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Evaluating the outcomes of problem-based learning in postgraduate medical education: A systematic review and meta-analysis

Évaluation des résultats de l'apprentissage par problème dans la formation médicale postuniversitaire : une revue systématique et une méta-analyse

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Article abstract

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Objective: The aim of this systematic review and meta-analysis was to synthesize learning outcomes of PBL in PGME contexts.

Methods: The authors systematically searched MEDLINE, Embase, APA PsycINFO, AMED, CINAHL, Web of Science, ERIC, and Cochrane databases from January 1, 1950, to July 1, 2022 for original studies that reported Kirkpatrick outcomes of PBL in PGME contexts. Outcomes data were extracted. Quantitative data relating to learning outcomes were meta-analyzed using a random-effects model to generate weighted mean differences.

Results: Of 4310 abstracts screened, the authors included 21 studies encompassing anesthesia, family medicine, internal medicine, occupational medicine, pediatrics, psychiatry, public health and surgical residency programs. The studies reported reaction (n = 12), learning (n = 15), behavioural (n = 6) and/or results outcomes (n = 4). Meta-analysis of the three eligible articles demonstrated no significant difference after PBL in pre- and post-test results (pooled mean difference=0.13%, 95% CI, -6.74–7.00). There were observed improvements in satisfaction levels and self-reported behavioural outcomes following PBL.

Conclusions: Although similar learning outcomes were observed using PBL and the usual teaching in PGME, PBL was associated with benefits in trainee satisfaction and behavioural changes that contribute to learning and performance. PGME programs should consider incorporating PBL into curricula.

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Reviews, Theoretical Papers, and Meta-Analyses

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Évaluation des résultats de l'apprentissage par problème dans la formation médicale postuniversitaire: une revue systématique et une méta-analyse

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Abstract

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Conclusions: Although similar learning outcomes were observed using PBL and the usual teaching in PGME, PBL was associated with benefits in trainee satisfaction and behavioural changes that contribute to learning and performance. PGME programs should consider incorporating PBL into curricula.

Résumé

Contexte : Les éducateurs doivent maintenant incorporer des formats pédagogiques plus actifs dans l'enseignement médical, tels que l'apprentissage par problèmes (APP). Compte tenu des données mitigées concernant l'utilisation l'APP dans la formation médicale postuniversitaire, il est nécessaire de synthétiser l'état des connaissances à cet effet, afin d'éclairer l'application de l'APP dans les contextes de formation médicale postuniversitaire.

Objectif : L'objectif de cette revue systématique et de cette méta-analyse était de synthétiser les travaux concernant l'APP effectués dans les contextes de formation médicale postdoctorale.

Méthodes : Les auteurs ont effectué des recherches systématiques dans les bases de données MEDLINE, Embase, APA PsycINFO, AMED, CINAHL, Web of Science, ERIC et Cochrane entre le 1er janvier 1950 et le 1er juillet 2022 pour identifier les études originales faisant état du niveau d'apprentissage basé sur le modèle de Kirkpatrick concernant l'APP dans des contextes de formation médicale postdoctorale. Les données relatives aux résultats ont été extraites. Les données quantitatives relatives aux niveau d'apprentissage ont été méta-analysées à l'aide d'un modèle à effets aléatoires afin de générer des différences de moyennes pondérées.

Résultats : Sur les 4 310 résumés examinés, les auteurs ont inclus 21 études portant sur des programmes de résidence en anesthésie, en médecine familiale, en médecine interne, en médecine du travail, en pédiatrie, en psychiatrie, en santé publique et en chirurgie. Les études ont fait état des réactions (n = 12), de l'apprentissage (n = 15), du comportement (n = 6) et/ou des résultats (n = 4). La méta-analyse des trois articles admissibles n'a pas montré de différence significative après l'APP dans les résultats pré- et post-test (différence moyenne regroupée = 0,13 %, IC à 95 %, -6,74-7,00). Des améliorations ont été observées dans les niveaux de satisfaction et les résultats comportementaux autodéclarés à la suite de l'APP.

Conclusions : Bien que des résultats reliés à l'apprentissage similaires aient été observés en utilisant l'APP comparativement à l'enseignement habituel dans le cadre de la formation médicale postdoctorale, l'APP a été associé à des avantages en termes de satisfaction des apprenants et de changements de comportement qui contribuent à l'apprentissage et au rendement. Les programmes d'éducation médicale postdoctoraux devraient envisager d'intégrer l'APP dans les programmes d'études.

Introduction

Active instructional formats encourage students to engage, reflect, and contribute to the learning process. Compared with passive, teacher-centered instructional formats, active instructional formats have demonstrated improved knowledge retention and application.[1,2] In recent years, medical education is shifting from passive to active instruction for its merits in improving cognition, collaboration, and self-directed learning skills, and intrinsic motivation.[3]

Problem Based learning (PBL) is an active instructional format. PBL is typically facilitated over multiple sessions. In the first session, a clinical problem is presented to small groups of students and led by a facilitator. Team members work together to understand the problem, identify questions to answer, solidify existing knowledge, acknowledge gaps in knowledge, and formulate learning objectives. After dedicated time for self-study (e.g., literature review, practical experience and/or formal lectures), the group reconvenes for a second session with the facilitator to discuss the findings and consolidate their learning. PBL has been incorporated across the spectrum of medical education, spanning from undergraduate medical education[3] to continuing medical education.[4]

PGME trainees could benefit from PBL. In some studies in PGME contexts, but not all, there have been improved behavioural outcomes. PGME trainees were more competent in their communication, problem-solving, and self-learning skills, and showed more initiative than trainees instructed with passive learning instructional formats.[5–7] While the effect of PBL on knowledge was variable—with studies favouring PBL[8] or traditional lectures,[9] and one showing no significant difference between the two groups[10]—students taught by PBL tended to outperform their conventional counterparts on clinical examinations and on faculty evaluations.[11,12]

Yet, the application of PBL in PGME context has drawbacks. Transforming a teaching practice into PBL can be challenging as medical educators may have limited experiences with PBL structure and training. Faculty and teaching staff may be unfamiliar with PBL format and thus, tend to teach in the same passive instructional formats in which they were taught during their own undergraduate years.[13] As a result, they may be slow to adapt the PBL format where needed.[14] Another concern with implementing PBL in PGME is the material and educator resource investment. PBL instructional formats require more time and potentially more facilitators to accommodate small group learning.[15] Organizing sessions within the busy PGME context, with variable attendance due to vacations and post-call days, also represents a challenge. Level of knowledge acquisition,[16,17] facilitator buy-in,[15] and scheduling logistics in PBL are additional barriers to implementing PBL in PGME contexts.

In view of the mixed study outcomes data on the use of PBL in PGME contexts, training programs may be reluctant to embrace PBL. There is a need to consolidate and synthesize the data to determine the application of PBL formats across all areas of PGME to guide whether implementing PBL should be undertaken by PGME programs. Accordingly, the purpose of this systematic review and meta-analysis is to synthesize the available literature and make sense of conflicting results of PBL studies in PGME.

Methods

Selection of studies

In 2022, the authors performed a systematic search of MEDLINE, Embase, APA PsycINFO, AMED, CINAHL, Web of Science, ERIC, and Cochrane from January 1, 1950 to July 1, 2022. The following subject headings were used to search for studies: “Problem-based Learning,” “Education,” “Medical,” and “Internship and Residency”. For non-subject heading-based databases, the authors search strategy was as follows: (("Problem-Based Learning") AND (("graduate medical education") OR ("Internship") OR (“Residency"))).

The authors managed the articles using the web-based software Covidence.[18] Duplicate articles were removed, and two authors independently performed title and abstract screening (CT and JS) to identify the articles for full text review. Conflicts were resolved collaboratively or with a third investigator if uncertainties persisted. Full text review was subsequently performed by one author (CT). This paper followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines.[19]

Eligibility criteria

The authors included original studies of PBL in PGME contexts that reported learner outcomes described by the Kirkpatrick Evaluation Model for analysis. The model comprises four levels of criterion: “reaction” assesses participant satisfaction and perception of the program, often through qualitative scales or structured interviews; “learning” measures the effect of training on knowledge

and skill as evaluated by scored examinations pre- and post-training; "behaviour" describes an observable shift in participant thinking or mindset that leads to practical changes; and "results" specifies how these changes impact practice or patient care. The authors excluded articles that were in an undergraduate medical education context, described outcomes outside the Kirkpatrick criteria, were published in a non-English language, or published as an abstract, letter, or conference paper.

Data extraction and analysis

Each of the two reviewers (CL and TL) independently extracted the country of publication, medical specialty of participants, PBL format, and quantitative and qualitative outcomes data. The reviewers independently appraised the study quality using the Medical Education Research Study Quality Instrument (MERSQI), which evaluates 10 criteria in six domains.[20] This tool evaluates on a 3-point scale the design, sampling, data type, validity of evaluation instruments, data analysis, and outcomes of a given study for a maximum score of 18.

Data relating to learning outcomes were meta-analyzed using a random-effects model to generate weighted mean differences using Stata 17.[21] The authors chose to perform the analysis in two steps, first assuming a higher correlation estimate of 0.8 and then assuming no correlation. A *p*-value of <0.05 was considered statistically significant.

Author positionality

The authors represented medical students (EM, CT, TL), a research assistant (JS), a statistician (IM), and a program director of a PGME training program (SB). At the outset of the study, the authors held shared beliefs about the value of active learning and were open-minded about how PBL could impact Kirkpatrick outcomes.

Results

The literature search returned 4310 unique studies. (Figure 1) After title and abstract screening, the authors reviewed 97 full-text articles. Of these, the authors excluded 61 articles due to inappropriate outcomes (*n* = 33), methods (*n* = 12), or population (*n* = 9); non-English language (*n* = 5); or duplicate articles missed by Covidence (*n* = 2). Twenty-one studies were included for analysis.

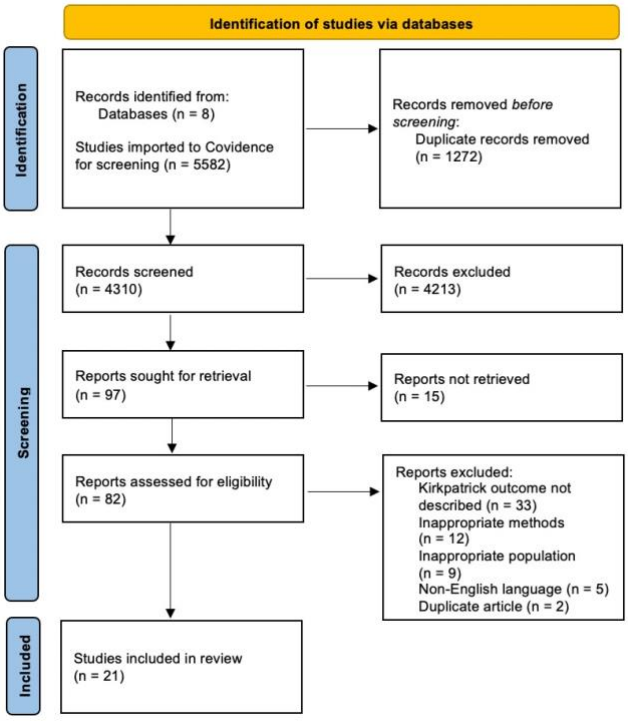

Figure 1.Prisma Chart

Study characteristics

An overview of study characteristics is summarized in Table 1 and Table 2. The studies were published between 1989–2018, with the majority conducted in the United States (*n* = 13). There was a diverse background of specialities including anesthesia, family medicine, internal medicine, occupational medicine, pediatrics, psychiatry, public health and surgery. Most studies were observational (*n* = 13). The authors appraised the study quality using the MERSQI tool and is summarized in Table 3. The mean score was 11.07 +/- 3.38, with four studies having scores less than nine. PBL sessions were either embedded into existing academic training program (*n* = 13) or were set as an additional session outside of the program time (*n* = 8). PBL sessions were facilitated in person (*n* = 19), virtually (*n* = 1), or both virtually and in person instruction (*n* = 1).

Kirkpatrick's outcomes

The Kirkpatrick model evaluates training programs in their ability to meet the needs of the organization and participants through measuring participant reaction, learning outcomes, behavioural changes, and results. [22] As summarized in Table 1, most studies reported reaction (*n* = 12) and learning outcomes (*n* = 15), with fewer reporting behavioural (*n* = 6) or results (*n* = 4) outcomes. Nine studies reported more than one Kirkpatrick outcome.

Table 1.

Resident Speciality	Author(s) and Year	Reference number	Country	Number of Participants (intervention; control)	Virtual or In person PBL	Duration of PBL	Measurement Tool(s) for PBL	Kirkpatrick Scale level Evaluated			
								Reaction	Learning	Behaviour	Results
Anesthesia	Carrero (2007)	37	Spain	54 (29;25)	In-person	90 min PBL session daily for two days for two consecutive years	Pre/Post PBL tests scores	0	1	0	0
	DeOliveiraFilho (2005)	40	Brazil	12 (5;7)	In-person	Two 60 min PBL sessions for two academic terms	Pre/Post PBL tests scores	0	1	0	0
	Komasawa (2018)	38	United States	35 (35;0)	In person	Six to eight hour PBL sessions for one day for three consecutive years	Self confidence survey for anesthesia related crisis management	0	0	1	0
	Sakai (2013)	41	United States	178 (93;85)	In person	90 min PBL for four consecutive years.	Consultation solicitations & research projects	0	0	1	0
Family Medicine	Grol (1989)	39	Netherlands	63 (31;32)	In person	Weekly PBL sessions for one year	Maastricht progress test	0	1	1	1
	Prislin (1997)	34	United States	85 (27;58)	In person	Weekly PBL sessions for six years	Pre/post PBL 5-point Likert surveys	0	1	0	1
	Sass (2001)	24	United States	9(9;0)	In person	Weekly PBL sessions for four weeks	Post-rotation Interview	1	1	1	0
Internal Medicine	Cook (2009)	25	United States	105 (55, 50)*	Virtual	Weekly 45 min PBL sessions for one year	Pre/Post PBL tests scores	1	1	0	0
	Foley (1993)	26	United States	7(7;0)	In person	34 hours of PBL sessions per week for two months	Post-rotation Interview	1	0	0	0
	Mulder (2009)	36	Netherlands	91(91;0)	In person	Once weekly two hour PBL sessions for eight weeks	Pre/Post PBL tests scores	0	1	0	0
Occupational medicine	Smits (2003)	9	Netherlands	118 (59;59)	In person	Once weekly one day PBL session for four weeks	Pre/post PBL test scores and performance review	1	1	0	1
Pediatrics	Goodyear (2005)	27	United Kingdom	14 (7;7)	In person	Not provided	OSCE and Pre/Post course self assessment sheets	1	1	0	1
	Ozuah (2001)	28	United States	80 (39;41)	In person	Twice weekly PBL sessions for three months	Self administered questionnaire	1	0	1	0
Psychiatry	Heru (2011)	29	United States	9 (9;0)	In person	Eight PBL Sessions over three weeks	Informal Testimony	1	0	0	0
	Schultz-Ross (1999)	30	United States	23 (23;0)	In person	Three PBL sessions per year for 2 consecutive years	5-point Likert-type Scales	1	1	0	0
	Shefet (2011)	31	Israel	93 (93;0)	In person	Two-day PBL sessions	Satisfaction feedback sheets	1	1	1	0
	Yates (1996)	33	United States	12 (12;0)	In person	Weekly PBL sessions for one year	Educational experiences survey	1	0	0	0
Public Health	Heading (2007)	23	Australia	9 (9;0)	In person	Three PBL sessions over four days	Semi-structured interviews	1	1	0	0
Surgical	Itani (1997)	43	United States	64 (64;0)	In person	Once weekly 60 min PBL session for one year	ABSITE questionnaire	0	1	0	0
	Lee (2008)	35	United States	42 (42;0)	Virtual and in person	Weekly PBL sessions for two consecutive years	ABSITE questionnaire and scores	0	1	0	0
	Nguyen (2006)	32	United States	55 (55;0)	In person	Weekly PBL sessions for six months	ABSITE questionnaire and scores, resident satisfaction survey	1	1	0	0
							Total	12	15	6	4

Table 2

Resident Speciality	Author(s) and Year	Reference number	Country	Number of Participants (intervention; control)	Virtual or In-person PBL	Duration of PBL	Measurement Tool(s) for PBL	Kirkpatrick Scale level Evaluated			
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							Total	12	15	6	4

Reaction and satisfaction outcomes

The studies used participant surveys, feedback sheets, interviews, and testimonies to assess participant reaction to the PBL intervention.[9,23–33] Eight of 12 studies concluded high satisfaction, favourable attitudes, and preference for PBL over traditional lectures.[24,26,28–33] (Tables 1 and 2) Of the two studies that did not improve attitudes or satisfaction in learners after PBL, one group cited appreciation for the variety of PBL offered despite there being no significant difference in satisfaction.[27] The PBL group in Smits et al. was the only included study to report lower satisfaction as compared to the lecture-based group in post-intervention and follow-up interviews.[9] The authors hypothesized that the lower satisfaction was due to familiarity with passive formats and insufficient orientation to active formats.

Learning and knowledge outcomes

Knowledge acquisition was assessed using test scores, including American board exam scores in surgery and family practice[9,24,25,27,30–32,34–40] and scores on Objective Structured Clinical Examinations.[27] Of the 15 studies that assess learning and knowledge outcomes, four studies had control groups comparing quantitative data.[9,27,39,40] Pre- and post-intervention quantitative data were available for six of 15 studies.[9,35–37,39,40] Other studies collected qualitative data through learner perception of knowledge or did not report test scores.[24,26,30,31,33,34,38,39,41] Meta-analysis of only those that included control groups and reported pre and post intervention scores comprised three studies[9,37,40] and demonstrated no significant difference after intervention in pre- and post-test results between PBL and the instructional format in the control group (pooled mean difference= 0.13%, 95% CI, -6.74–7.00). (Figure 2) The PBL sessions of the three studies included in the meta-analysis followed a typical PBL format as previously described.[42]

Behaviour outcomes

Behaviours studied included appreciation for the social determinants of health,[24] confidence in using demographic data,[24] confidence in management of anesthesia-related crises,[41] specific resource consultation in research,[41] research ability,[41] prevalence of self-directed learning,[28] and teamwork.[31] All behaviours were self-reported and showed an improvement in all domains. Of note, self-directed learning was rated higher with PBL, though there was no significant long-term effect.[28]

Results outcomes

While direct patient outcomes were not measured in the results, clinical skills were assessed by expert evaluation of consultation skills and medical performance, clinical review using performance indicators and Likert surveys in behavioural science practice activity. The effects of PBL on results were mixed: PBL was associated with significantly higher performance indicator scores compared with lecture-based learning;[9] there was a significant difference in provided care in some behavioural conditions after PBL;[34] and a PBL group had improved medical performance while the traditional learning group showed better consultation skills.[39]

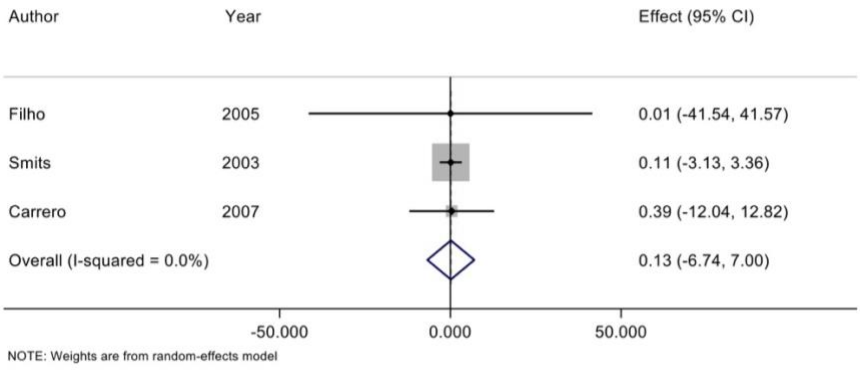

Figure 2. Forest plot depicting meta-analysis of learning and knowledge outcomes

Table 3.

Author (year)	Reference number	Study design* (number of Institutions)	Response Rate, % ∓	Type of Data §	Validity of Evaluation Instruments or measures ‖			Data Analyses¶		Highest Level of Outcome assessed	MERSQI score
					Internal Structure	Content Validity	Criterion validity	Appropriateness	Sophistication		
Carrero (2007)	37	RCT (2)	≥75%	Objective measure	NR	Reported	Reported	Appropriate	Beyond descriptive analysis	Knowledge	15
Cook (2009)	25	RCT (1)	≥75%	Objective measure	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Knowledge	15.5
deOliveiraFilho (2005)	40	Single group pre/post test(1)	NA	Objective measure	Reported	Reported	NR	Appropriate	Beyond descriptive analysis	Knowledge	11.5
Foley (1993)	26	Single group cross sectional (2)	NA	Subjective assessment by study subject	NA	NA	NA	Appropriate	Comparisons made	Satisfaction	6
Goodyear (2005)	27	Nonrandomized 2 groups (1)	≥75%	Subjective assessment by study subject	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Results	12
Grol (1989)	39	Nonrandomized 2 groups (1)	≥75%	Objective measure	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Results	14.5
Heading (2007)	23	Single group cross sectional (3)	NA	Subjective assessment by study subject	Reported	NR	Reported	Appropriate	Comparisons made	Knowledge	8.5
Heru (2011)	29	Single group post test only (1)	NA	Subjective assessment by study subject	NA	NA	NA	Appropriate	Comparisons made	Satisfaction	5.5
Itani (1997)	43	Single group post test only (1)	NA	Objective measure	NA	NA	NA	Appropriate	Beyond descriptive analysis	Knowledge	10
Komassawa (2018)	38	Single group cross sectional (2)	NA	Objective measure	Reported	Reported	Reported	Appropriate	Descriptive analysis only	Behaviour	11.5
Lee (2008)	35	Nonrandomized 2 groups (1)	NA	Objective measure	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Knowledge	13
Mulder (2009)	36	Single group pre/post test(1)	<50%	Subjective assessment by study subject	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Knowledge	10.5
Nguyen (2006)	32	2 group nonrandomized (1)	NA	objective measure	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Knowledge	13
Ozuah (2001)	28	2 group nonrandomized (1)	≥75%	Subjective assessment by study subject	NR	NR	Reported	Appropriate	Beyond descriptive analysis	Behaviour	10.5
Prislin (1997)	34	2 group nonrandomized (1)	50-74%	Objective measure	Reported	NR	Reported	Appropriate	Beyond descriptive analysis	Results	13
Sakai (2013)	41	2 group nonrandomized (1)	50-74%	Objective measure	NR	NR	NR	Appropriate	Beyond descriptive analysis	Behaviour	11
Sass (2001)	24	Single group post test only (1)	NA	Subjective assessment by study subject	NA	NA	NA	Appropriate	Comparisons made	Behaviour	5
Schultz-Ross (1999)	30	Single group pre/post test(1)	NA	Subjective assessment by study subject	Reported	NR	reported	Appropriate	Beyond descriptive analysis	Knowledge	9.5
Shefet (2011)	31	Single group post test only (1)	<50%	Subjective assessment by study subject	NA	NA	NA	Appropriate	Comparisons made	Behaviour	6
Smits (2003)	9	RCT (1)	≥75%	Objective measure	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Results	15.5
Yates (1996)	33	RCT (1)	≥75%	Objective measure	Reported	Reported	Reported	Appropriate	Beyond descriptive analysis	Satisfaction	15.5

Discussion

This systematic review and meta-analysis synthesizes the current body of knowledge on PBL outcomes in PGME context. Our results highlight how PBL had similar learning outcomes to traditional teaching formats in PGME contexts, with the added benefits of increased satisfaction and facilitation of behavioural changes.

While critics of PBL in PGME highlight logistical issues, PBL was logistically feasible in a multitude of PGME contexts. PBL was successfully integrated into one-day workshop[37,38] and over longer time periods, such as within full-year programs.[26,33,34,36,39,43] The flexibility of the PBL structure allowed programs to achieve their specific objectives in the constraints of the local environment while also maintaining PBL principles.

PBL increases resident satisfaction. While this may seem less important than other outcomes, learner satisfaction is an important factor for effective and continuous improvement of PGME programs.[44,45] Previous reviews surveying PBL in UGME also highlight how PBL improves satisfaction: PBL was reported by medical students as "nurturing and enjoyable."[11] The high level of satisfaction and preference of PBL over traditional lectures is relevant for educators as it reflects the positive perception of PBL.[38,39] The lower satisfaction with PBL due to learner expectations as reported by Smits et al. highlights the importance of orienting learners to the expectations and active nature of PBL.[9]

Additionally, PBL increases behaviours beyond what was achieved with usual formats. The increase in positive learner behaviour, including self-directed learning,[28] research,[41] analysis of clinical problems,[31] and confidence[9] after PBL in PGME contexts is an important finding for educators. Engaging regularly in self-directed learning, collaboration, and confidence-building allows physicians to provide the most informed care, contribute to medical knowledge, and create a cycle of growth whereby increasingly challenging presentations offer continuing opportunities to learn.

Interestingly, PBL may not improve learning outcomes as currently measured. The PBL approach places less emphasis on achieving high assessment scores, so learners are more likely to study for understanding rather than exams.[7,17] It is important to recognize that of 15 studies reporting learning outcomes in this review, a minority of studies had control groups comparing quantitative data on PBL to traditional formats.[9,27,39,40] It is also difficult to control for confounding factors such as instructor variability or learner availability in the context of work and on-call demands.[7,45]

The impact of PBL on result outcomes were mixed; few studies evaluated patient outcomes and some indirectly evaluated clinical performance. While result outcomes are often considered to be the most important, Cook et al.[46] highlight several challenges of focusing on patient outcomes including potentially biased outcome selection and failure to establish a causal link. These perspectives highlight that results outcomes may not be feasible. In our study, these challenges were exemplified in four studies that indirectly assessed supervisors' evaluation of learner performance with no standardized rating system and were subject to biased outcome selection.[9,34,39,40] Thus, results outcomes may not always be possible to study in PGME contexts.[46]

Similar findings have been reported with PBL in undergraduate medical education contexts. A recent scoping review of 124 studies[6] identified that undergraduate medical learners were highly satisfied with PBL, and PBL was more effective than other formats in improving problem solving skills and behaviors such as communication skills and self-learning skills. Like the PGME context, there were mixed knowledge outcomes however PBL was consistently no worse than traditional formats for academic performance.[6] Logistical issues and greater human resources are also barriers in undergraduate medical education contexts.[6]

There are several gaps in the literature regarding PBL in PGME that require further investigation. Firstly, in a CBME era, future studies could explore PBL on growth mindset. Fostering a growth mindset necessitates active engagement, effort, and focus;[47] PBL offers this by scheduling time for collaborative exploration, self-study, and facilitated discussion with an expert of presented cases. While no studies formally assessed the mindset of learners, the goals of PBL on skills development and motivation are in alignment with that of a growth mindset and is seen in the effects on behaviour and reaction.[48] Secondly, few studies evaluated patient outcomes, possibly due to the difficulty in isolating one learner's contributions in collaborative care. With initiatives such as the GEMINI database, Canada's largest hospital data and analytics network,[49] future studies may be able to link teaching interventions with patient outcomes. Lastly, while there is emerging research examining the delivery of PBL in an online environment,[25,50] literature reporting on virtual

delivery of PBL in PGME is scarce. In a post-COVID-19 pandemic era, future studies should investigate the option of virtual delivery of PBL and the use of learning technologies within PBL formats.

There are limitations that merit discussion. Firstly, "problem-based learning" is not a rigidly defined approach and is similar to other forms of active learning such as case-based learning, forms of small group learning, and flipped classroom models. PBL was chosen as it was specific to medical education, though the term's ambiguity may have resulted in some studies being excluded in this review. Secondly, while frequency and duration of PBL formats were reported for each article, other PBL design variations and facilitator differences were not reported in the studies limiting the ability for the authors to further evaluate these PBL models. Thirdly, only 45% (*n* = 9) of studies included a control group, few studies captured all the PBL outcomes of interest, and few studies captured long term patient and resident outcomes of PBL in PGME. Fourthly, across the 21 studies included, the mean MERSQI score was 11.07 +/- 3.38 (range of 5-15.5, of possible 18). The reliance on self-reporting questionnaires also represents important limitations. To overcome these limitations, future studies should aim to include a report of all PBL design and facilitation details as well as outcomes, with a randomized control trial design.

Conclusion

PBL in PGME has its merits in strengthening outcomes of education including attitudes and behaviours of residents at no detriment to their acquisition of medical knowledge. While there may be initial reservations in implementing PBL, existing infrastructure used for teaching residents can facilitate the scheduling and transition to PBL in a multitude of PGME contexts. The implementation of PBL can be a valuable educational strategy for residents and medical educators in PGME programs.

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