in me wants to mold them and direct them."	(Pedersen et al., 2009, p. 241).

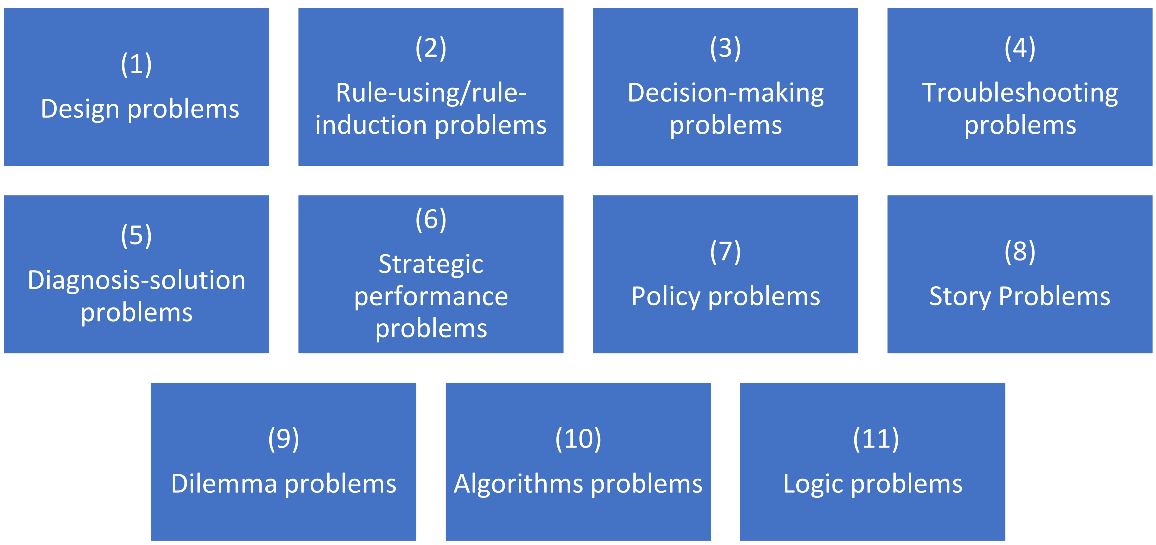
	"the hardest thing was: being able to let go . . . as a teacher and let the students explore because we're so used to having exactly what we want the students to know and understand."	(Ertmer et al., 2009, p. 46)
(3) Use of Technology	"Make sure you know your technology Know your stuff before you get into it because that just wastes time as far as concerned."	(Ertmer et al., 2009, p. 46)
	"This semester the expedition is on astronomy and origin stories. . . And the science portion is on astrobiology, basic force and motion and astronomy . . . So that's where the software issues came into play."	(Liu et al., 2012, p. 54)
(4) Promoting Collaboration among Students	"Teachers expressed in the interviews that implementing teamwork and establishing effective teams was not easy even when they recognized the benefits."	(Nariman et al., 2016, Teachers struggle to let go, Para. 2)
	"They have to collaborate on their own, but unfortunately, some of our kiddos just don't have that skill yet."	(Liu et al., 2021; p. 287)
(5) Assessment Formulation	"How will I know everyone does the same amount of work and is addressing the same learning outcomes?"	(Goodnough & Cashion, 2006, p. 286)
	"We had talked with our coordinator about how it doesn't necessarily match up with our benchmark testing."	(Liu et al., 2021, p. 288)
(6) Time Management	"I mean we did it because we are trying to stay with fidelity, but I totally would have dropped it for the sake of time"	(Gale et al., 2019 p. 25)
	"I don't feel that good as a whole, and it's hard because of time."	(Magaji, 2021; p. 222)

Findings for Research Question 3

The third research question stated, "*How do the types of problems used in PBL within K12 settings in empirical literature align with Jonassen's 11 types of problems*?" Out of the 37 studies in the data set, 73% (n=27) recorded information about the problem used in their respective studies. However, not all provided enough information to determine the exact type of the problem used. The data analysis revealed that about 27% (n=10) of studies conducted gave little to no information that could help classify the type of problem used. This section focuses on investigating the types of problems that were incorporated in the studies and how they aligned with Jonassen's (2010) types of problems: (1) story problems, (2) rule-using/rule-induction problems, (3) decision-making, (4) troubleshooting, (5) diagnosis-solution, (6) strategic performance, (7) policy problems, (8) design problems, (9) dilemmas, (10) algorithms, and (11) logic problems.

Figure 16

Types of Problems as Suggested by Jonassen (2010)



Jonassen (2010) emphasized that instructional designers should carefully select the types of problems they use in problem-solving curricula. This is because different problems demand sets of skills to solve and align with different learning outcomes (Jonassen, 2010). By aligning the problem type with the desired educational objectives, instructional designers can better enhance students' problem-solving abilities and meaningful learning experiences. He also noted that problems did not always come in discrete forms as they had been outlined. Similar to real-life problems, these problems may sometimes aggregate, which he referred to as 'problem aggregate' (Jonassen, 2010, p. 19). See Table 11 below for a general overview of the types of problems used.

Design Problems

These problems involve applying domain knowledge to create something original that meets specific criteria and constraints. The problem solver goes through an iterative process with the design to arrive at a solution. Jonassen (2010) observed that many professions require solving design problems each day. However, each approach applies different methods and forms to achieve goals. He also underscored the fact that each community of practice had its own models that they applied to the design process. For example, he noted that many within the instructional design community utilize the ADDIE model to solve design problems (Jonassen, 2010). There were usually multiple paths or solutions to any design problem. Other examples of professions that use design problems include architectural design, software development, instruction, or a symphony. According to Jonassen (2010), "design problem is the most complex and ill-structured kind of problem-solving" (p. 138).

The 37 studies in the data set were analyzed at this stage. The analysis revealed that approximately 73% (n=27) reported the topic or clues about the problem used while implementing PBL. Further analysis revealed that approximately 43% (n=16) of the problems identified could be classified as *design problems*. Studies (Liu et al., 2006; Liu et al., 2012; Liu et al., 2021; Pan et al., 2022; Pedersen et al., 2009) that adopted the 'Alien Rescue' problem (n=15) were in the domain of design problems. Alien Rescue required students to develop solutions that would provide suitable habitats for the aliens based on specific requirements through applying their knowledge of the solar system. In two other studies by Simon and Klein (2007) and Simon et al. (2004), a problem called 'Up, Up and Away' was adopted. This problem tasked students to plan a global balloon circumnavigation involving creative and practical applications of their knowledge across multiple disciplines. Students were asked to design a feasible route and consider various factors such as weather patterns and geographical constraints to achieve their goal.

In another study by Gale et al. (2019), the SLIDER problem was used. This tasked students to use their understanding of energy, motion, and forces to create an automatic braking system for a robotic truck. This kind of problem may involve multiple approaches towards creating an original braking system.

Although these were identified primarily as design problems, the analysis also identified other aggregating problem types. For example, the study by Nariman et al. (2016) required students to design a movie trailer using iMovie to illustrate the ocean food chain, which falls into the category of design problems. However, they were asked to complete it using a graphic organizer to identify and label functions of external structures, which fits within the domain of rule-using/rule-induction problems.

Diagnosis-Solution Problems

Diagnosis-solution problems require the problem solver to use troubleshooting to identify a problem. However, beyond correcting the problem and restoring functionality, the problem solver performs further analysis of different factors contributing to the problem and provides multiple solutions (Jonassen, 2010). These problems are usually associated with medical procedures. The data analysis identified and classified 16% (n=6) of the problems as diagnosis-solution problems. The study by Chin and Chia (2008) used a weight loss problem that required students to investigate various slimming methods, diagnose their effectiveness and health risks, and propose the best course of action.

The study by Buck et al., (2012) adopted a problem requiring students to assess why various groups who wrote to NASA came up with their conclusions, and then determine the right course of action. This involved diagnosing the current situation, evaluating different hypotheses or conclusions provided by others, and then arriving at a well-reasoned solution or course of action. Another study by Valdez et al., (2019) also adopted a diagnosis-solution problem. In the study, students were asked to diagnose whether a necklace was truly made of gold by analyzing its properties and comparing them to the characteristics of pure gold before making an informed decision. These studies also included aggregate problems, with the majority being decision-making problems since the student must make informed decisions based on their findings or diagnoses.

Rule-Using/Rule Induction Problems

Rule-using problems require the application of specific rules to arrive at a solution (Jonassen, 2010). These problems generally have a specific purpose or goal that is limited but not restricted to a particular procedure or method. For example, they could be as simple as using a search engine to look for information on the Internet.

Out of the 37 studies analyzed, only one adopted a rule-using/rule-induction problem to implement PBL. The card game activity adopted by the study conducted by Ihsen et al. (2011) tasked students to follow specific rules to play and guess words. This was a two-part problem where they played a card game to win rewards to buy parts to build their robot. Students guessed and played the game based on the rules of the card game. They could be successful by understanding the rules they had been taught and applying them specifically to the requirements for each card.

Decision-Making Problems

In decision-making problems, the problem solver chooses the best option among limited alternatives based on given criteria (Jonassen, 2010). The criteria are usually suggested or provided to the problem solver (Jonassen, 2010). Examples include rational business or personal decisions.

Only one conducted by Saye and Brush (2004) utilized a decision-making problem. Students were asked to make decisions about the best course of action for achieving social justice, evaluate different options, and make persuasive arguments based on their constructed knowledge. They had to consider multiple alternatives and evaluate different options based on criteria related to social justice.

Troubleshooting Problems

These problems involve diagnosing and fixing faults in systems, such as technical or mechanical issues. Troubleshooters use symptoms to generate and test hypotheses about different fault states (Jonassen, 2010). Examples might include computer repair and car maintenance. One always needs a combination of domain and system knowledge to troubleshoot effectively.

Based on the above criteria, the analysis identified one study (Yeo et al., 2014) that used troubleshooting problems. Students were required to investigate the cause of a rollercoaster accident by identifying and analyzing various factors that could have contributed to the failure. They were asked to investigate the malfunction and systematically address faults in the system. This study focused on using the troubleshooting approach to develop their problem-solving skills.

Story Problems

Jonassen (2010) explains that story problems make problem-solving more meaningful by framing problems within a narrative context. Story problems, commonly found in mathematics and the sciences, typically embed the values needed to solve an algorithm within a brief narrative or situation. Learners must select the appropriate formula, extract the necessary values from the narrative, and insert them into the formula to solve for the unknown quantity. Jonassen (2010) maintained that of all the problem types, the most common in classrooms is the story problem, though it is not the most innovative.

Analyzing the data revealed two studies (Ahdhianto et al., 2020; Mustafa et al., 2019) that adopted story problems when implementing PBL. In both situations, students were given a mathematical problem in a story form and were asked to first identify the mathematical problem, write it out, and then solve it. The purpose of the study conducted by Mustafa et al., (2019) was to explore how scaffolded multimedia learning environments might mitigate PBL implementation obstacles. The aim of Ahdhianto et al. (2020) was to improve students' mathematical problem-solving and critical thinking skills. According to Jonassen (2010), efforts to utilize more innovative problem types have not been successful because this kind of problem is comparatively easy to create. However, the analysis revealed that the story problem was not widespread since only two studies used story problems to implement PBL.

Strategic Performance Problems, Policy Analysis Problems, Dilemma Problems, Logical Problems, Algorithmic Problems

The analysis of the 27 studies that recorded the type of problem adopted for PBL implementation did not identify any problems aligning with the following problem types: strategic performance problems, policy analysis problems, dilemmas, and logical problems.

Summary of Research Question 3

Research Question 3 sought to investigate the types of problems adopted in the selected studies to implement PBL. The focus was to analyze these problems and determine their alignment with the types of problems proposed by Jonassen (2010). The analysis of the 37 studies revealed that PBL implementations in K-12 settings predominantly utilized design problems; there was little diversity in the types of problems adopted across the studies in relation to Jonassen’s (2010) types of problems. Design problems, which are complex and ill-structured, were used most frequently, and particularly in science and mathematics classrooms. Other problem types such as diagnosis-solution, rule-using, algorithmic, decision-making, troubleshooting, and story problems were also identified, though to a lesser extent. Table 11 below gives an overview of the distribution.

Table 11

Overview of Studies and the Types of Problems They Incorporated Using PBL

	Reference	Purpose of Studies	Name of Problem	Logic problems	Story problems	Algorithms	Rule-using/rule-induction problems	Decision making	Troubleshooting	Diagnosis-solution problems	Strategic performance	Policy-analysis problems	Design problems	Dilemmas
1	Ihsen et al., (2011).	Promote interest in robotics and engineering among pupils through gender-inclusive Problem-Based Learning.	Card game/ Robotics				X							
2	Chin, C., & Chia, L. G. (2008)	Using PBL in a project-based science (program) develop students thinking and problem-solving skills by allowing them to solve authentic problems	Weight loss							X				
3	Saye & Brusg (2004)	Explores how scaffolded, multimedia learning environments might mitigate PBL implementation obstacles	Decision Point!					X						
4	Roy et al., (2014)	PBL intervention for environment conservation education, specifically forest fires in Tanzania	Forest Fires										X	
5	Syaifuddin & Mohammed (2017)	Analyze the level of student learning activities and to increase their competence in mathematical problem-solving through PBL	algebraic operations	Study does not give enough information to enable categorization										
6	Rice & Merrick (2023)	Explore how teachers at … utilize the on-campus fabrication lab to promote the implementation of PBL.	Mixed										X	
7	Mustafa et al., (2019)	Describe students' mathematical thinking ability through the Mathematical PBL Model	Identify Math Problem		X									
8	Ding et al., (2021)	Engaging students in investigating an authentic social problem, from different perspectives with PBL	Hole in the Sky										X	
9	Chin & Chia, (2006)			Study does not give enough information to enable categorization										
10	de Pinho,et al (2021)	A procedural study of a PBL tutorial cycle with high school students new to the method regarding human respiration and circulation physiology	human respiration and circulation physiology							X				
11	"Anshori, I. (2021).	Find improvements in the quality of the process and learning outcomes of sociology through PBL modeling integrated with Islamic values	social change											
				Study does not give enough information to enable categorization										
12	Gale et al., (2019)	Implementation of SLIDER, a problem-based learning 8th-grade physical science curriculum	SLIDER										X	
13	Buck et al., (2012).	Provide a descriptive, as well as interpretive, account of Seventh-grade girl cognitive and procedural engagement in a problem-based earth and space unit, Specifically focusing on how various instructional strategies influenced engagement	The New Star							X				
14	Prahani et al., (2022)			Study does not give enough information to enable categorization										
15	Pan et al., (2022)	An adaptive scaffolding system to support middle school science problem-based learning (PBL) activities	Alien Rescue										X	
16	Nariman et al., (2016)	Implementing problem-based learning (PBL) in an elementary school … to implement the NGSS using PBL	Molecules to Organism: Structures and Processes										X	
17	Kwon et al., (2021)	Investigated how a computer science (CS) problem-based curriculum impacted elementary students' CS learning and attitudes.	block-based coding										X	
18	Magaji, A. (2021)			Study does not give enough information to enable categorization										
19	Simons & Klein (2007)	Examined how scaffolds and student achievement levels influence inquiry and performance in a problem-based learning environment.	Up, Up, & Away!										X	

20	Simons et al., (2004)	Examine the instructional strategies utilized, teacher and student attitudes, and student achievement when a sixth-grade teacher and her 19 students implemented a hypermedia, problem-based learning unit.	Up, Up, & Away!,										X	
21	Cerezo, (2004)	Examine problem-based learning (pbl) and how students in the middle grades math and science classroom perceived its effectiveness.	Adding a patio to our house										X	
22	Valdez et al., (2019)	Investigate the effectiveness of the problem-based learning (PBL) approach in enhancing the problem-solving skills in Chemistry	Buying a gold necklace							X				
23	Noble et al., (2020)			Study does not give enough information to enable categorization										
24	Yeo et al., (2014)	Using the knowledge-creation approach as a boundary object between the two seemingly contradicting activities to overcome learning science content and developing problem-solving skills challenges	What caused the rollercoaster accident?						X					
25	Ahdhianto, et al., (2020)	Improve students' mathematical problem-solving and critical thinking skills using PBL	mathematical problem-solving and critical thinking		X									
26	Evendi, & Verawati, (2021)			Study does not give enough information to enable categorization										
27	"Liu, Cho & Schallert (2006)	Examined the effect of a computer-enhanced PBL on students' learning, … the relationship among students' self-efficacy attitude toward science and achievement.	Alien Rescue										X	
28	Nurlaily et al., (2019)			Study does not give enough information to enable categorization										
29	Horak & Galluzzo (2017	Explore the effect of problem-based learning (PBL) on student achievement and students perceptions of classroom quality	Ferret It Out										X	
30	Pedersen et al., (2009)	Examined how teachers determine both how they assessed student learning and their reasons for these assessment practices	Alien Rescue										X	
31	Century, J., Ferris, K. A., & Zuo, H. (2020)	Students are asked to take the role of an ecologist and investigate the real-world problem of the invasive Burmese python in the Everglades	Ecological investigation/ How did we get here										X	
32	Ertmer et al., (2009)			Study does not give enough information to enable categorization										
33	Wirkala & Kuhn (2011)	Examining the effectiveness of PBL	the Columbia space shuttle disaster							X				
34	Liu et al., (2012)		Alien Rescue										X	
35	Goodnough & Cashion (2006)	Delve into the complexities of PBL and examine its feasibility as a curriculum and instructional approach in the context of high school science teaching and learning.	The cystic fibrosis problem							X				
36	Liu et al., (2021)	Investigate why 25 middle school teachers chose to implement a technology-enriched PBL program, the challenges they encountered, and the facilitation strategies they used to address those challenges	Alien Rescue										X	
37	Li & Stylianides (2018)			Study does not give enough information to enable categorization										

Chapter Five

Discussion and Conclusion

This chapter focuses on discussing the study findings, limitations, and recommendations for research and practice in instructional design. This integrative literature review examined PBL instructional strategies and teachers' experiences when implementing PBL. It also investigated the types of problems that are incorporated when implementing PBL in K-12 classrooms. PBL has long been recognized as an innovative and effective instructional strategy, particularly for enhancing critical thinking through solving authentic problems. Critical thinking and problem-solving skills are desirable 21st-century skills for employability and development. These are the skills that governments, policymakers, institutions, etc. are advocating for and investing in. However, despite these promising opportunities, the adoption of PBL in K-12 education remains limited. This situation has often been attributed to the significant challenges teachers face when implementing PBL. Researchers have studied different aspects of these challenges, especially as they pertain to teachers, and have drawn various conclusions.

PBL, was originally an instructional strategy developed to revolutionize medical education in the 1970s, and medical schools have consistently adhered to standardized models (Barrows, 1996). In contrast, the application of PBL in K-12 education has demonstrated considerable flexibility, allowing teachers to maintain the fundamental principles of PBL while adjusting the structure depending on educational contexts and student needs. This flexibility has led to the emergence of different strategies and models tailored to the unique demands of K-12 classrooms. This study focused on investigating how the strategies used aligned with Torp and Sage's (1998, 2002) PBL model for K-12 classrooms. Additionally, the study investigated the types of problems teachers incorporate into their PBL activities. Jonassen (2000) has emphasized the importance of carefully designing problems to align with specific educational outcomes. He argues that the nature of the problem significantly influences the learning process and the learning outcomes from the curriculum. This study also examined empirical studies within a 20-year period from 2004 to 2024. This represents the period following the introduction of the NCLB policy in the United States. This policy emphasized standardized testing for students, an approach that is not emphasized in PBL. The purpose was to observe any patterns or emerging trends resulting from these educational policies, especially among studies from the United States.

In light of the considerations above, an integrative review was selected as the most appropriate methodology to address the needs, "to summarize what is known about a topic and to communicate the synthesis of the literature to a targeted community" (Toronto, 2020, p. 1) and to bring a "value-added contribution to the new thinking in the field" (Torraco, 2005, p. 358). To ensure a structured and purposeful approach to this study, three research questions were formulated to guide the investigation:

1. How have PBL implementation strategies/models in K-12 education been described in empirical literature?
2. How have K-12 teachers' experiences/challenges with PBL implementation been described in empirical literature?"
3. How do the types of problems used in PBL within K-12 settings in empirical literature align with Jonassen's (2010) types of problems?

Through a comprehensive search of available literature, 37 peer-reviewed empirical articles were identified for inclusion in the study's data set. All were published in the English language between 2004 and 2024. Studies from the USA, representing approximately 57% (n=21), made up highest number of publications from a particular country. Indonesia recorded the next highest number of publications at approximately 16% (n=6). The remaining 10 were distributed among Canada, Germany, Taiwan, the UK, Singapore, the Philippines, and Tanzania.

The participants in the studies were mainly K-12 teachers. Among the teachers, only 37% (n=8) had used PBL at least once. Many of these teachers were implementing PBL for the first time. Almost all the teachers involved in the studies participated in a series of professional development programs to equip them with skills to implement their lessons using PBL. By synthesizing these studies, this integrative review highlights and contributes to a deeper understanding of how PBL can be effectively adapted and implemented in K-12 education, providing valuable guidance for instructional designers, other educators, and researchers in the field.

Discussion of Findings

This section discusses the research findings in relation to questions formulated to guide the study. The questions focused on K-12 teachers' implementation strategies, their challenges, and the types of problems they used.

Question #1

The first research question asked, "*How have PBL implementation strategies/models in K-12 education been described in empirical literature?"* This question aimed to identify the strategies or models that K-12 teachers adopted when implementing PBL. To guide data collection, the study sought to align these strategies with the seven-step model by Torp and Sage (1998, 2002) specifically designed for K-12 classrooms.

The analysis revealed that most studies did not adhere to a specific model, but instead initiated various activities that could align with the steps outlined by Torp and Sage (1998, 2002). Only a few studies (Century et al., 2020; Chin & Chia, 2006; de Pinho et al., 2021; Ertmer et al., 2009; Evendi & Verawati, 2021; Rice & Merrick, 2023; Wirkala & Kuhn, 2011; Goodnough & Cashion, 2006) explicitly mentioned using a particular framework. These strategies could broadly be categorized into the three broad categories of preparation, iterative activities, and presentation and evaluation stages.

Although Torp and Sage (1998, 2002) suggested that their first stage be optional, the study found that almost all the analyzed studies included activities to prepare students for the PBL class. This inclusion likely stems from the fact that many students and teachers were encountering PBL for the first time and needed a period for preparation (Teachers’ Experience with PBL. Table 7)A significant observation at this stage was the emphasis on ensuring students' prior knowledge of the topic. Prior knowledge was crucial because students needed it to design study objectives and direct the problem or task. Some teachers used pretests to assess students' prior knowledge and readiness for the class (Ahdhianto et al., 2020; Pedersen et al., 2009). Without adequate prior knowledge, students could become stuck and unable to progress. One study noted that when students lacked prior knowledge, the teacher had to intervene more frequently than typical PBL scaffolding would require (Saye & Brush, 2004).

Question #2

Research Question 2 stated, “*How have K-12 teachers' experiences/challenges with PBL implementation been described in empirical literature?”* This question aimed to investigate the nature of teachers' experiences with PBL, focusing specifically on the challenges they faced when adopting and implementing this instructional approach. The findings from the empirical literature examined six broad areas of teacher activities within PBL implementation: problem design and development, scaffolding, technology integration, assessment formulation, time requirements, and promoting collaboration among students (Goodnough & Cashion, 2006; Li & Stylianides, 2018; Magaji, 2021; Nariman et al., 2016; Valdez et al., 2019).

The findings were in agreement with the common assumption that teachers generally struggle to design authentic problems for their classes (Buck et al., 2012; Cerezo, 2004; Chin & Chia, 2008; Ding et al., 2021; Nurlaily et al., 2019; Rice & Merrick, 2023), often finding it challenging to align these problems with curriculum standards and ensure they are relevant to students' interests. The complexity of creating multidisciplinary problems and the extensive planning required exacerbate these challenges. Consequently, many teachers tend to rely on preexisting problems rather than designing their own (Chin & Chia, 2008; Liu et al.,2006; Nariman et al., 2016; Simons & Klein, 2007). This reliance on preexisting problems was evident in numerous studies, where the problems used were not originally created by the teachers themselves but rather adapted from available resources. This dependency emphasizes the need for more support and resources to help teachers design and develop authentic, curriculum-aligned problems that effectively engage students in the PBL process.

Additionally, the findings from this study confirmed earlier research highlighting the challenges teachers faced when transitioning from traditional teaching roles to facilitating student-centered learning through scaffolding (Nariman et al., 2016; Pedersen et al., 2009). Balancing guidance and autonomy, managing the physical and emotional demands of scaffolding, and adjusting to the role of a facilitator rather than a direct instructor were significant hurdles. These findings underscore the need for more support and resources to provide teachers with skills to navigate the PBL process effectively.

Perhaps the most significant finding, which is not usually emphasized in terms of teachers' challenges with PBL, relates to time. Time constraints are central to all other aspects of teachers' challenges. Teachers require more time to plan and design authentic problems, prepare and integrate technology into their lessons, and manage every phase of the PBL process effectively (Chin & Chia, 2006; Nurlaily et al., 2019; Saye & Brush, 2004) . Teachers tended to compare the time they spent teaching through traditional, teacher-centered methods with the additional time that they needed when preparing for PBL (Ihsen et al., 2011). In traditional settings, lessons are more straightforward and require less preparatory work, whereas PBL demands extensive time input upfront (Ihsen et al., 2011). Therefore, addressing time constraints is crucial for successfully implementing PBL, as it underpins the ability to design engaging problems, facilitate learning through scaffolding, integrate technology effectively, and assess students' performance, among other things.

Another revelation from the findings was that, while teachers did not find assessment formulation particularly challenging, and were convinced of their students' learning with PBL, they continually contemplated how to assess individual contributions fairly within group tasks (Goodnough & Cashion, 2006; Liu et al., 2021). Teachers were thus concerned about their students' performance on standardized testing required for their various institutions. Many teachers included a posttest assessment in their implementation process, an aspect that is not typically emphasized in PBL (Pan et al., 2022; Pedersen et al., 2009). This concern underscores the need for developing assessment strategies that can effectively measure individual student performance within a group context, ensuring a fair and comprehensive evaluation of each student's achievements.

Despite these challenges, the findings were mixed regarding teachers' willingness to continue using PBL. Some teachers were eager to continue due to the positive impact on student engagement and learning (Chin et al., 2006; Kwon et al., 2021; Mustafa et al., 2019), while others were deterred by the significant time and resource demands, finding the workload overwhelming (Liu et al., 2021). Overall, while teachers acknowledged the benefits of PBL, their experiences with the associated challenges influenced their decisions about its future use emphasizing the need to address these challenges to support sustained implementation.

Question #3

The third question was, "*How do the types of problems used in PBL within K-12 settings in empirical literature align with Jonassen's (2010) types of problems?"* Jonassen (2010) has recommended that teachers be careful when selecting problems for PBL in order to achieve the curriculum goals. The types of problems outlined are: (1) story problems, (2) rule-using/rule-induction problems, (3) decision-making, (4) troubleshooting, (5) diagnosis-solution, (6) strategic performance, (7) policy problems, (8) design problems, (9) dilemmas, (10) algorithms, and (11) logic problems. This question sought to investigate the problems used in the literature and how they aligned with Jonassen's types of problems.

While a few studies explicitly described the problems used, those that did predominantly aligned with design problems. Approximately 43% of the studies (n=16) employed design problems, where students applied domain knowledge to create original solutions through iterative processes. This alignment indicates that design problems are particularly favored in K-12 PBL settings and across various disciplines, but most especially within science and math classrooms (Liu et al., 2006; Liu et al., 2012; Liu et al., 2021). The findings also demonstrated that most of the problems used in these studies were pre-existing rather than originally created by the teachers (Gale et al., 2019; Simon et al., 2004; Simon and Klein,2007). Even though the problems cited may fit into multiple types as described by Jonassen, it appears doubtful that teachers were designing problems with Jonassen's (2010) recommendations in mind. Jonassen

(2010) admitted to the reality that there was limited research and support for teachers to plan the types of problems they used in problem-solving classrooms. Aside from the two studies that created their own problems using the 3C3R design model by Hung (2009), none of the studies detailed how they arrived at their problems beyond meeting curriculum requirements. This lack of explicit problem design methodology highlights a gap between theoretical recommendations and practical application among K-12 teachers.

Moreover, the analysis suggests that while teachers were motivated to meet curriculum requirements, they may not have considered Jonassen's (2010) recommendations for problem types, which advocate for the selection of problems that enhance specific problem-solving skills and promote deeper learning.

Implications for Practice

When thoughtfully implemented, PBL serves as an instructional strategy that cultivates 21st-century problem-solving and critical thinking skills through active student engagement with real-world, authentic problems (Brush & Saye, 2017). While PBL is fundamentally a student-centered approach, the role of teachers is pivotal in achieving the intended educational outcomes. The findings have revealed and highlighted different areas in which teachers are challenged in their efforts. These highlights have various implications for sustaining and maintaining interest in PBL as an effective instructional strategy for cultivating 21st-century skills in problem-solving and critical thinking. Some implications that can be deduced are discussed below.

Professional Development

This study has discussed how teachers value students' engagement and the overall quality of learning facilitated through PBL, despite their challenges. Teachers are eager to try so far as they feel supported in this endeavor. Different types of teachers' challenges have also been highlighted. Some involve problem design and development, role transition in scaffolding, and the assessment of individual performance within group studies among others (Goodnough & Cashion, 2006; Li & Stylianides, 2018; Magaji, 2021; Valdez et al., 2019).

Continuous effort must be dedicated to encouraging both in-service and pre-service teachers to develop the theoretical understanding and practical application of various student-centered learning theories. Emphasis should be placed on cultivating effective classroom management skills and implementing differentiated instruction that addresses students' diverse needs. Additionally, these efforts must promote proficiency in facilitating collaborative learning and employing effective questioning techniques, all of which are critical for implementing any constructivist pedagogy. Experts in the field must collaborate in creating robust professional development programs focused on these specific areas. Such training sessions and programs should be organized intermittently to ensure continuous support and upskilling for teachers. Again, instructional designers must endeavor to create online modules that are easily accessible to teachers who need support.

By addressing these challenges through targeted and ongoing professional development programs, in-service and pre-service teachers could be better equipped to implement PBL and other constructivist pedagogies effectively, thereby enhancing student engagement and promoting deeper learning outcomes.

School Authorities' Support

This study has revealed the important role that school authorities can play in supporting teachers in using PBL (Ertmer et al., 2009; Lui et al., 2021). In order to promote and sustain interest in the adaptation of PBL for K-12 education, it is imperative that school principals and other stakeholders actively create a supportive environment for this instructional strategy. This involves not only fostering a culture that values innovative teaching methods but also investing in the necessary materials and resources to facilitate PBL. Schools should allocate time for teachers to plan and collaborate, ensuring they are not overwhelmed by the demands of PBL. Investing in technological tools and learning materials is also crucial, providing teachers and students with the resources they need to engage fully in the problem-solving process.

Policy Frameworks

Analysis of publication trends in the US on PBL implementation strategies and teachers' challenges in K-12 classrooms from 2004 to 2024 (See Table 6) revealed a pattern that may have been influenced by two major educational policies such as the No Child Left Behind Act (NCLB) of 2002 (Ydesen & Dorn, 2022) and the Every Student Succeeds Act (ESSA) of 2015. The NCLB Act, with its emphasis on standardized testing and accountability (Freer-Alvarez, 2016), appears to have constrained the adoption of holistic educational methods like PBL as evidenced by the low number of related publications between 2004 and 2010. Conversely, the enactment of ESSA, which focuses on addressing individual student needs and promoting innovative teaching methods (Adler-Greene, 2019), corresponds with a slight increase in PBL-related publications post-2015, peaking in 2021. This could indicate that ESSA has renewed interest in PBL. Therefore, policymakers must continue to support and enact policies that foster innovative teaching strategies such as PBL.

Limitations of the Study

Toronto and Remington (2020) have stated that research methodologies, including integrative review, are subject to potential biases that can threaten their conclusions. Their recommendation is that these limitations should always be identified, discussed, and presented to readers. This study of K-12 teachers' strategies and challenges in adapting PBL and the types of problems used when implementing PBL has offered a valuable opportunity to highlight teachers' experiences with this teaching strategy. Nonetheless, it is important to acknowledge any limitation related to the findings reported.

The first limitation of this study is that all data collection, evaluation, analysis, and categorization were conducted by a single researcher. While such an approach could ensure consistency in the implementation of the methodology, it also introduces the possibility of interpretive biases attributable to the singular perspective of the reviewer. van Merriënboer (2014), in his chapter "Research Paradigms and Perspectives on Learning" in the 4th edition of the *Handbook of Research on Educational Communications and Technology*, argues that researchers must be aware of their existing beliefs and understandings, and, "the fact that [these] paradigms heavily affect their research methods and findings" (p. 21).

To minimize the occurrence of biases, the researcher adhered strictly to the methodology outlined by Whittmore and Knafl (2005). The keyword search and database selection were meticulously conducted in collaboration with two expert librarians from Virginia Tech at different intervals. Search results were downloaded into Zotero and subsequently uploaded to Covidence, where the PLASMA framework was employed to support the selection and analysis of data. Titles, abstracts, and full documents were reviewed according to well-defined inclusion and exclusion criteria to ensure the validity of the final data set. Additionally, data extraction and coding were performed patiently and diligently, with periodic comparisons to ensure that no essential data was overlooked.

Secondly, in order to generalize this study's findings, it is important to recognize that the participants, settings, and disciplines included in this synthesis do not encompass the entire body of research related to teachers who adopt PBL. This study exclusively focused on K-12 teachers and their educational settings. Such an application limits the applicability of the results to other learning contexts, such as colleges and higher institutions of learning where PBL is also encouraged. Though the findings provide a valuable foundation for understanding teachers' experiences, strategies, etc. related to PBL implementation, they cannot be generalized across different settings without further research. Further studies are necessary to validate and extend the application of these conclusions to educators in other institutions.

Thirdly, the number of studies analyzed could also present limitations. There is no established minimum or maximum regarding the number of studies required for conducting an integrative literature review. However, when the number of included studies is small, the findings are highly susceptible to the influences of the inclusion and exclusion criteria. This can affect the researcher's ability to comprehensively address the research question.

Fourthly, it is important to note that the data for this study were sourced from journals and electronic databases maintained through subscriptions by the university library. The accessibility of these resources is contingent upon the university’s subscription plans, which are subject to periodic review and modification. Changes in subscription plans may affect the availability of certain journals and databases in the future, potentially hindering the ability to replicate this study.

Recommendations for Future Research

To promote and sustain PBL interest, K-12 teachers, researchers, and stakeholders in the field must collaborate to directly invest time and other resources towards motivating and encouraging teachers to participate in future research. The researcher recommends a focus on the following areas:

Time Management in PBL

Time constraints at different stages were identified as a major barrier to PBL implementation (Gale et al., 2019; Magaji, 2021). Further research should examine effective time management strategies that can support teachers to integrate PBL without feeling overwhelmed.

Support Systems

Teachers adopt instructional strategies that align with their belief systems. Therefore, it is important to identify support systems in the teacher environment that promote the usage of PBL. Further research can investigate the types of support that are most beneficial for teachers such as mentoring, peer collaboration, and administrative backing, in an effort to build a community around PBL at an institution.

Problem Design and Development

One of the major challenges was related to the design and development of authentic problems for PBL (Buck et al., 2012; Cerezo, 2004; Chin & Chia, 2008). Further research can explore the specific difficulties teachers face, and develop tools, frameworks, and resources to support them in creating high-quality PBL problems. This could also enhance problem design skills with a special focus on the existing types of problems as recommended by Jonassen (2010).

Assessing Individual Performance

While teachers were convinced of PBL's effectiveness, they were critical of its ability to measure individual performance (Goodnough & Cashion, 2006; Liu et al., 2021). Some teachers, as a result, used a posttest evaluation to better understand each student's learning in relation to the lesson goals. Further research can focus on developing assessment strategies and tools that can provide accurate and fair evaluations of individual contributions. This can help teachers feel more confident in their ability to measure student learning outcomes effectively.

Conclusion

PBL remains a promising instructional strategy for developing essential 21st-century skills. Despite the challenges K-12 teachers face in implementing PBL, they are enthusiastic about its benefits (Chin et al., 2006; Kwon et al., 2021; Mustafa et al., 2019). This study has highlighted the different aspects of teachers' strategies and challenges related to PBL using an integrative review method. Addressing these challenges will require collective effort by all stakeholders including educational policymakers, institutions, researchers, and instructional designers. This effort should focus on creating supportive infrastructure that includes robust professional development programs, comprehensive resource allocation, and flexible policies that encourage the adoption of PBL. By working together, teachers will be well-equipped with the necessary skills and tools to implement PBL effectively.

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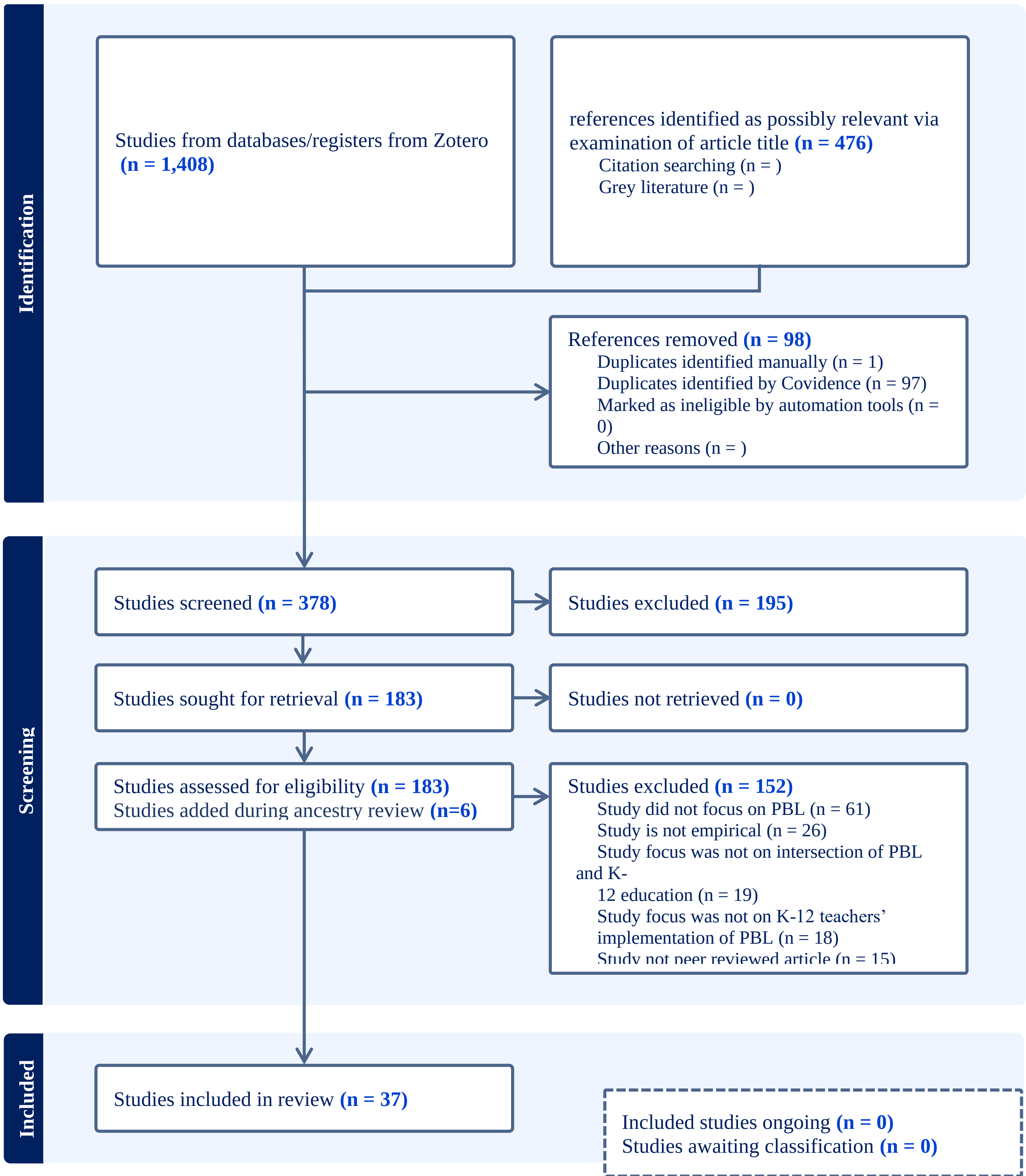
APPENDIX A

PRISMA for Data Collection and Screening



APPENDIX B

Examples of References that Illustrate Teachers' Instructional Strategies Aligning with Torp and Sage's (1998, 2002) PBL Model

Stage	Example	Study
Prepare the Learner	A precycle meeting was carried out on day 1, in which we explained what PBL is and how the activity would be carried out. "After the pre-test, the experimental and control group students participated in learning activities for 3 meetings" "The first day was spent forming student groups, explaining how to access the PBL unit on the computer, and introducing the unit to students."	(de Pinho et al., 2021, p. 751) (Ahdhianto, et al., 2020, p. 2016) (Simons & Klein, 2007, p. 52)
Meet the problem	"The first step in the study was for the students to watch the three videos …" "The letters were read multiple times to identify instances in which students recommendations referenced engineering DCIs and the application of relevant science concepts". "Trigger - The teacher, Ms. Cho, presented the trigger problem to the students "(p. 757)	(Roy et al., 2014, p. 78) (Gale et al., 2019, p. 17) (Yeo et al., 2014, p. 757)
Iterative Circle of activities	Students conducted research on space concepts related to problem through computer-based activities "brain-storming and researching activities … Videos and discussions on creating a culture of kindness. Students research how acts of kindness in their school and daily lives …" "Students identified puzzling problem related to how a roller coaster worked, and discussed the problem via Knowledge Constructor (during and after lesson time). … Group reports were submitted for teacher feedback at the end of each week"	(Buck et al., 2012, p. 159). (Kwon et al., 2021, p. 2768) (Yeo et al., 2014, p. 757)
Generate possible solutions	"Students explore and investigate the possible solutions using practical logic"	(Rice & Merrick, 2023) (Kwon et al., 2021, p. 2769)

	Students spend 8 lessons researching, planning, designing, and developing their Scratch project. Multiple check-ins and scaffolds help support development Students compiled the various components for their project portfolio on days 11 through 13 (p. 52)	(Simons & Klein (2007, p. 52)
Determine best-fitting	Students managed to conclude on the path of action for their group, including recommendations for the various colonies. As a class, students synthesized their findings and decided their position towards the inquiry question. A set of checklist for the three strands of the project (Balloon Design, Travel Plan, and Supply List) is included for final project assessment (p. 218)	(Saye & Brush, 2004, p. 369) (Ding et al., 2021, p. 90) (Simons et al., 2004, p. 218)
Present the solution (Assessment)	Students completed and presented summative performance assessment, which was a persuasive letter to NASA on which hypothesis students found most plausible based on concepts learned during the (p. 159) The remaining 40% was apportioned evenly between the group presentation and contributions to the group	(Buck et al., 2012, p. 159) (Saye & Brush, 2004, p. 362)
Debrief the problem	"Students reflect on their presentations and ask questions" "The teacher closed most of the sessions with a short review, allowing students to report their progress Even though the teacher debriefed each session, the final one could not be done in this study." "So we are going to be doing some self-reflection, self-evaluation, some group evaluation, and teacher evaluation throughout this process?" P. 45	(Simons & Klein, 2007, p. 67) (Simons et al., 2004, p. 229) (Ertmer et al., 2009, p. 45)

APPENDIX C

References of Studies Identified for Integrative Review

References of Studies Identified for Integrative Review
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APPENDIX D

Overview of studies and the types of problems they incorporated using PBL

	Reference	Purpose of Studies	Name of Problem	Logic problems	Story problems	Algorithms	Rule-using/rule-induction problems	Decision making	Troubleshooting	Diagnosis-solution problems	Strategic performance	Policy-analysis problems	Design problems	Dilemmas
1	Ihsen et al., (2011).	Promote interest in robotics and engineering among pupils through gender-inclusive Problem-Based Learning.	Card game/ Robotics				X							
2	Chin, C., & Chia, L. G. (2008)	Using PBL in a project-based science (program) develop students thinking and problem-solving skills by allowing them to solve authentic problems	Weight loss							X				
3	" Saye & Brusg (2004)	Explores how scaffolded, multimedia learning environments might mitigate PBL implementation obstacles	Decision Point!					X						
4	Roy et al., (2014)	PBL intervention for environment conservation education, specifically forest fires in Tanzania	Forest Fires										X	
5	Syaifuddin & Mohammed (2017)	Analyze the level of student learning activities and to increase their competence in mathematical problem-solving through PBL	algebraic operations	Studies does not give enough information to enable categorization										
6	Rice & Merrick (2023)	Explore how teachers at … utilize the on-campus fabrication lab to promote the implementation of PBL.	Mixed						X				X	
7	Mustafa et al., (2019)	Describe students' mathematical thinking ability through the Mathematical PBL Model	Identify Math Problem		X									
8	Ding et al., (2021)	Engaging students in investigating an authentic social problem, from different perspectives with PBL	Hole in the Sky										X	

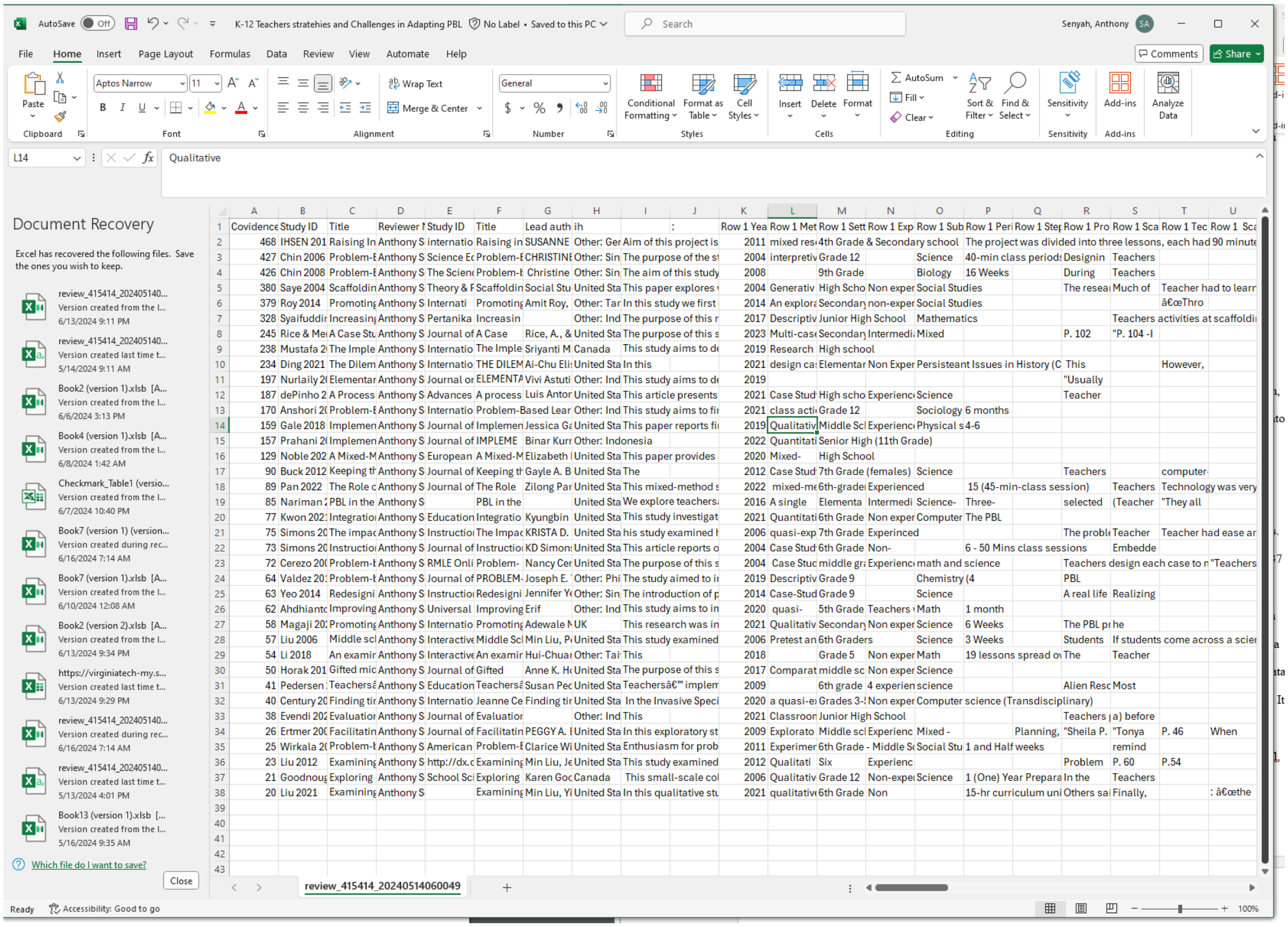
9	Chin & Chia, (2006)			Studies does not give enough information to enable categorization										
10	de Pinho,et al (2021)	A procedural study of a PBL tutorial cycle with high school students new to the method regarding human respiration and circulation physiology	human respiration and circulation physiolog y							X				
11	"Anshori, I. (2021).	Find improvements in the quality of the process and learning outcomes of sociology through PBL modeling integrated with Islamic values	social change											
				Studies does not give enough information to enable categorization										
12	Gale et al., (2019)	Implementation of SLIDER, a problem-based learning 8th-grade physical science curriculum	SLIDER										X	
13	Buck et al., (2012).	Provide a descriptive, as well as interpretive, account of Seventh-grade girl cognitive and procedural engagement in a problem-based earth and space unit, Specifically focusing on how various instructional strategies influenced engagement	The New Star							X				
14	Prahani et al., (2022)			Studies does not give enough information to enable categorization										
15	Pan et al., (2022)	An adaptive scaffolding system to support middle school science problem-based learning (PBL) activities	Alien Rescue										X	
16	Nariman et al., (2016)	Implementing problem-based learning (PBL) in an elementary school … to implement the NGSS using PBL	Molecules to Organism: Structures and Processes										X	
17	Kwon et al., (2021)	Investigated how a computer science (CS) problem-based curriculum impacted elementary students' CS learning and attitudes.	block-based coding										X	
18	Magaji, A. (2021)			Studies does not give enough information to enable categorization										
19	Simons & Klein (2007)	Examined how scaffolds and student achievement levels influence inquiry	Up, Up, & Away!										X	

		and performance in a problem-based learning environment.												
20	Simons et al., (2004)	Examine the instructional strategies utilized, teacher and student attitudes, and student achievement when a sixth-grade teacher and her 19 students implemented a hypermedia, problem-based learning unit.	Up, Up, & Away!,										X	
21	Cerezo, (2004)	Examine problem-based learning (pbl) and how students in the middle grades math and science classroom perceived its effectiveness.	Adding a patio to our house										X	
22	Valdez et al., (2019)	Investigate the effectiveness of the problem-based learning (PBL) approach in enhancing the problem-solving skills in Chemistry	Buying a gold necklace							X				
23	Noble et al., (2020)			Studies does not give enough information to enable categorization										
24	Yeo et al., (2014)	Using the knowledge-creation approach as a boundary object between the two seemingly contradicting activities to overcome learning science content and developing problem-solving skills challenges	What caused the rollercoaster accident?						X	X				
25	Ahdhianto, et al., (2020)	Improve students mathematical problem-solving and critical thinking skills using PBL	mathematical problem-solving and critical thinking		X									
26	Evendi, & Verawati, (2021)			Studies does not give enough information to enable categorization										
27	"Liu, Cho & Schallert (2006)	Examined the effect of a computer-enhanced PBL on students' learning, … the relationship among students' self-efficacy attitude toward science and achievement.	Alien Rescue										X	
28	Nurlaily et al., (2019)			Studies does not give enough information to enable categorization										
29	Horak & Galluzzo (2017	Explore the effect of problem-based learning (PBL) on student achievement	Ferret It Out										X	

		and students perceptions of classroom quality												
30	Pedersen et al., (2009)	Examined how teachers determine both how they assessed student learning and their reasons for these assessment practices	Alien Rescue										X	
31	Century, J., Ferris, K. A., & Zuo, H. (2020)	Students are asked to take the role of an ecologist and investigate the real-world problem of the invasive Burmese python in the Everglades	Ecological investigati on/ How did we get here										X	
32	Ertmer et al., (2009)			Studies does not give enough information to enable categorization										
33	Wirkala & Kuhn (2011)	Examining the effectiveness of PBL	the Columbia space shuttle disaster							X				
34	Liu et al., (2012)		Alien Rescue											
35	Goodnough & Cashion (2006)	Delve into the complexities of PBL and examine its feasibility as a curriculum and instructional approach in the context of high school science teaching and learning.	The cystic fibrosis problem							X				
36	Liu et al., (2021)	Investigate why 25 middle school teachers chose to implement a technology-enriched PBL program, the challenges they encountered, and the facilitation strategies they used to address those challenges	Alien Rescue										X	
37	Li & Stylianides (2018)			Studies does not give enough information to enable categorization										

APPENDIX E

Data Set Extract from Covidence to Excel



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	Covidence	Study ID	Title	Reviewer I	Study ID	Title	Lead auth	ih		:	Row 1 Yea	Row 1 Met	Row 1 Sett	Row 1 Exp	Row 1 Sub	Row 1 Peri	Row 1 Step	Row 1 Pro	Row 1 Sca	Row 1 Tec	Row 1 Sca
2	468	IHSEN 201	Raising In	Anthony S	internatio	Raising in	SUSANNE	Other: Ger	Aim of this project is		2011	mixed res	4th Grade & Secondary school			The project was divided into three lessons, each had					90 minute
3	427	Chin 2006	Problem-E	Anthony S	Science Ec	Problem-E	CHRISTINE	Other: Sin	The purpose of the st		2004	interpretiv	Grade 12		Science	40-min class periods		Designin	Teachers		
4	426	Chin 2008	Problem-E	Anthony S	The Scienc	Problem-b	Christine	Other: Sin	The aim of this study		2008		9th Grade		Biology	16 Weeks		During	Teachers		
5	380	Saye 2004	Scaffoldin	Anthony S	Theory & F	Scaffoldin	Social Stu	United Sta	This paper explores		2004	Generativ	High Scho	Non exper	Social Studies			The resea	Much of	Teacher had to learn	
6	379	Roy 2014	Promoting	Anthony S	Internati	Promoting	Amit Roy,	Other: Tar	In this study we first		2014	An explora	Secondary	non-exper	Social Studies					â€œThro	
7	328	Syaifuddir	Increasing	Anthony S	Pertanika	Increasin		Other: Ind	The purpose of this r		2017	Descriptiv	Junior High School		Mathematics				Teachers activities at scaffoldi		
8	245	Rice & Mei	A Case Stu	Anthony S	Journal of	A Case	Rice, A., &	United Sta	The purpose of this s		2023	Multi-case	Secondary	Intermedi	Mixed			P. 102	"P. 104 -I		
9	238	Mustafa 2	The Imple	Anthony S	Internatio	The Imple	Sriyanti M	Canada	This study aims to de		2019	Research	High school								
10	234	Ding 2021	The Dilem	Anthony S	Internatio	THE DILEM	Ai-Chu Eli	United Sta	In this		2021	design ca	Elementar	Non Exper	Persisteant Issues in History (C			This		However,	
11	197	Nurlaily 2	Elementar	Anthony S	Journal or	ELEMENTA	Vivi Astuti	Other: Ind	This study aims to de		2019							"Usually			
12	187	dePinho 2	A Process	Anthony S	Advances	A process	Luis Antor	United Sta	This article presents		2021	Case Stud	High scho	Experience	Science			Teacher			
13	170	Anshori 2	Problem-E	Anthony S	Internatio	Problem-Based Lear		Other: Ind	This study aims to fir		2021	class acti	Grade 12		Sociology	6 months					
14	159	Gale 2018	Implemen	Anthony S	Journal of	Implemen	Jessica Ga	United Sta	This paper reports fi		2019	Qualitativ	Middle Scl	Experience	Physical s	4-6					
15	157	Prahani 2	Implemen	Anthony S	Journal of	IMPLEME	Binar Kurr	Other: Indonesia			2022	Quantitati	Senior High (11th Grade)								
16	129	Noble 202	A Mixed-M	Anthony S	European	A Mixed-M	Elizabeth I	United Sta	This paper provides		2020	Mixed-	High School								
17	90	Buck 2012	Keeping th	Anthony S	Journal of	Keeping th	Gayle A. B	United Sta	The		2012	Case Stud	7th Grade (females)		Science			Teachers		computer-	
18	89	Pan 2022	The Role c	Anthony S	Journal of	The Role	Zilong Par	United Sta	This mixed-method s		2022	mixed-me	6th-grader	Experienced		15 (45-min-class session)			Teachers	Technology was very	
19	85	Nariman 2	PBL in the	Anthony S		PBL in the		United Sta	We explore teachers		2016	A single	Elementa	Intermedi	Science-	Three-		selected	(Teacher	"They all	
20	77	Kwon 2021	Integratio	Anthony S	Education	Integratio	Kyungbin	United Sta	This study investigat		2021	Quantitati	6th Grade	Non exper	Computer	The PBL					
21	75	Simons 20	The impac	Anthony S	Instructio	The Impac	KRISTA D.	United Sta	his study examined h		2006	quasi-exp	7th Grade	Experinced				The proble	Teacher	Teacher had ease ar	
22	73	Simons 20	Instructio	Anthony S	Journal of	Instructio	KD Simons	United Sta	This article reports o		2004	Case Stud	6th Grade	Non-		6 - 50 Mins class sessions			Embedde		
23	72	Cerezo 200	Problem-b	Anthony S	RMLE Onli	Problem-	Nancy Cer	United Sta	The purpose of this s		2004	Case Stud	middle gra	Experience	math and science			Teachers design each case to n			"Teachers
24	64	Valdez 201	Problem-b	Anthony S	Journal of	PROBLEM-	Joseph E.	Other: Phi	The study aimed to ir		2019	Descriptiv	Grade 9		Chemistry	(4		PBL			
25	63	Yeo 2014	Redesigni	Anthony S	Instructio	Redesigni	Jennifer Ye	Other: Sin	The introduction of p		2014	Case-Stud	Grade 9		Science			A real life	Realizing		
26	62	Ahdhianto	Improving	Anthony S	Universal	Improving	Erif	Other: Ind	This study aims to in		2020	quasi-	5th Grade	Teachers	Math	1 month					
27	58	Magaji 202	Promoting	Anthony S	Internatio	Promoting	Adewale M	UK	This research was in		2021	Qualitativ	Secondary	Non exper	Science	6 Weeks		The PBL pr	he		
28	57	Liu 2006	Middle scl	Anthony S	Interactive	Middle Scl	Min Liu, P	United Sta	This study examined		2006	Pretest an	6th Graders		Science	3 Weeks		Students	If students come across a scier		
29	54	Li 2018	An examir	Anthony S	Interactive	An examir	Hui-Chuar	Other: Tai	This		2018		Grade 5	Non exper	Math	19 lessons spread ov		The	Teacher		
30	50	Horak 201	Gifted mic	Anthony S	Journal of	Gifted	Anne K. H	United Sta	The purpose of this s		2017	Comparat	middle sc	Non exper	Science						
31	41	Pedersen	Teachersâ	Anthony S	Education	Teachersâ	Susan Pec	United Sta	Teachersâ€™ implem		2009		6th grade	4 experien	science			Alien Resc	Most		
32	40	Century 20	Finding tir	Anthony S	Internatio	Jeanne Ce	Finding tir	United Sta	In the Invasive Speci		2020	a quasi-ex	Grades 3-5	Non exper	Computer science (Transdisciplinary)						
33	38	Evendi 202	Evaluatior	Anthony S	Journal of	Evaluatior		Other: Ind	This		2021	Classroon	Junior High School					Teachers	a) before		
34	26	Ertmer 200	Facilitatin	Anthony S	Journal of	Facilitatin	PEGGY A. E	United Sta	In this exploratory st		2009	Explorato	Middle scl	Experienc	Mixed -		Planning,	"Sheila P.	"Tonya	P. 46	When
35	25	Wirkala 20	Problem-b	Anthony S	American	Problem-E	Clarice Wi	United Sta	Enthusiasm for prob		2011	Experimer	6th Grade - Middle Sc		Social Stu	1 and Half weeks			remind		
36	23	Liu 2012	Examining	Anthony S	http://dx.c	Examining	Min Liu, Je	United Sta	This study examined		2012	Qualitati	Six	Experienc				Problem	P. 60	P.54	
37	21	Goodnoug	Exploring	Anthony S	School Sci	Exploring	Karen Goc	Canada	This small-scale col		2006	Qualitativ	Grade 12	Non-exper	Science	1 (One) Year Prepara		In the	Teachers		
38	20	Liu 2021	Examining	Anthony S		Examining	Min Liu, Yi	United Sta	In this qualitative stu		2021	qualitative	6th Grade	Non		15-hr curriculum uni		Others sai	Finally,		: â€œthe
39																					
40																					
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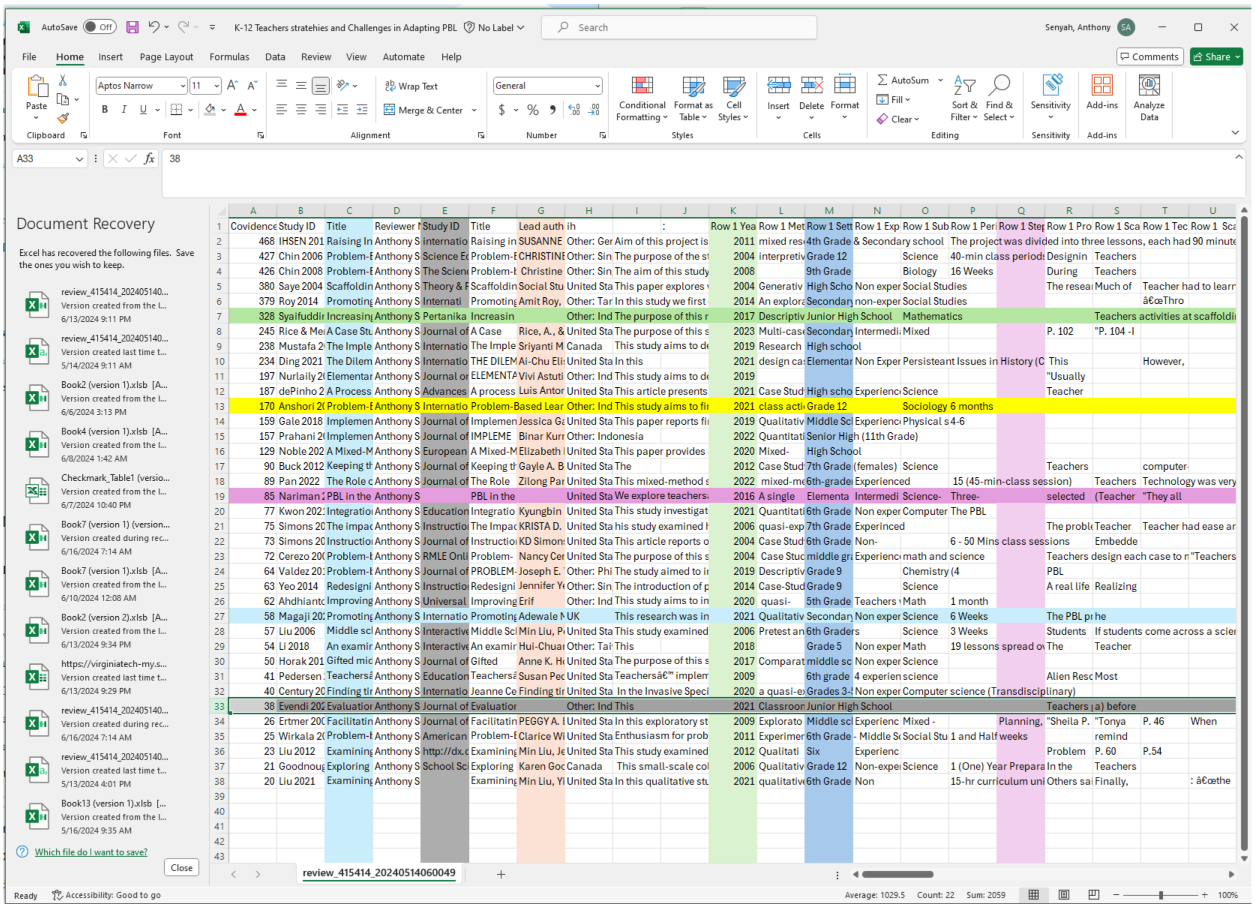
42																					
43																					

APPENDIX F

Extracted data Colored for Easy Reading and Analysis



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
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11	197	Nurlaily 2(	Elementar	Anthony S	Journal or	ELEMENTA	Vivi Astuti	Other: Ind	This study aims to de		2019							"Usually			
12	187	dePinho 2	A Process	Anthony S	Advances	A process	Luis Antor	United Sta	This article presents		2021	Case Stud	High scho	Experienc	Science			Teacher			
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33	38	Evendi 202	Evaluatior	Anthony S	Journal of	Evaluatior		Other: Ind	This		2021	Classroom	Junior High School					Teachers	a) before		
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35	25	Wirkala 2(	Problem-b	Anthony S	American	Problem-E	Clarice Wi	United Sta	Enthusiasm for prob		2011	Experimer	6th Grade	- Middle S	Social Stu	1 and Half weeks			remind		
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37	21	Goodnoug	Exploring	Anthony S	School Sci	Exploring	Karen Goc	Canada	This small-scale col		2006	Qualitativ	Grade 12	Non-exper	Science	1 (One) Year Prepara		In the	Teachers		
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