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Project-based and Problem-based Instruction: A Literature Review

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PROBLEM-BASED AND PROJECT-BASED INSTRUCTION:
A LITERATURE REVIEW

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By

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ABSTRACT

Science, technology, engineering, and mathematics (STEM) education has undergone great transformative reform during the last two decades with revised education standards calling for increased rigor to promote conceptual understanding of ideas and transferable 21st Century practices. Student-centered inquiry-based pedagogies like problem- and project-based instruction (PBI and PjBI) have begun to take root in K-12 STEM classrooms as an answer to the reform call. However, there is some disagreement of the specific characteristics of each pedagogy. There is also limited information regarding prevalence of these pedagogies in practice, their contextual patterns, degree to which they benefit all children, and the benefits/challenges of each method of instruction in the classroom. Thus, the purpose of this project was to systematically review the empirical research (*n* = 35 articles) on problem- and project-based instruction in K-12 education from 2000 to 2017 to build an empirical case for why they should be used in STEM education and to fill in some of the informational gaps.

Keywords: Project-Based Instruction, Problem-Based Instruction, STEM Education, K-12

I dedicate this thesis to my grandmother, Terry Kirkland, who has always inspired in me a passion for education and a drive for success. I also dedicate this work to my best friend, Colten, whose constant encouragement and advice throughout the thesis-writing process was both insightful and unwavering.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Over the past few decades, there has been an explicit push for active, inquiry-based approaches in the classroom (York, 2017) as well as a demand for deeper-level learning practices that "increase problem-solving, critical thinking, and creativity (Smith, 2017, p. 2)." Both Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS) have placed a focus on student-centered, inquiry-based instruction that promotes a conceptual understanding of material (National Governors Association Center for Best Practices, 2010; Three Dimensional Learning, 2018). Because of the new focus on learning conceptually rather than rote memorization, these standards have sparked a shift away from traditional forms of instruction (i.e. direct and lecture-based) and have created a movement towards inquiry-based instructional practices – especially in science, technology, engineering, and mathematics (STEM) classrooms. This movement is intended not only to increase rigor and relevance in learning the content, but to also help meet current job demands where the STEM job market steadily increases by an average of 3.3% annually (S&E Occupations, 2011). With the goal of becoming internationally competitive and increase the coherence between the supply of qualified STEM graduates and the demand to meet the rising STEM needs, K-16 teachers need curricular and pedagogical suggestions for increasing rigor and relevance for teaching STEM subjects.

One possible solution to help teachers meet the demands for increased rigor and relevance in STEM is project-based instruction (PjBI) and problem-based instruction (PBI). In general, both forms of instruction work to include authentic, real-world problems that are the focus of a lesson or unit, and students work together to attempt to solve those problems using content knowledge (PBL, 2001, PjBL, n.d.). Through PBI and PjBI, students are learning their core content, oftentimes with the aid of technology, in ways that address a multi-faceted, ill-defined problem either given to or brought forth by students.

Despite the fact that project-based and problem-based instruction have been around for decades (Research Spotlight in PjBL, n.d.) and appear to be positive for developing student conceptual understanding, there has been a lack of consensus on what is meant by either. Within the ever-growing body of literature on student-centered instructional methods, terms like inquiry-based, project-based, problem-based, unguided discovery, open-sourced, intentional learning, and hands-on, minds-on learning are often, unfortunately, used interchangeably (Mergendoller & Thomas, n.d.). This ambiguity surrounding project-based and problem-based instruction lends itself well to fitting in a variety of contexts and fields of study like STEM; many forms of student-centered learning do overlap in some respects, such as giving students choice in their learning that is appealing to most teachers (Condliffe, Quint, Visher, Bangser, Drohojowska, Saco, & Nelson, 2017). However, this lack of distinction between what is project-based or problem-based and what is not becomes dangerous when project-based and problem-based learning are inextricable from other forms of student-centered learning and lacking in stand-alone empirical research.

Likewise, no comprehensive literature review has been conducted over empirical research in PBI and PjBI in the last few decades, decades that have seen tremendous educational reform. Thus, there is a need to review the research on PBI and PjBI to highlight the benefits of these instructional methods, and to determine to what degree these benefits are aligned to demands of current educational reform in STEM education -- i.e., to increase rigor and relevance along with 21st century skills that will not only provide students with a deep conceptual understanding of material, but ultimately prepare them for careers in STEM or work in a STEM-related field.

Therefore, the purpose of this review is to systematically examine the empirical research on PBI/PjBI from 2000 to 2017 to establish why PBI/PjBI should be promoted in STEM education for grades K-12. Specifically, this literature review has concentrated on the following research questions:

Research Question 1: How are project-based and problem-based learning defined in the research, and what are the primary characteristics of each?

Research Question 2: How prevalent is PBI/PjBI research in K-12 STEM education and what are the general contextual patterns of this research?

Research Question 3: To what extent and in what ways does the research surrounding PBI/PjBI investigate issues of equity and diversity in K-12 STEM education?

Research Question 4: What are the commonalities and differences in benefits and challenges between PBI or PjBI in K-12 STEM education?

Research Question 5: What suggestions could be made for future PBI/PjBI research in K-12 STEM education?

CHAPTER TWO

METHODOLOGY

Inclusion and Exclusion Criteria

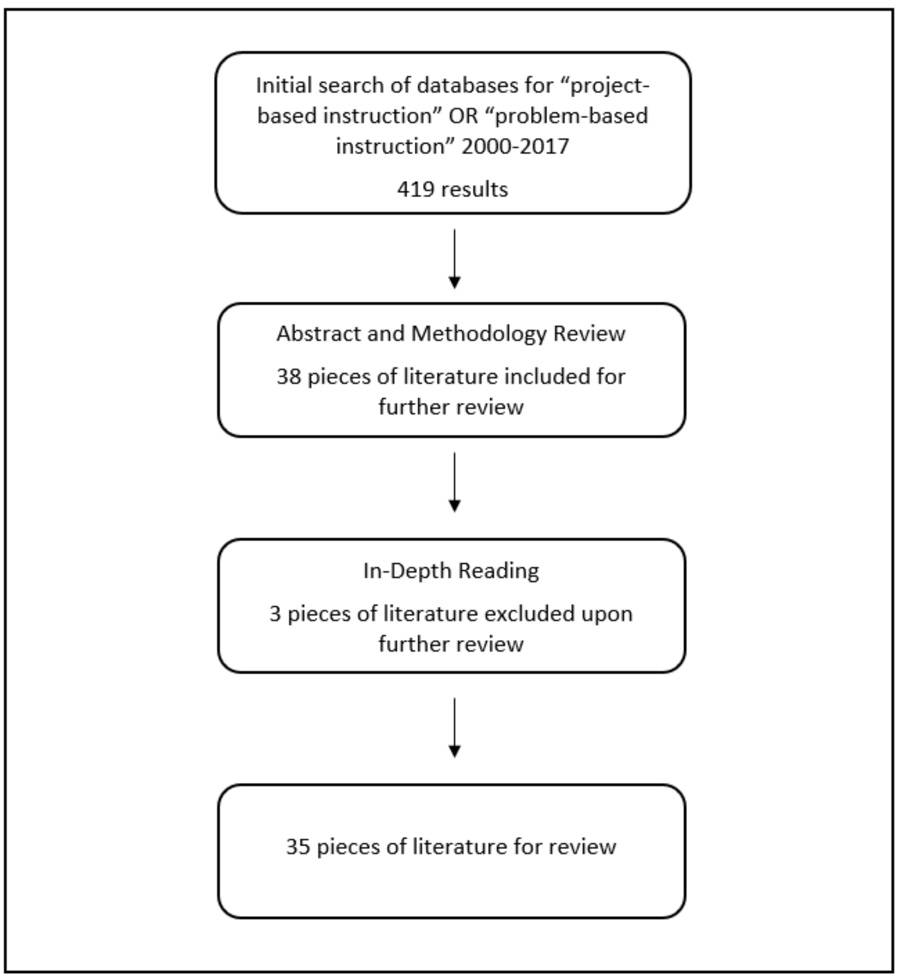
The inclusion/exclusion criteria for the studies reviewed were determined by the integration of conceptual and pragmatic considerations. First, there are major gaps in the knowledge base of PBI particularly when it comes to the divide between theory and practice (Corcoran & Silander, 2009). Also, prior reviews were based on small sample sizes that were observational and qualitative in nature (Corcoran & Silander, 2009). Therefore, the inclusion criteria for the reviews in this study (i.e., empirical, sample size of [$N \geq 4$]) were formed in part by the criticisms and suggestions of Corcoran and Silander (2009). The sample size of greater than or equal to four was used as many of the studies had a comparison of PBI to another mode of instruction (i.e. direct instruction, lecture-based instruction, 'traditional instructional methods'), and so there were at least two classrooms for each group studied. Had the sample size been greater than or equal to a larger number, the research would have yielded much fewer results. Next, the criteria were aligned with the research questions posed, including only research conducted in a K-12 setting, and whether the article included problem-based or project-based instruction as one of the main instructional methods focused on in the research. Finally, to ensure that the empirical studies were of quality, only peer-reviewed research with triangulated data was considered.

Search and Abstract Review Methods

To search for literature, the collection of databases with access provided from Western Kentucky University was used. Specifically, Academic Search Complete, Education Full Text (H.W. Wilson), Educational Administration Abstracts, ERIC (U.S. Department of Education), PsycARTICLES, Psychology and Behavioral Sciences Collection, PsycINFO, and Teacher Reference Center databases were used. Using the Boolean search parameters “project-based instruction” or “problem-based instruction” and constraining the search to January 2000 to December 2017, peer-reviewed, full-text documents of academic articles without regard to field of study, the search yielded only 270 results. When the results were expanded to include peer-reviewed articles from GALE, Springer, SAGE Journals, Wiley, and Taylor & Francis collections of Western Kentucky University’s online library, 419 results were found. However, when removing duplicates, only 253 articles were yielded. Each of the abstracts were reviewed using the inclusion criteria previously stated. Occasionally, the methodology needed to be examined to ensure the data was empirical, triangulated, or had a large enough sample size. Of the two hundred fifty-three articles, two hundred fifteen articles were excluded because they did not meet one or more criteria. Therefore, based on the abstracts and methodology reviewed, 38 pieces of literature (approximately 15%) were included for a full review.

To begin an in-depth reading and review of the 38 pieces of literature, a spreadsheet was created in order to systematically analyze the research based on basic bibliographic information; methodological details; whether the article included PBI, PjBI, or both; whether the definition of the instructional methods examined were given; and any other data that was felt would aid in answering the research questions posed. After further investigation of the articles, 3 were found to be inappropriate for the review. The most common reason for exclusion among the articles was that upon in-depth reading, it was discovered that they were only peripherally related to PBI/PjBI. Figure 1 contains a flow chart illustrating the process of narrowing the research to the 35 pieces of literature used for review.

Figure 1. Methodology Using Inclusion/Exclusion Criteria



CHAPTER THREE

DIFFERENTIATING BETWEEN PROBLEM- AND PROJECT-BASED LEARNING

Problem-based and project-based instruction can be traced back to two sources—educational constructivist founder John Dewey in the early 20th century (Research Spotlight in PjBL, n.d.) and a medical program in McAster University in 1968 (Walker & Leary, 2009). Over time, however, the increase in the amount of research conducted on PBI/PjBI resulted in a variety of definitions of these terms. Therefore, in the sections that follow, a general consensus is established for defining characteristics of PjBI and then PBI, followed by disparities between researchers when defining each term. Finally, an operational definition is given based on these patterns.

Project-Based Learning/Instruction (PjBI)

Research on project-based instruction (PjBI) can be distilled down to a set of defining characteristics, and there was relative consensus on these characteristics among the articles studied with relatively few discrepancies. PjBI begins with a “driving question” that arises from authentic, real-world, ill-defined problems (Petrosino, 2004) and is intended to promote collaboration and cooperation among the learning community (Hung, Hwang, & Huang, 2011). Because students work together to solve an authentic problem, there is a level of autonomy inherent in PjBI; however, the range of autonomy will differ lesson to lesson and classroom to classroom based on a variety of factors (i.e. lesson content, time constraints, objectives) (Dresden & Lee, 2011; Petrosino, 2011). In PjBI, students engage in a variety of processes including investigation and problem-solving which culminates in a final product (e.g., report, model, proposal, design) that showcases depth of student learning that can be shared with others (Barak & Zadok, 2007; Karaçalli & Korur, 2014; Selmer, Rye, Malone, Fernandez, & Trebino, 2014). Finally, PjBI requires students to reflect on their learning and outcomes, which allows them to practice and/or develop their metacognitive skills (Dresden & Lee, n.d.; Newman, Dantzler, & Coleman, 2015; Selmer et al., 2014).

The teacher's role in a PjBI-led classroom is that of a facilitator of learning where their primary duty is to scaffold students' conceptual understanding. For example because PjBI typically requires students to develop and/or answer ill-defined questions – questions they may not be particularly comfortable dissecting after years in a traditional setting-- it might be necessary for the teachers to initially scaffold the problem-solving process (e.g., investigation and data collection protocols) to prevent cognitive overload (Duncan & Tseng, 2010; Holmes & Hwang, 2016; Jakovljevic & Ankiewicz, 2016). These scaffolds would diminish or change in focus as students gain more experience with PjBI.

As said previously, there were some discrepancies that arose in the research, particularly pertaining to student autonomy and the community of learners in PjBI. For example, there is some disagreement among researchers as to whether this problem is posed by the teacher or the students themselves, as there is a wide range of levels of student autonomy given under the label PjBI. Some researchers, like Morales & Bang (2012), argue that students should have full autonomy when posing their question, investigating, and collecting data, while others like Selmer et al. (2014) take a less radical approach, stating that students should have most of the responsibility for learning, but that the question should be posed by the teacher in a well-defined, but complex, way. Another discrepancy between researchers was who became a part of the community of learners during the PjBI experience. Some researchers argued that the lesson or unit should involve a community of students (Duncan & Tseng, 2010; Petrosino, 2004), while others believed this community should extend beyond the walls of the classroom and include members of society (Newman et al., 2015; Selmer et al., 2014). Still others had different opinions on the length of PjBI, going from as little as two weeks (Dresden & Lee, n.d.) to as long as 16 weeks (Hung et al., 2012).

Regardless of the differences in conclusions draw from the research among individual researchers, a final consensus based on the many articles included for review is that project-based instruction be defined in the following way:

> Project-Based Instruction (PjBI) is a student-centered pedagogical approach in which a community of learners must solve an authentic problem through collaboration and cooperation by inquiry and data collection, that this investigative process be scaffolded by the teacher acting as a facilitator of learning, and that the result of which cumulates into an artifact and a reflection of the process by the students.

Problem-Based Learning/Instruction (PBI)

Research featuring problem-based instruction (PBI) had much greater variation in the descriptions and thus, defining distinct characteristics for the model is more challenging than the research on PjBI. For example, there is some disagreement about who initiates and directs PBI with some research indicating that it is teacher-directed (Drake & Long, 2009) and others suggesting it should be student-directed (Nordin, Samsudin, & Harun, 2017). Likewise, the degree to which collaboration or group work is a *key* characteristic in PBI is also less known (Drake & Long, 2009; Robinson, Dailey, Hughes, & Cotabish, 2014). There is some general consensus that PBI assessment should be focused more on the learner's process and thoroughness of solving the problem rather than the on the final answer (Sengur & Tekkaya, 2006; Ward & Lee, 2004). However, the types of problems are less definitive; some research suggests the types of problems should be based on real-world scenarios, while others recommend the problems should be ill-defined and/or carefully organized and constructed (Gomez-Pablos, Martín del Pozo, Munoz-Repiso, 2017; Wright, Shumway, Terry, & Bartholomew, 2012). One interesting thing to note is that none of the research on PBI stated that this model of instruction required an authentic problem or collaboration of any sort, as in PjBI. In addition, while every problem in problem-based instruction should result in a solution, there was no product that needed to be created in tandem with this solution like PjBI. In order to be aligned with the broad characterization of PBI in the literature, the final consensus for a definition of problem-based instruction is as follows:

> Problem-Based Instruction is a student-centered model where students are presented with an ill-defined, real-world problem and the teacher acts as a facilitator. This pedagogical approach to learning focuses on the process rather than the product during assessment.

A Comparison of Problem-Based to Project-Based Instruction

The following 3-column chart illustrates the similarities and differences between PBI and PjBI:

Table 1

Similarities and Differences of Characteristics of PjBI and PBI

Project-Based Instruction	PjBI & PBI	Problem-Based Instruction
• Focus is on the cumulating product/artifact • Generally well-defined characteristics in the research • Community of learners involves members of society in collaboration • Cooperative learning integrated • Typically long-term (2-15 weeks)	• Begins with a real-world question • Student-centered • Self-directed learning • Teacher acts as facilitator • Constructivist-based • No “right way” to solve • Scaffolded	• Focus is on the process • Generally broad in the research • Community of learners is the students only • Cooperative learning optional • Typically short-term (approximately a few days per problem)

As can be seen from the chart above, there are many general similarities, but a few prominent differences between PBI and PjBI. To begin with, both are student-centered, student-driven constructivist-based pedagogical approaches that begin with authentic, ill-defined problems or questions. Both require the teacher to serve as a facilitator of learning, and one of the teacher's responsibilities as a facilitator is to help scaffold the inquiry process. However, the stark differences between PjBI and PBI include the length of time, the strictness of characterization, the focus for assessment, and the type of community context. The community for PjBI involves cooperative learning and collaboration between peers and members of society, but PBI does not even require small-group work in all cases. Project-based instruction typically takes much longer to implement than problem-based instruction, and although both spend the majority of the time solving the problem at hand, PjBI tends to focus on the artifacts used as a demonstration of learning rather than the process when assessing the students. Finally, and perhaps most importantly, is that project-based instruction has a more specific characterization and list of vocabulary adjoined to it, such as driving question, artifact, and collaboration. Problem-based learning, on the other hand, is very broad and apt to personalization by those who use it. Because the definition of problem-based learning in the field of education is simply learning through [real-world] problems, this pedagogical approach can take on a variety of forms. It is flexible, but it is likely to cause variations in the research when it comes to student outcomes and implementation of methods.

CHAPTER FOUR

PREVALENCE OF PBI/PjBI IN STEM AND CONTEXTUAL PATTERNS

Of the research included in the review, thirty-five (88%) of the forty articles were specific to one or two disciplines. The overwhelming majority of these articles (80%) were directly related to STEM disciplines. Furthermore, only seven articles were non-STEM, subject-specific articles. Table 2 below describes the spread of the articles within problem-based and project-based within a range of subjects by author name. The special needs articles include gifted studies and ESL studies, as those were the only groups of students with special needs studied within PBL and PjBL. The “Other” section includes non-STEM, but still subject-specific, articles. The last row of each section includes articles non-specific to any discipline but still directly related to PBI or PjBI. As this review focused primarily on PBI/PjBI in STEM Education, only these articles are analyzed in this section.

Table 2

Discipline contexts found in literature review

Type of Instruction	Subject/Discipline	Authors
Problem-Based Instruction	Math	Firdaus, Wahyudin, & Herman (2017); Lan et al. (2010); Wright et al. (2012); Xiaogang et al. (2007)
	Science	Chang (2001); Drake & Long (2009); Nordin, Samsudin, & Harun (2017); Robinson et al. (2014); Sungar & Tekkaya (2006)
	Engineering/Technology	Chang (2001); Newell (2008)
	Special Needs	Robinson et al. (2014)
	Other	Mergendoller, Maxwell, & Bellisimo (2000); Ward & Lee (2004)
	Non-Specific	Dole, Bloom, & Doss (2017); Hmelo-Silver, Duncan, & Chinn (2007);

		Hung & Loyens (2012); Kirschner, Sweller, & Clark (2006); Schmidt et al. (2007)
Project-Based Instruction	Math	Han, Capraro, & Capraro (2014); Holmes & Hwang (2016)
	Science	Colley (2005); Colley (2008); Dresden & Lee (n.d.); Duncan & Tseng (2010); Han, Capraro, & Capraro (2014); Newman, Dantzler, & Coleman (2015); Petrosino (2004); Schneider et al. (2002); Selmer et al. (2014); Weizman, Shwartz, & Fortus (2008)
	Engineering/Technology	Barak & Zadok (2009); Gomez-Pablos, Martin del Pozo, & Munoz-Repiso (2017); Grant & Branch (2005); Han, Capraro, &

		Capraro (2014); Hung, Hwang, & Huang (2011); Inserra & Short (2013); Jakovljevic & Ankiewicz (2015); Karacalli & Korur (2014); Martinez & Schilling (2010); Morales, Bang, & Andre (2013)
	Special Needs	Beckett (2005)
	Other	Grant (2011); Grant & Branch (2005); Halvorsen et al. (2012); Hung, Hwang, & Huang (2011); Mikulec & Miller (2011)
	Non-Specific	Dole, Bloom, & Doss (2017); Kwon, Wardrip, & Gomez (2014)

Note. the table above has multiple sources that have been repeated in multiple categories due to the article belonging in multiple disciplines.

PBI versus PjBI in STEM Learning

Based on the data collected for this review, the bulk of the research conducted on PBI and PjBI since the turn of the 21st century has been composed of literature focused in STEM disciplines. While many of these articles in the table above have been focused on the integration of technology into PBI/PjBI settings, the others have primarily been science-based PBI/PjBI studies. There were very few studies in math, and nearly all of the studies were problem-based in nature. There was only one study that could have fallen under the “Engineering” category. One interesting finding of the research is that since the beginning of this century, there has been a rise of what is known as “project-based science”. Project-based science is exactly what the name implies—project-based instructional methods in the science disciplines. However, since a relatively large body of research has surrounded the topic of PjBI in science, it is fitting that it be given its own name.

Problem-Based Studies in STEM

Within the articles of problem-based literature, there were eleven results within the STEM disciplines. Seven of these articles (64%) were directly related to technology of some sort integrated into the PBL lessons. Beyond technology, other topics that have been researched in relation to PBI include student perspectives, motivation, achievement, learning strategies, and differentiation practices. Although the technological aspect was what most of the articles had in common, there was a unique spread of research topics within problem-based studies; even among the studies that included technology, the way they studied technology and PBI together varied widely. For example, one study focused on using PBI to teach a new computer software (Wright et al., 2012), while another study compared PBI facilitated by a teacher to a participatory simulation on a computer (Newell, 2008). Yet other studies focused on the integration of technology as an aide within the PBI setting, such as Lan, Sung, Tan, Lin, & Chang’s (2010) attempts to support problem-based computational estimation with mobile devices. In Wright et al.'s (2012) study, they compared problem-based learning to other forms of instruction to teach the geometry program Geometer's Sketchpad to students. They found that student achievement was the highest when implementing direct instruction versus problem-based, but students ranked book learning and problem-based learning as more effective than direct instruction for their own learning (Wright et al., 2012). This shows that in at least one study, there is a discrepancy between student perceptions and achievement.

Aside from the ever-increasing incorporation of technology into PBL research, another topic that is focused on extensively in the literature is student achievement. It is interesting to note that while most of the hypotheses in the research surrounding student achievement in PBL stated that the researchers believed it would not be as effective as other forms of instruction, nearly every research article centered on PBL has indicated that it is at least as effective as direct or other traditional forms of instruction. For example, results from one study showed that those in the PBL group (n=67) were better able to apply their knowledge of scientific method and experimental design when presented with real-world problems as opposed to the control group (n=60) (Robinson, Daily, Hughes, & Cotabash, 2014). In the study that compared PBL to participatory simulation through an online program, the online program was more effective at expanding students' overall achievement (this includes knowledge and application), but that the students' pre- and post- test scores showed no difference in the knowledge section (Chang, 2001). However, the PBL approach did show significant gains in the knowledge portion. These results, in other words, provided some evidence that the PBL approach was more effective than the online approach in terms of grasping understanding of the content, but that the computer approach was more effective in allowing students to transfer and apply that content (Chang, 2001). In yet another study involving technology and studying achievement, (Newell, 2008) found that the problem-based learning method was not only at least as effective as direct instruction, but actually produced more positive outcomes than direct instruction when PBL was paired with computer-internet technology.

The National Education Association, a founding member of the Partnership for 21st Century Skills, states that there are four big "C's" that should be integrated into every lesson and every classroom in order to ensure students develop into productive citizens in the 21st century: collaboration, communication, creativity, and critical thinking (National Education Association, 2012). Over half of the problem-based research articles in STEM (55%) focused on at least one of these four "C's." The major emphasis within PBL, surprisingly, was in collaboration with peers. All of the studies claimed that students appeared to collaborate with their peers more than students in a traditional, direct instruction setting (Drake & Long, 2009; Gomez-Pablos et al., 2016; Nordin et al., 2017). Whether this collaboration is correlated to student achievement was not studied. Another surprising finding was the lack of focus on critical thinking in PBL; only one of the articles focused on critical thinking within a problem-based context (Sengur & Tekkaya, 2006). They contend that when students construct knowledge in a context similar to that context in which they use that knowledge (in other words, a PBL setting), students are more encouraged to think critically about problems (Sengur & Tekkaya, 2006). Although there were a multitude of studies that focused on collaboration in a PBL setting, no articles specifically focused on increase of general communication or increase of communication skills or creativity within a STEM discipline. Considering the shift in standards for STEM content towards CCSS and NGSS, critical thinking within a PBI context should be a focus for future research.

One final, and perhaps most prominent, pattern within the problem-based research in a STEM context is the student perceptions and beliefs studied. Lan et al. (2010) found that both student perceptions and achievement growth using PBL were both positive. Although Nordin et al. (2017) did not study student perceptions toward PBL, they did find that student perceptions toward the content of conservation did improve through learning in a problem-based context. Chang (2005) found that students in a PBL computer-assisted learning environment were more motivated and took a more active role in student learning than the direct instruction control group. Another, yet less promising, article said students reported valuing the student-centered aspect of PBL but that this did not extend to other aspects of learning (Sengur & Tekkaya, 2006). For example, the PBI group (n=30) self-reported being more motivated to learn than the control group (n=31) in a direct instruction setting, but that there was no statistically significant difference in students self-efficacy for learning and performance among learning conditions. Furthermore, students perceived the biology content to be "interesting, important, and useful for understanding future content" as noted by the researchers (Sengur & Tekkaya, 2006). Although the other studies did not directly focus on student perception, beliefs, and motivation, all studies peripherally tied these to their studies. There was only one case (noted earlier by Chang's study) that claimed that student learning beliefs were not affected by a problem-based setting. There were no studies that claimed PBL had a negative effect on student perceptions and beliefs towards themselves, the instructional method, or the content in which the method was implemented.

Project-Based Studies in STEM

The focus of the PjBI articles was qualitative rather than quantative in nature. More specifically, while most of the articles were completely or mostly qualitative in nature (i.e. describing the PjBI process, student interviews), there were many that still contained measurable, quantitative outcomes (i.e. student achievement, motivation, self-regulation, incorporation of 21^{st} century skills). There was also a focus on comparing PjBI to other forms of instruction and incorporating technology to test its effectiveness.

Research examining project-based instruction in STEM (n = 3 or 25% of the viable articles reviewed) indicates that PjBI increases student achievement. For example, one study found that students from low-SES backgrounds (n=30) improved far more academically in a PjBI context than a traditional classroom approach (Holmes & Hwang, 2016). Considering the charge for the No Child Left Behind Act was to close the racial/economic achievement gap within schools and this research finding, PjBI might be a factor that could help to mitigate this phenomenon (Holmes & Hwang, 2016). In addition, all three research studies in this sample found that knowledge retention was higher for students who experienced PjBI than for students who did not (Holmes & Hwang, 2016; Hung, Hwang, Huang, 2011; Karacalli & Korur, 2014). This finding has profound implications for classroom practices.

Student motivational factors and perceptions about PjBL are other factors commonly studied within PjBL in STEM research. For example, students in one study who experienced PjBL reported an increase in intrinsic motivation, perceived autonomy, appreciation for peer learning, and self-regulatory skills (Holmes & Hwang, 2016). This increase in student motivation was also demonstrated in a study that incorporated technology with PjBI (Hung, Hwang, & Huang, 2011). In addition, in one article researching project-based instruction using robotics, there was more engagement and a stronger motivation among students who did not typically engage in lessons to work both independently and in collaboration with others (Barak & Zadok, 2007).

There were three other measurable skills present in PjBI research literature—creativity, collaboration, and critical thinking. All of the research that focused on these three outcomes showed a correlation between the use of project-based instruction and the increase in these three areas. Gomez-Pablos et al. (2017) found that student creativity was developed within, but perhaps not as a result of, working in a PjBL setting. In the research by Morales, Bang, and Andre (2012), they made a set of criteria in their rubric that focused on creativity, and in their discussion, they discussed how "creative play" enhanced the learning process. Creative play in their study was defined as off-task activities that ultimately contributed to student learning (Morales, Bang, & Andre, 2012).

Concerning the focus on collaboration as an observable, measurable behavior in the research, Morales, Bang, and Andre (2012) found that 30 of the 116 (26%) instances of social interactions coded within their research related to peer-mentoring and social dynamics in the classroom were collaborative interactions where participants were in equal roles, indicating that there seemed to be an increase in collaboration between students in a PjBI setting versus a more teacher-centered instructional setting, such as direct instruction. Likewise, Petrosino (2004) found that by having students interact like real scientists in the field, students felt more motivated and engaged in the data collection process and had a deeper understanding about the connections between the collection and implications of the data for the content being studied.

Half of the articles found in literature pertaining to relevant PjBI research involved some use of technology and to what degree the use of technology correlated to positive student outcomes. The technology used in the projects varied widely—no one project implemented the same technological tools. Many of these studies claimed that their findings supported past research that claims that PjBL is an effective tool for motivating students, increasing conceptual understanding their understanding, and also increasing student learning strategies such as organization and determining importance of information (Hung, Hwang, & Huang, 2012; Jakovljevic & Ankiewicz, 2016; Morales, Bang, & Andre, 2013). There was in increase in both academic achievement and retention in PjBI groups studied (Karacalli & Korur, 2014). These results indicate that the use of technology in a PjBI setting may result in overall higher student success.

Together this research suggests that project-based instruction could benefit students' achievement, knowledge retention, and motivation. Likewise, this research has indicated that PjBI in STEM could help to develop students' 21st Century Skills (i.e., collaboration, communication, creativity, and communication) (National Education Association, 2012) even though this research is limited in scope and quantity.

CHAPTER FIVE

PROBLEM-BASED AND PROJECT-BASED LITERATURE PERTAINING TO ISSUES OF EQUITY/DIVERSITY

Only three (11%) of the twenty-eight articles included in the review explicitly focused on special needs of students. None of these articles included any studies pertaining to race/ethnicity. One of the articles focused on teaching ESL students through project-based instruction and was considered a non-STEM discipline-specific article and included in a previous section. One of the articles was more general, focusing on how PjBL affects high, middle, and low achievers, inherently including the exceptional students both above and below average. The final research article addressed multiple instructional interventions in STEM for gifted children, and among those instructional practices implemented was problem-based.

The first study for learners concerning equity was created by Han, Capraro, & Capraro (2014), and focused on how diverse levels of achievers were affected by STEM PjBI. This was a three-year longitudinal case study of a high school in Texas, where they attempted to investigate not only how PjBI affects math achievement for students of different levels, but also how these students' individual factors (i.e. race/ethnicity, gender, SES, gifted) influenced this achievement through advanced research analysis methods. The researchers in this study found that low performing groups of students performed at a higher level than the middle and high performing groups when considering student achievement in PjBI. They also found that Hispanic students' growth outperformed their non-Hispanic counterparts over the course of the study on student achievement. This achievement was measured by the TAKS exam at the end of each year. However, they did find that individual factors played a significant role in student achievement, especially in low-SES students, and contended that students' economic status contributed to their lack of engagement in projects, impacting their achievement over time.

The final research article found pertaining to students with exceptionalities was a study focused on a problem-based instructional intervention for gifted students in STEM called STEM Starters. Robinson et al. (2014) found that the 87 students included in the two-year study benefitted from being allowed to explore the content through problem-based units. Robinson et al. (2014) reported that the students were better able to design scientific experiments when presented with a real-world problem, and that the students could also bridge connections through different scientific content and concepts. This study was implemented through problem-based lessons that were guided by Next Generation Science Standards (NGSS), which encourages students to actively engage in inquiry-based, problem-centered experiences (Three Dimensional Learning, 2018).

In total, there were only four articles that could be considered as centering on the effect of PBL/PjBL on issues related to equity and diversity (e.g. SES groups, minorities, students with exceptionalities). There were a wide variety of special needs addressed within the articles—low-SES, race/ethnicity, gifted, ESL, and low-achieving—but the lack of research that relates these instructional strategies to how they can be differentiated to meet the needs of these students presents a gap that can and should be filled with future research in these areas. Within education, there is a focus on research-based strategies that increase students learning and, in particular, strategies that promote differentiation in the classroom. While this differentiation has been the focus for many studies for cooperative learning, there is still a need for more studies in PBL/PjBL related to differentiation. Three of the four articles that did focus on differentiation and other issues of equity and/or diversity were within the context of project-based instruction. This indicates an area of growth for future research—specifically targeting to what degree problem-based research addresses the needs of diverse populations.

CHAPTER SIX

COMMONALITIES AND DIFFERENCES BETWEEN BENEFITS AND CHALLENGES OF PROJECT-BASED VERSUS PROBLEM-BASED INSTRUCTION

The purpose of this review was to discover why PBI or PjBI should be used in STEM education in a K-12 setting. Although there have been reviews conducted on both PBI and PjBI in the past few decades, none have centered on research conducted in K-12 settings. While including postsecondary studies would effectively paint a more comprehensive picture of what the entire body of research says concerning these instructional methods, there were a few reasons for only including K-12 studies. The first reason is a practical one—teachers in a K-12 setting who want to keep up with research-based practices can use this as a tool for determining whether to include PBI or PjBI in their classroom. Secondly, what is considered effective in a postsecondary setting may not transfer to a K-12 setting. There are a strict set of standards in K-12 schools that need to be implemented, larger variation of student needs and developmental differences between the ages of the students being studied in K-12 versus post-secondary, and other factors that could contribute to a difference of results. Thus, a need was revealed for a literature review specifically for K-12 studies. The results of the review found that despite the seemingly heavy amount of research for problem-based instruction and project-based instruction in postsecondary settings, there was a serious lack of research in the K-12 setting. The overwhelming majority of the articles that were found were non-scientific and prescriptive in nature; rather than studying the effectiveness of these pedagogical methods, they simply began with the assumption that the methods were already effective and described how to use them in the classroom. Of the studies that were scientific, the majority were within STEM disciplines.

Despite the lack of a large body of research surrounding both problem-based and project-based instruction, there were some various similarities and differences that can be drawn from this study. To begin with, both PBL and PjBL studies reported that as compared to more traditional forms of instruction such as lecture-based and direct instruction, students in both PBL and PjBL settings were better able to bridge connections between the content they were learning and both prior knowledge and content in other contexts. This indicates that students had a deeper conceptual understanding of the content when they were actively learning and constructing knowledge, which is the case with both instructional strategies and is aligned with what research says about constructivist learning theory (Piaget, 1973). In addition, implementation of either instructional type led to an increase in both critical thinking and collaboration, although the studies focused far more on collaboration than on communication.

One of the major distinctions found between the two instructional methods was the technology component within each. Project-based studies were far more likely to incorporate technology as the content focus (i.e. webpage design, a VR classroom, robotics), while PBL was more likely to integrate technology as an aid to the instructional method (i.e. use of calculators, computers) and how these affect the effectiveness of the method (Chang, 2001; Gomez-Pablos, Martin del Pozo, & Munoz-Repiso, 2017; Han, Capraro, & Capraro, 2014; Hung, Hwang, & Huang, 2011; Inserra & Short, 2013; Jakovljevic & Ankiewicz, 2015; Karacalli & Korur, 2014; Morales, Bang, & Andre, 2013; Newell, 2008). An implication for teachers here is that based on the research, there are likely far more guides for implementing projects in the classroom when the focus is on technology, and far more resources for implementing problem-based instruction with the aid of technology.

A second major distinction found between PBI/PjBI research in STEM was the area of STEM focused on within each instructional method. Problem-based studies were far more frequented by math classrooms than by any other area within STEM, but project-based studies were more concentrated in biology and technology related courses. This makes sense within context. Math classrooms are based around problems that need to be solved, and so problem-based instruction seems as if it should naturally occur in a math classroom. However, a limitation of this research and among math education in general is the tendency to sanction math as a subject that stands alone from other subjects. In reality, mathematics is a language that all subjects speak, and the flexibility of project-based instruction would allow for an interdisciplinary project of mathematics within other content that may be wonderfully successful, if only research would focus on it.

There were also some significant differences found between student outcomes in PBI versus PjBI. Students in a project-based setting had a negative perception about the amount they have learned, yet the assessments repeatedly showed that they performed at least as well as the control groups. In addition, the knowledge retention in PjBL was higher for students versus non-PjBL instructional practices. Problem-based studies did not exhibit either of these findings, and in fact the converse of the former statement was true: some studies in PBL showed that lecture-based and direct instruction showed more positive growth academically than the problem-based instructional strategy for multiple studies. Students and teachers both perceived book learning and direct instruction as more effective than problem-based instruction (Wright et al., 2012). However, paradoxically, students in PBL reported having a higher perception of utility value and appreciation of the content they were learning than the PjBL studies reported.

This has many implications for the classroom setting. First of all, these studies all indicate that both problem-based and project-based are valid instructional methods that are at least as effective as traditional methods of instruction for improving student achievement in multiple content areas. However, project-based studies are seemingly more effective both in terms of student achievement and student perceptions of the content. One major concern from teachers is that PjBL takes too long to implement, but Petrosino (2004) contends that although the PjBL approach seems to take longer than a unit taught using traditional methods, more standards were covered in the PjBL unit than the traditional one, because more connections were being made. Secondly, it seems from the research that it is important to increase not only student perceptions, but also teacher perceptions of the effectiveness of PjBI in the classroom. Students are highly engaged in a PjBL setting and so it may feel to students that they are learning less because they are enjoying the content more. This misconception is one that aligns easily with content in a real-world setting—it is difficult to highlight where we use mathematics, for example, when we are enjoying our favorite hobbies because we are doing mathematics conceptually and hands-on rather than theoretically through practice problems. It is important for students to recognize when they are learning and applying the content both in a PjBL setting and in the real world. It may be even more important to help teachers reach this same recognition in order to facilitate this metacognition in their students through project-based and problem-based learning.

CHAPTER SEVEN

CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

The major question this literature review was attempting to answer was "Why should we promote PBI/PjBI in STEM, particularly for grades K-12?" The results for problem-based instruction are inconclusive. When student perception, teacher perception, and student achievement results all indicated that direct instruction was a more effective method for student learning, problem-based learning cannot be recommended specifically over any other method. However, problem-based instruction is such a broad method, and because of the inconclusive and broad definitions of this method, there may be more research under another term that better supports problem-based instruction. For example, there is plenty of research that supports inquiry-based and cooperative learning instructional strategies, and both of these could be components of problem-based learning under a narrower definition. In addition, perhaps there was an incongruency between the appropriateness of the strategy and the goals they were assessing for student achievement. Finally, due to the scarcity of articles in a K-12 setting that focused on PBI/PjBI, what conclusions can be made about the findings are limited.

However, the body of research gathered for this review all indicate that project-based instruction should be implemented in STEM. There was a significant closure of gaps in both low- and high-SES students and low- and high-performing students when implementing PjBL. In addition, students had a more positive perception of PjBL than any other instructional methods that the studies had compared it against. Project-based instruction is aligned well with NGSS and ACTFL standards and could aid in the No

Child Left Behind Act by closing achievement gaps. Each unit of PjBL covers multiple instructional standards, and as knowledge retention is higher in PjBL than other traditional modes of instruction, there would be less re-teaching that would save time later in the year for teachers. For all of these reasons based on the research studied, project-based instruction should be included not only in STEM, but in all disciplines.

The fifth research question that built up to the overall driving question was, "What suggestions could be made for future PBI/PjBI research in K-12 STEM education?" Future research for problem-based instruction should primarily be focused on constructing a more specific definition of what characteristics compose PBL. Then, once a consensus has been formed, there should be more studies that focus on how to properly assess problem-based instruction. Should the focus of PBL assessment be on rubrics like in PjBL or should students be assessed in a more traditional way like exams? This is one question that could be focused on. As far as future research for both problem-based and project-based studies, the following questions are proposed:

- *How can student perceptions be improved within PBL/PjBL?*
- *How does PBL/PjBL incorporate 21st century skills?*
- *How can 21st century skills be assessed using PBL/PjBL strategies?*
- *How does PBL/PjBL differentiate for students of different levels?*
- *What is the future of PBL/PjBL instruction and technology?*
- *Is there ever a context in which PjBL is ineffective or inappropriate for instruction?*
- *What are factors that inhibit PBL/PjBL from being implemented in classrooms?*

For the benefit of classrooms everywhere, it is hoped that the questions asked in this review be taken into consideration and studied soon. In this way, we can either promote new strategies in an ever-changing and accelerating world or discourage the ineffective ones from taking root with research-based explanations.

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