

A review to identify key perspectives in PBL meta-analyses and reviews

Citation for published version (APA):

Hung, W., Dolmans, D. H. J. M., & van Merriënboer, J. J. G. (2019). A review to identify key perspectives in PBL meta-analyses and reviews: trends, gaps and future research directions. *Advances in Health Sciences Education, 24*(5), 943-957. <https://doi.org/10.1007/s10459-019-09945-x>

Document status and date:

Published: 01/12/2019

DOI:

[10.1007/s10459-019-09945-x](https://doi.org/10.1007/s10459-019-09945-x)

Document Version:

Publisher's PDF, also known as Version of record

Document license:

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A review to identify key perspectives in PBL meta-analyses and reviews: trends, gaps and future research directions

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Received: 23 June 2019 / Accepted: 14 November 2019 / Published online: 25 November 2019
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Abstract

In the past 50 years, the original McMaster PBL model has been implemented, experimented, revised, and modified, and is still evolving. Yet, the development of PBL is not a series of success stories, but rather a journey of experiments, failures and lessons learned. In this paper, we analyzed the meta-analyses and systematic reviews on PBL from 1992 to present as they provide a focused lens on the PBL research in the past 5 decades. We identified three major waves in the PBL research development, analyzed their impact on PBL research and practice, and offered suggestions of research gaps and future directions for the field. The first wave of PBL research (polarization: 1990–mid 2000) focused on answering the question “Does PBL work?” and the outcomes. The results were conflicting. The researchers took polarizing positions and debated over the merits of PBL throughout this wave. However, the contradictory results and the debates in fact pushed the researchers to look harder for new directions to solve the puzzle. These efforts resulted in the second wave (from outcomes to process: mid 2000–mid 2010) that focused on the question “How does PBL work?” The second wave of PBL research targeted at investigating the effects of implementation constituents, such as assessment formats or single versus curriculum wide implementations. The third wave (specialization: mid 2010 and onward) of PBL research focused on “How does PBL work in different specific contexts?” These research widened our perspectives by expanding our understanding of how PBL manifests itself in different contexts. Given the diversification of PBL and more hybrid PBL models, we suggest “Why does PBL with particular implementation characteristics for specific outcomes work or not work in the condition where it is implemented?” to be the question to answer in the next wave of PBL research.

Keywords Problem-based learning · Narrative review · Reflection · Meta-analyses · Systematic reviews · Trends and future directions

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Introduction

More than 50 years ago, John Evans created a list of objectives for a new medical school curriculum. These objectives eventually became the backbone of McMaster's Problem-based Learning (PBL) medical education curriculum (Servant-Miklos et al. 2019), meant to alleviate longstanding issues with graduates being unable to apply what they have learned (Barrows 1996; Barrows and Tamblyn 1980; Schmidt 1983) and being underprepared for the physical, social, and emotional demands of healthcare environments. A few years after McMaster's implementation of PBL, this pedagogical approach was brought to Europe, and thence the Maastricht model was born. Over the past 50 years, PBL has spread across the world in many different disciplines and at all levels of education (Hung and Loyens 2012).

In contrast with traditional lecture-based instructional conventions, PBL utilizes problem-driven instruction, self-directed learning, and small-group learning to structure students' study of subjects. It shifts learning from memorizing abstract factual knowledge to developing knowledge that can be applied; from passively receiving knowledge to actively seeking knowledge; and from individually building personal understanding alone to collaboratively constructing socially shared knowledge with others. Thus, PBL is meant to equip students with an integrated set of knowledge, skills, and attitudes to become independent problem solvers and better knowledge seekers, effective team players, and lifelong learners.

PBL is deemed as one of the most innovative pedagogies in history and may have proliferated widely, but it is not perfect. The original McMaster PBL model has been iteratively trialed and modified. For example, from Howard Barrows' PBL model, to the Maastricht model, to the Singapore model, or to the Aalborg model (Wijnia et al. 2019). Yet the development of PBL is not a series of success stories; it is instead a journey of experiments, failures, and lessons learned. Successes help advance our understanding of a field, but so do failures and struggles. For instance, tutor quality and training issues (Leary et al. 2013) or group dynamic and processing issues (Fontejn and Dolmans 2019) still need solutions.

Since its first implementation in the 1970s, many studies have been conducted—including several reviews and meta-analyses—to understand PBL and solve various known issues. Now, at its 50-year anniversary, it is appropriate to stop and reflect on what conceptual paradigm shifts have taken place, what lessons we can learn from past iterations, and how they can inform future research. In this paper, we synthesize meta-analyses and systematic reviews of PBL research over the past 50 years, identify gaps in our current understanding of PBL, and suggest future directions for the field.

Research Questions:

- What conceptual perspectives dominated PBL reviews over the past 50 years?
- What gaps can we discover, and what research agenda might close these gaps and help us move forward?

Methods

To answer these two research questions, we chose narrative review as the research method for this study. Narrative review is deemed suitable for analyzing a wide range of studies to answer a broad research question (Cook et al. 1997), especially for providing conceptual

clarity on a topic or for a descriptive synthesis of findings and identifying gaps (Gordon et al. 2018; Grant and Booth 2009). The term Problem-based Learning (PBL) is defined in this review with a broader context to include pedagogical approaches that simultaneously support: (1) problem-initiated and problem-driven learning, (2) self-directed learning with tutor facilitation, and (3) collaborative learning in small groups. In this review, we targeted the meta-analyses and systematic reviews on PBL.

Literature search

A search was conducted in the databases of PsycInfo, MEDLINE Complete, Health Source: Nursing/Academic Edition, ERIC, EBSCO MegaFILE, CHIAHL Complete, and Academic Search Premier, with publication year range of 1980–2019. The search used keywords problem-based learning, PBL, problem-oriented learning, POL, problem-based approach, problem-based learning program, PBLP, meta-analysis, and systematic review, which generated 1415 hits. Further filters of full text, peer-reviewed, academic journals, and reference available, were applied, reducing the number to 156 articles. We then conducted the first preliminary scan of the titles and abstracts to determine the nature of the articles and identified 56 relevant meta-analyses, systematic reviews, or literature reviews. All 56 articles were fully reviewed.

Inclusion and exclusion criteria

The inclusion criteria used in this review were that the included articles must: (1) examine studies where learning contexts met the definition of PBL given earlier; (2) be a meta-analysis or literature review, (3) study effects or outcomes of PBL, (4) and be published. The studies included in this review included both quantitative or qualitative systematic analyses.

Upon further review, 10 articles were excluded because they did not meet the inclusion criteria (e.g., were unpublished). The final 46 articles were read and summarized for further synthesis. The authors conducted individual analysis and synthesis independently, then several meetings took place where the authors discussed, debated, and reached consensus on the trends, gaps, and directions from the reviews. In what follows, we present a descriptive synthesis of the key findings.

Results

Since its first implementation in 1969 (Servant-Miklos et al. 2019), we identified three waves of PBL research, each with its own unique focus based on needs from the PBL community and prior studies (Fig. 1).

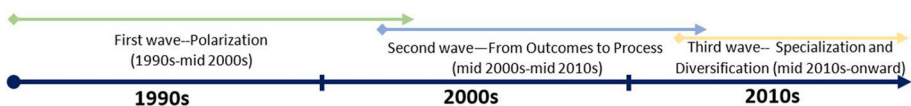


Fig. 1 Timeline of the three waves of PBL research development

The first wave: polarization

The first wave of PBL meta-analyses and systematic reviews rose in the early 1990s. Because of resistance from faculty on what was deemed as a controversial instructional practice by the skeptics at that time, both advocates and opponents of PBL were eager to know whether PBL met its promises. The pioneering meta-analyses were conducted by Norman and Schmidt (1992), Albanese and Mitchell (1993), and Vernon and Blake (1993), along with others (e.g. Berkson 1993; Wolf 1993). The first and foremost question they asked was “Does it work?”. In other words, is PBL better than traditional instruction in terms of learning outcomes?

This is a typical research question for justifying the use of a new intervention (Cook et al. 2008). Indeed, Cook et al. (2008) proposed a framework that classifies education research into three categories: description, justification, and clarification. Description studies propose or describe what can or has been done in the past, justification studies examine the outcomes of the intervention (does it work?), and clarification studies scrutinize how, why, and when the intervention works. The studies in the first wave reflect the nature of the justification research category, which is typical for early stages of research on an educational intervention.

Some of the meta-studies we reviewed suggested that PBL was effective in enhancing students’ clinical knowledge, skills, and motivation (e.g. Albanese and Mitchell 1993; Kalaian et al. 1999; Norman and Schmidt 1992; Vernon and Blake 1993), whereas others found that PBL did not enhance students’ general problem solving ability (Norman and Schmidt 1992) or else failed to deliver on its promises (i.e. application of knowledge, clinical reasoning skills, self-directed learning skills, collaborative skills) all together (Berkson 1993). These polarizing views over the merits of PBL and traditional instruction continued from the 1990s well into 2000s. For example, Kalaian, Mullan, and Kasim’s meta-analysis (1999) reported positive effects of PBL on student standardized clinical science measures (NBME II) but lower performance on basic science measures (NBME I), Dochy, Segers, Van den Bossche, and Gijbels’ meta-analysis (2003) found that PBL was effective for student skills development and retention, and Colliver’s systematic literature review (2000) concluded no positive effects of PBL on student performance.

Though some early meta-analyses showed better retention of knowledge following PBL, the retention duration measured in those studies was relatively short. To see the long term effects of PBL, Koh et al. (2008) reviewed 13 studies that measured prolonged effects of PBL on physicians’ competence after graduation (1–23 years). These authors found that PBL was effective in cultivating students’ social and professional competencies, including coping with uncertainty, communication skills, self-directed learning, teamwork, appreciation of social, emotional, legal, and ethical aspects of health care, and attitudes toward personal health and well-being. Their findings thus reinforced prior findings from Vernon and Blake (1993) and Schmidt et al. (2009) meta-analyses.

The second wave: from outcomes to process

The polarizing findings from the first wave of meta-analyses baffled PBL researchers. Nevertheless, more research findings emerged to shed light on this puzzle. Kalaian et al. (1999) noticed in their meta-analysis that years of experience with PBL implementation was a significant predictor of PBL’s positive effects. Dochy et al. (2003) also observed a positive

correlation between cognitive demands in terms of retrieval strategies used for tests and PBL student performance on knowledge acquisition and application, which later inspired Gijbels et al.'s (2005) meta-analysis that specifically studied the effects of assessment on PBL students' various levels of performance and began the second wave of PBL research. Neville's meta-analysis (2009) further confirmed that PBL's effects on basic knowledge acquisition seemed to hinge on the knowledge assessed only at an application level.

In searching for ways to unpack the contradictions, Hmelo-Silver et al. (2007) challenged the question "does it work?" that dictated the first wave of PBL research and suggested that when, where, and what type of learning outcomes and how PBL works the best should be the focus of PBL research. This shift in research questions characterized the second wave of PBL research, refocusing on clarification as described in Cook et al.'s (2008) framework. However, the clarification studies in this wave focused more on investigating "how" rather than "why" it works. That is, they focused on discrete components of PBL implementations (e.g., assessment methods) as well as the effects of different types of cognitive processing (e.g., critical thinking and learning approaches) on learning outcomes, instead of the holistic underlying mechanism that explains the "why."

Implementations and cognitive processing

Following on their previous findings, Gijbels et al. (2005) investigated relations between assessment formats and the PBL students' performance on three levels of knowledge structure: concepts (level 1), principles (level 2), and linkage of concepts/principles to conditions and procedures when applying knowledge (level 3). They found that PBL students performed significantly better than did traditional students on the level 2 and 3 tests, but negative effects of PBL appeared on students' performance for level 1 tests. Moreover, only 8 out of 40 studies included in their review assessed students' performance at level 3, thus revealing that the majority of assessments in PBL before 2005 focused mainly on basic understanding of isolated concepts rather than integrated principles and in situ knowledge application.

Walker and Leary's (2009) meta-analysis later arrived at a similar conclusion to Dochy et al.'s (2003): the positive effects of PBL were most pronounced for tests of knowledge application. Further work by Belland et al. (2009) further assessed the validity of assessment instruments reported in 33 PBL studies, arguing for a lack of sufficient description and rationale for assessment construction, as well as misalignment between assessments format and the constructs being measured, which casted a shadow on the validity of the instruments of these studies. Thus, the inconsistent PBL results may stem from imprecise measures of learning outcomes.

Schmidt et al. (2009) also conducted a meta-analysis on a large number of curriculum comparison studies conducted within a single medical school, thereby controlling for heterogeneity of PBL implementations. They showed that PBL was most effective in improving students professional and interpersonal skills. More specifically, PBL students consistently performed better than did traditional students in practical medical skills, graduated in shorter time; had greater sense of wellbeing; and lower attrition rates. Small but positive effects of PBL were also found in the students' medical knowledge acquisition and diagnostic reasoning. In contrast, Walker and Leary's (2009) meta-analysis looked at the effects of different models on PBL outcomes, and found that employed closed-loop PBL (i.e., reiterative PBL, or returning to the original problem and revising one's reasoning after the initial self-directed study; Barrows 1986) produced sizeable effects. In addition,

they examined the effects of problem types using Jonassen's (2000) problem typology, and found that students' performance varied in solving different types of problems (for details regarding the types of problems, please see Jonassen 2000).

To further elucidate how PBL might facilitate the student learning process, Leary et al. (2013) examined the relationships between tutor characteristics (content expertise, training, experience) and student learning outcomes. They found no significant relationship between tutor content expertise and student learning nor between trained and untrained tutors on student learning. However, the students' basic knowledge gains patterns under the facilitation of untrained tutors seemed to be similar to their knowledge gain under a lecture-based approach. There was also a modest negative correlation between tutor experience and student learning that only appeared in multiple PBL course implementations, not single-course PBL. Whether tutor fatigue could be a possible cause will require more studies to confirm.

Polyzois et al. (2010) systematic review examined effects of whole-curriculum PBL versus single-course PBL from six comparative studies. They concluded that single PBL course intervention in a traditional curriculum consistently produced better results than an exclusively PBL curriculum. They also found that PBL better enhanced students' critical thinking, problem solving, and creativity than did traditional instruction because of its flexible learning process. Further, when examining nursing students' development of critical thinking, Kong et al. (2014) observed that the students who received PBL instruction for two semesters improved their overall critical thinking scores, while the PBL students who went through only one semester of PBL did not. Similarly, Dolmans et al. (2016) observed that the effects of PBL were more impactful in curriculum wide implementation than single course implementation on students' deep learning approach. However, Polyzois et al.'s (2010) systematic review showed opposite findings of Dolmans et al.'s (2016).

The third wave: specialization

The third wave of meta-analyses and systematic reviews continued on in the spirit of clarification research, but also diversified into a wider range of contexts, such as online platforms, discipline specializations, and cultures.

Digital modality and online platform

Entering the twenty-first century, the options for presenting PBL problems or delivering PBL courses has extended to digital modes and online platforms. In their meta-analysis, Car et al. (2019) reported that digital technology was mainly used for full delivery of distance-based PBL or supporting different components of face-to-face or blended PBL, such as the presentation of problems. Gavvani et al. (2015) investigated specifically the effects of modality of PBL problem presentation. Examining five eligible studies, they found no difference between problems presented in paper and digital forms on student learning. Though the effects were not significantly distinguishable, 73% of students were more satisfied with digital scenarios than paper scenarios. They also found in one of the studies that the digital scenarios decreased tutor's facilitation time more in exclusively digital environments (92%) than in paper-digital blended environments (41%). Kim et al. (2018) conducted a Bayesian meta-analysis on the effects of computer-based scaffolding on PBL on students' STEM learning, finding that computer-based scaffolding was effective in

improving higher-order skills in PBL environments. However, providing multiple scaffolding strategies in a computer-based supported PBL system was counterproductive.

Disciplines

One major shift in the meta-analyses in this wave was a move from an all-inclusive approach to discipline specialization. The disciplines included in these meta-analyses included dental education, prosthodontics education, nursing education, pre-clinical medical education, pharmacy education, clinical education, pediatric education, radiology education, tertiary education, and STEM education (due to the length limit of the paper, for discipline specific meta-analyses, please refer to the reference section). The overall findings among these meta-analyses were basically aligned with the previous all-inclusive meta-analyses. For example, PBL promoted student work-based skills (Sayyah et al. 2017), problem solving and self-study ability (Liu et al. 2019), and critical thinking in nursing students (e.g. Kong et al. 2014; Shin and Kim 2013). However, it did not enhance knowledge acquisition in pre-clinical students (Hartling et al. 2010) nor hands-on skills in prosthodontics students (Eslami et al. 2014). Interestingly, Shin and Kim (2013) found in their review that studies involving fourth-year undergraduate nursing students showed better results than the ones involving junior students. This finding echoed the duration factor observed by Dolmans et al. (2016) and Kong et al. (2014) discussed earlier.

Cultures

Another notable phenomenon in this wave of PBL is a surge of meta-analyses that included exclusively PBL studies in a Chinese health sciences context (for details, please see the references) or in an Iranian context (Sayyah et al. 2017). The Chinese meta-analyses included disciplines of undergraduate medical education, pharmacy education, pediatric education, radiology education, pharmacology education, and effects of hybrid PBL+LBL (lecture-based learning) on students' learning outcomes, bearing similar aims and characteristics as their western counterpart of first wave PBL research that focused on conceptual learning outcomes. Another commonality shared among these Chinese meta-analyses is the use of standardized summative assessments for measuring student learning outcomes. Interestingly, unlike their western counterparts, most of these Chinese meta-analyses found significant differences in basic knowledge acquisition (measured by theoretical scores) in favor of PBL, in addition to PBL students' significantly better performance in higher order learning outcomes than their traditional instruction peers (Table 1).

Discussion

The first wave of PBL research focused on the question "Does PBL work?" to justify the adoption of PBL as a pedagogy (Justification). However, the purpose or goal did not come to fruition due to conflicting findings, in turn sparking a long debate about the merits of PBL. Nevertheless, the contradictory results pushed researchers to examine various aspects of PBL and informed the second wave of research to clarify the issues that emerged from the first wave of meta-analyses (Clarification). For example, whereas Colliver (2000) argued that the positive effects of PBL were due to a self-selection sample bias, Dochy et al. (2003) suspected that misalignment between the targeted type of knowledge and the

Table 1 Characteristics of the three waves of PBL research

Wave	Research purpose	Fundamental question	Investigation focus	Influential works	Significance
First wave: polarization 1990s–mid 2000s	Justification	“Does it work?”	Effectiveness of PBL (outcomes)	Norman and Schmidt (1992) Albanese and Mitchell (1993) Vernon and Blake (1993)	Began systematic examination of effectiveness of PBL Instigated long-time debate about effectiveness of PBL
Second wave: from outcomes to process mid 2000s–mid 2010s	Clarification	“How does it work?”	Implementation constituents (e.g. assessment formats) and single versus curriculum wide implementations individual learning outcomes (e.g., critical thinking, process)	Gijbels et al. (2005)	Confirmed a relationship between assessment formats and types of learning outcomes Pioneered study of effects of implementation constituents Shifted research focus from outcomes to underlying causes and processes
Third wave: specialization and diversity Mid 2010s and onward	Clarification	“How does it work?”	Specialization in specific instructional delivery platforms, disciplines, and cultures	N/A	Specialization in disciplines and cultures provided contextualized knowledge about PBL

format of assessment was to be blamed for the conflicting results. The sample bias hypothesis did not seem to hold a firm ground, perhaps due to its inability to explain all outcomes, and was not pursued by other researchers. On the other hand, Gijbels et al. (2005) followed up on the prior observation of Dochy et al. (2003) and confirmed their assessment format hypothesis that, in our opinion, directed the second wave of PBL research to focus on the effects of implementation constituents on student learning outcomes.

Implementation differences were investigated, such as single course versus curriculum wide implementations, or assessments focusing on factual knowledge or knowledge application. Though on the surface the first wave reported contradictory findings, there were generally agreeable patterns in the results from the first and second wave of reviews and meta-analyses (e.g. Strobel and van Barneveld 2009). First, PBL is effective in enhancing students' higher order learning outcomes, such as clinical reasoning, domain specific problem-solving skills, knowledge application and transfer, long term retention, self-directed learning skills, collaborative skills, as well as social and professional skills. Second, students perceived PBL more positively than traditional instruction. Third, PBL was slightly less effective than traditional instruction in helping students acquire sufficient breadth of basic factual knowledge (e.g. Albanese and Mitchell 1993).

Another highlight during the second wave that gave PBL researchers an additional push was Kirschner et al.'s (2006) statement claiming that PBL and other constructivist pedagogies do not work. Proponents of PBL (e.g. Schmidt et al. 2007; Hmelo-Silver et al. 2007) in turn offered their counterarguments, which triggered deep reflections among PBL researchers. Hmelo-Silver et al. (2007) argued that the field had been asking the wrong question and should instead focus on questions about "how" and "under what conditions" PBL is effective. This reflection helped shift the focus of PBL research. The work of Gijbels et al. (2005) helped start a new direction in PBL meta-research focusing on the process and implementation types instead of solely outcomes, which enabled the field to see how PBL works under specific conditions; for example, whether the format of assessment is well aligned with learning outcomes, or whether implementation type (i.e., curriculum wide or for a single course) is appropriate.

The heated debate among the three papers of Kirschner et al. (2006), Schmidt et al. (2007), and Hmelo-Silver et al. (2007) during 2006–2007 seemed to be a turning point for the polarizing viewpoints among PBL researchers starting to converge. PBL researchers began to realize that education is not black and white. Perhaps it is a more pragmatic approach to harness the strengths of PBL in enhancing students' higher order thinking, acknowledge its limitations, and draw upon the strength of traditional instruction for building students' basic knowledge base. With this insight, Neville (2009) suggested a hybrid model of PBL that incorporates more lectures to better facilitate students' learning. Similarly, Hartling et al. (2010) also reported advice from a study that used hybrid PBL in the early stage of the curriculum to help structure the learning and ease the transition into a pure PBL approach. In our opinion, the decision on the format of hybrid PBL should depend on a number of considerations, such as learners' prior knowledge, the amount of procedural information that the tutor needs to provide, or how much part-task practice is required (van Merriënboer and Kirschner 2018).

As the second wave of PBL dove deeper into the process of the pedagogy, the third wave of PBL research widened our perspective horizontally across different contexts, such as discipline, culture, and delivery modes. Equipped with a variety of studies from different contexts, the PBL research with a specialization in disciplines, culture, or delivery platform characterized the third wave of PBL research. Though the third wave was not as exciting as the first or second wave, the contribution of this wave of research is invaluable

in expanding our understanding of how PBL manifests itself in different contexts, paving the way for the next wave of PBL research.

Though the 2nd and 3rd waves focused on clarifying how PBL works under certain conditions, these studies have not provided a clear picture as to why PBL works or does not work under these conditions. One possible reason for the lack of clarity might be due to the natural progression of studying a phenomenon. Humans normally take two approaches to identifying and understanding the cause for a phenomenon under study, which are covariational and mechanistic causal reasoning (Kelley 1973; Thagard 2000). The former looks at patterns quantitatively based on the probabilities of an occurrence to seek possible causal relationships (i.e., atheoretical). The latter is a more sophisticated causal reasoning approach that aims to qualitatively understand the underlying mechanism of the phenomenon by conceptualizing its systemic inter-causal relationships (i.e., theoretical). However, these two approaches do not exclude each other. We often switch back and forth between the two approaches to identify, hypothesize, conceptualize, and verify our theories about the phenomenon under study. The existing three waves of PBL research seem to take a covariational approach to studying PBL. Thus, to uncover the missing piece left from the previous three waves of PBL research, we suggest that qualitatively conceptualizing the mechanism of PBL should be a primary goal of future study.

Future directions

Fifty years of research has given us a better understanding of PBL. The work of the third wave is not yet complete, and there are still many gaps that need to be filled. What directions should the fourth wave of PBL research take? We suggest a broad research question, “Why does PBL with particular implementation characteristics for specific outcomes work or not work in the condition where it is implemented?”

A new PBL implementation must be contextually appropriate in its disciplinary, institutional, social, and cultural environment. For example, different disciplines focus on different types of problems as well as types of knowledge and skill learning. Different learner populations require different types and levels of facilitation and scaffolding. To date, the research on the effects of PBL models (e.g. pure PBL, hybrid PBL, PjBL, CBL, IBL) on student learning is still scarce (Tawfik et al. in press), as is research on problem types and implementation types (curriculum vs. single course implementations). To gain insight on what particular implementation types or characteristics work under what conditions, a clear description of the context is necessary, because vague or imprecise descriptors could hinder the feasibility of meta-studies (Loyens and Rikers 2011; van Merriënboer 2013; Walker and Leary 2009). Moreover, while Chinese and Iranian meta-studies have appeared in the literature, more meta-studies from non-western cultural contexts are needed to expand the spectrum of PBL literature.

Answering the next wave of research questions requires a systemic understanding that is beyond the appreciation of individual constituents of PBL. As discussed earlier, mechanistic causal relations would be a suitable research focus to elucidate the broad question of “why PBL works”. This approach guides researchers to qualitatively depict the underlying mechanism of PBL from a systemic perspective. Such a depiction tells a story of how a PBL pedagogical system behaves the way it does (i.e., its products or end results) by describing how each PBL constituent interacts with their related constituents and feedback loop effects (i.e., process: e.g. tutor’s facilitation skills, student group processing, students’

confidence in the tutor, and learning outcomes), and more importantly, how these inter-causal effects collectively affect how the PBL pedagogical system functions.

These research directions must be guided by a conceptual framework. For example, principles for task-centered instruction (Francom 2017) as expressed in the 4C/ID model (van Merriënboer and Kirschner 2018) provides a conceptual framework to analyze and design different PBL implementations. Such principles indicate that types of problems (e.g., projects, cases), learning resources (e.g., study landscape, online resources), practice opportunities (e.g., skillslab, practicals) and types of guidance (e.g., tutoring, coaching) may need to be different for different learning domains, target groups and contexts. Engeström's (1987) activity theory also provides a helpful conceptual framework for studying a PBL pedagogical system from a social-cultural systemic perspective, which is vitally important for explaining why a PBL model may or may not work in another social-cultural context. Ciancolo and Regehr's (2019) Layered Analysis could additionally provide useful guidance for systematic evaluation of intended functions of PBL in a specific context, which is critical to unlock the "why" questions. By analyzing how it was implemented (techniques), what guides the design of the techniques (principles), and what informs the principles (philosophy) at three different layers, findings could help clarify the merits of different PBL models.

PBL is interdisciplinary in nature, which is operationalized with small group learning in the implementation. The existing PBL research has confirmed that PBL is highly effective in cultivating students' collaborative skills. However, research on interdisciplinary curriculum design and implementation has been lacking. Because the demand on health professionals' ability to function effectively and efficiently in interdisciplinary working environments is increasing, it is paramount to equip students with teamwork skills. Remaining questions include: Why and what makes interdisciplinary PBL implementation different from uni-disciplinary PBL implementation? What are the challenges and logistical issues we may encounter when implementing an interdisciplinary PBL curriculum? Reports and studies on both successful and failed cases will help fill these gaps.

Seeking answers to the "Why" questions is a process of theory construction. These theories are not built from only study results. Rather, theory construction should be informed by data and guided by a sound theoretical foundation. Because PBL is a pedagogical system implemented in real educational settings, PBL research could benefit from these contextual perspectives. Thus, in addition to the cognitive theoretical perspective upon which the existing PBL research has been based, other theories such as social-cultural constructivism, social psychology, culture formation or cultural influence and differences, organizational psychology, and so on, could expand our research perspectives to obtain a deeper understanding of the pedagogy. The theory-based research questions will give researchers a clear view for the purpose as well as the direction of their studies. Only then, could an appropriate research method be effectively selected to fulfill the purpose of the study.

A wide range of research methods could be employed for the "Why" clarification purposes of study. For example, qualitative research methods are powerful tools for revealing details for explaining the data observed. Qualitative methods have been used in PBL research for quite some time, but their use is still disproportionately lower than quantitative research, especially in meta-studies. Sequential exploratory, sequential explanatory, or concurrent triangulation mixed methods could help fill in this gap and provide both types of data from one study setting, rather than by after-the-fact inference or speculations. Also, realist reviews (Pawson et al. 2005) that use CMO (Context, Mechanism, and Outcomes) principles to configure the design of studies could guide researchers to answer the "Whys" not only in relation to the outcomes but also under the specific context. PBL is

implemented in educational settings where curricular renewals are often a necessity due to fast technological and societal changes. Therefore, design-based research could be more flexible and sensitive to capture the dynamic nature and details occurring during the process. Therefore, we suggest diversifying the research methods and tools to equip us with multiple lenses in order to see a more complete picture of PBL.

Limitations

This review included only meta-analyses or systematic reviews. This approach gives us a focused albeit a narrower lens. Therefore, some insightful findings might not have been included in this review due to the types of research (e.g. descriptive papers, qualitative studies or theoretical discussions) that would not be examined by most meta-studies. Further, the majority of the studies in this review were quantitative meta-analyses. Representation of qualitative meta-studies being disproportionately included is also a limitation of this review.

Conclusion

From investigating the questions “Does PBL work?” to “How does PBL work,” PBL research has come a long way in searching for answers in understanding this 50-year-old and ever-evolving pedagogy. Yet, the answers we obtained in fact generate more questions, which help deepen our understanding and widen our understanding about different dimensions in the pedagogical system of PBL. All of these dimensions deserve attention from the researchers as each bit of knowledge is a piece of the big puzzle. Now we have arrived at the time to ask the question “Why does PBL with particular implementation characteristics for specific outcomes work or not work in the condition where it is implemented?” More work is ahead.

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The references with an asterisk are the meta-analyses or systematic reviews included in this review.

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