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Concepts and Implementation of Digital Problem-Based Learning in Health-Related Study Programmes: A Scoping Review

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ABSTRACT

Problem-based learning (PBL) is currently a well-established and widely used teaching/learning method that follows a distinct structure, such as a seven-step approach. There is growing interest in providing PBL digitally. This scoping review aims to investigate whether the principles of PBL can be implemented in digital formats and whether comparable results in students' competence development can be achieved. A systematic literature search was conducted from January 2017 to March 2022 in accordance with the Joanna Briggs Institute (JBI) guidance for scoping reviews. The search yielded 1,007 studies, of which 7 were included in the review. The results demonstrated that traditional PBL can be implemented in both blended and fully online formats following its rationale. Most of the identified courses followed the seven-step approach, thereby providing a clear structure for alternating between the group learning and self-learning phases and related tasks. The results showed that blended or fully online PBL not only achieved the desired competence development but also promoted additional competencies such as communication skills through the digital learning context. These formats expand the possibilities of using PBL in health-related courses, effectively combining the benefits of analogue and digital worlds. However, appropriate resources in terms of both technical infrastructure and trained staff are required. In the future, the implementation of blended and fully online PBL should be described in more detail to evaluate their specific requirements.

Keywords: *Digital problem-based learning, Higher education, Online learning, Recommendations*

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INTRODUCTION

Problem-based learning (PBL) originated more than 50 years ago in the medical context to empower learners to solve clinical problems and support their lifelong learning (1). Based on a constructivist and student-centred approach, the integration of real-life problem situations enables students to autonomously deepen their previous knowledge through a structured approach.

PBL aims to not only expand cognitive knowledge but also continuously provide a link to application and promote practical relevance (2). As a result, competencies such as the ability to communicate and collaborate in solving complex problems, to adapt and innovate in response to new demands or changing circumstances and to use technology to build new knowledge are initiated, which are urgently needed to meet the challenges of the 21st century (3).

Meanwhile, PBL has been widely used beyond medicine in higher education (4–6). The McMaster PBL model can be regarded as the starting point, which has since been supplemented or extended by other models, such as the Maastricht seven-step approach or the 8-step model of the Berlin problem-oriented learning (POL) approach (5, 7–9, 10–12). Thus, there is no single, definitive model; instead, a wide range of PBL implementations exist today (5, 8, 9, 13).

All these models share a common structured and iterative PBL process, usually comprising three phases: problem representation and analysis, self-directed learning, and synthesis and knowledge sharing. Taking into account the seven-step approach, the following steps can be differentiated: (a) Clarify terms and concepts not readily comprehensible; (b) Define the problem; (c) Analyse the problem; (d) Draw a systematic inventory of the explanations inferred from step (c); (e) Formulate learning objectives; (f) Collect additional information outside the group; and (g) Synthesise and test the newly acquired information (11). Here, phase 1 includes steps (a) to (e), phase 2 includes step (f), and phase 3 includes step (g).

An important characteristic of PBL is that the learning process is driven by a specific problem situation (case) where learners draw on their prior knowledge (i.e., on previously acquired knowledge) as well as phenomenological and personal experiential knowledge. Ideally, this process reveals knowledge gaps or introduces more complex contexts that can be addressed or understood through a targeted search for additional knowledge and information. In this process, learners critically reflect on their knowledge (4, 8, 14, 15).

One of the main features of PBL is collaboration and discussion within small groups, usually with learners physically present (4). Learners are accompanied by lecturers, who are referred to in the literature as tutors, facilitators, or PBL lecturers and usually moderate the learning process (12, 16, 17). However, this approach places high demands on adequately trained staff as well as appropriate spaces and times (18).

Hmelo-Silver (4) and Hung et al. (5) indicated in their review that the differences between traditional didactic approaches and PBL in terms of learning outcomes and competencies have been studied, and that the results show a mixed picture. In terms of competency development, PBL shows clear advantages in clinical reasoning, problem-solving skills, knowledge application and transfer, long-term retention of learning, self-directed learning skills, collaboration skills, and social and professional skills (4, 5). Conversely, traditional teaching/learning methods tend to outperform PBL in terms of the breadth of basic factual knowledge.

Even before the COVID-19 pandemic, digital technologies were being incorporated into PBL (6). These approaches are referred to in different ways, most commonly electronic PBL (e-PBL) or digital PBL (DPBL), although no clear definition exists. This variability is also reflected in the implementation and thus in the spectrum, as well as the scope of the digital technologies being used. These technologies range from individual supporting tools, such as providing materials through learning management systems, to blended (face-to-face and asynchronous online units), and finally, to fully digital (asynchronous and synchronous online units) PBL courses.

Interaction between learners or learners and lecturers can take place synchronously, for example, through video conferencing and chat rooms, or asynchronously, for example, through web and discussion forums. In addition, digital media has expanded new opportunities for the delivery of materials, such as recorded lectures and videos.

Coiado et al. (19) also demonstrated that the roles of learners established in PBL (such as leader, innovator, searcher, scribe, reader, synthesizer, inquisitor, and audio-visual technician) are transferable or adaptable in DPBL. These roles are adjusted to suit the conditions of an online format, for example, the audio-visual technician may be responsible for sharing documents during a web conference.

From the tutor's perspective, differences emerge between face-to-face PBL and DPBL. For example, it has been found that a group session can take longer to conduct due to breaks and the additional time needed for students' participation. Digital technologies offer creative forms for students' participation, such as emojis or online chats, and allow for individual feedback between tutors and students via the chat function. However, DPBL presents greater student distractibility and passivity, which implies that tutors must be more actively involved in maintaining the flow of discussion. Despite these differences, student performance between face-to-face PBL and DPBL remains comparable.

Traditional PBL approaches, where the overall structure is presented as a digital format with asynchronous and synchronous units, have undergone a surge in development due to the COVID-19 pandemic, although relatively few examples are still available (12, 20, 21).

Studies also suggest that PBL and DPBL yield comparable outcomes (6, 18, 22). However, some studies have shown conflicting results, indicating lower performance among DPBL students compared to PBL students (23). Specific advantages and disadvantages of DPBL have been identified (3, 23–25), with goal-oriented learning being one of the benefits. The acceptance and success of DPBL depend on individuals as well as technical and structural factors (24).

Although the COVID-19 pandemic promoted online teaching and improved the IT infrastructure, DPBL strategies are still lacking. This presents a unique opportunity to examine the transfer from traditional PBL to DPBL under significantly improved technical conditions.

Although DPBL has been described in the past, little is known about whether it actually transforms PBL principles into the digital arena and how successful this process is in terms of outcomes. Consequently, this scoping review aims to explore DPBL approaches delivered in blended learning or fully online health-related study programmes. The review highlights how the principles and structure of PBL have been implemented digitally and assesses whether the intended competency development can also be achieved with these DPBL formats. In particular, the scoping review aims to answer the following research questions:

(a) What forms of DPBL can be identified in health-related study programmes?; (b) Do these DPBL approaches reflect PBL principles?; and (c) Is DPBL as successful as PBL in promoting competency development?

METHODS

A scoping review was conducted following the Joanna Briggs Institute (JBI) guidance for scoping reviews and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for scoping reviews (PRISMA-ScR) to identify the approaches used to conceptualise PBL into blended or fully online DPBL formats (26, 27). The PRISMA-ScR framework outlines 22 items, categorised into the following sections: title/abstract, introduction, methods, results, discussion, and funding. This study used all these items. A systematic literature search was conducted from 2017 to 2022 (March) in the following databases: Web of Science Core Collection, PubMed, CINAHL, Cochrane Library, and Scopus. The search strategy was developed to be literature-based and included the following search terms: "digital problem-based learning", "digital problem based learning", "online problem-based learning", "online problem based learning", "EPBL", "e-PBL", "online PBL", "electronic problem-based learning", "electronic problem based learning", "DPBL", "digital education in problem-based learning", "Problem-Based Learning"[MeSH Terms], "Education, Distance"[Mesh], online[Title], digital[Title], electronic[Title]; universit*, and "Universities"[MeSH Terms] (PubMed search). For search details, see the Appendix.

The following inclusion and exclusion criteria were defined:

Inclusion criteria:

a. DPBL, defined as the digital implementation of PBL in either a blended or fully online format
b. Description of the design of the DPBL course
c. Regular courses offered in a study programme focused on health and healthcare settings
d. Execution of an evaluation or study on the overall DPBL course or specific parts of it
e. Language: German or English
f. Publication between 2017 (January) and 2022 (March)

Exclusion criteria:

a. DPBL only mentioned briefly or single digital methods (e.g., Web conferencing tools) described in the DPBL course
b. Courses conducted outside of a particular study programme or involving students from different or unrelated study programmes (e.g., basic research)
c. PBL delivered exclusively in face-to-face or hybrid course formats
d. Other teaching formats such as case-based, team-based, or project-based learning
e. General descriptions of the PBL approach
f. Studies analysing learning outcomes with PBL or DPBL (e.g., soft skills)
g. Older than five years (published before January 2017)

h. Language: other than German or English
i. Publication types other than an original study, such as reviews, meta-analyses, books, or theses

A publication was included if PBL (e.g., seven-step approach) (11) was conceptually transformed into a digital teaching/learning format (DPBL) and offered as blended learning or fully online format. Only publications related to courses offered in a health-related study programme were considered. In addition, the publication was required to involve a study evaluating the DPBL course (either single aspects or the entire course). The digital tools used for DPBL were not restricted.

A total of 1,007 publications were identified. The selection of studies was performed independently by two researchers in three consecutive steps (title, abstract, and full text). If a clear decision could not be made on the basis of the information provided (e.g., title), the publication was included in the higher step to avoid excluding potentially relevant studies. The final selection of studies was made in the full-text review step. At each level, the inclusion and exclusion criteria were applied for selection (Figure 1), and any discrepancies in the assessments were resolved by consensus.

Publications were evaluated using a standardised data extraction table that included the following criteria in addition to aspects characterising the publication: first author, year of publication, title, scientific discipline, year of intervention, place/city of intervention, aim of the study, type of intervention, outcome measures, course/study programme, definition of the terms PBL and DPBL, form of DPBL, underlying concepts, evaluation, and conclusion. Both researchers specified all criteria to ensure a similar application. In the next step, all relevant information on these topics was extracted independently by one researcher from the selected study and cross-checked by the other researcher. The study quality was not reviewed due to the methodological approach and substantial heterogeneity of the studies.

Additionally, a thematic analysis was conducted to summarise the study results. Referring to qualitative content analysis, the study findings were thematically grouped.

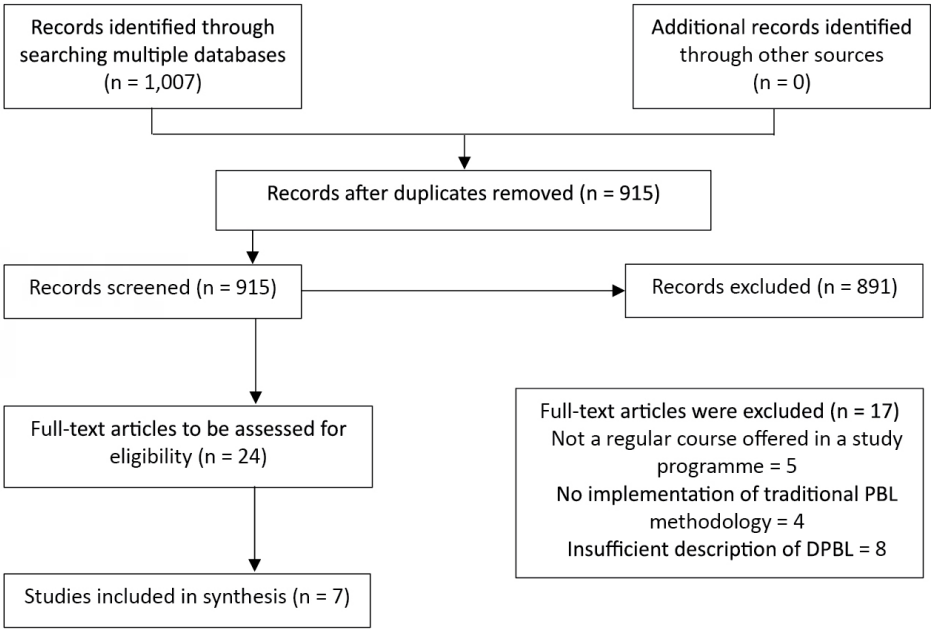

Figure 1: PRISMA flow chart for scoping review.

RESULTS

Overview

Seven studies were included in the scoping review (Table 1), which covered different health-related study programmes, including two in medicine, two in dentistry, and one each in public health, speech-language pathology, and occupational therapy (28–33). The course duration varied from 1 to 8 weeks (28–33). The studies were geographically diverse. Among the DPBL courses, three were delivered in a blended learning format and four were fully online.

Table 1: Characteristics of selected studies

First author	Publication year	Country	Study programme	Duration DPBL course	DPBL format
de Jong et al. (32)	2017	The Netherlands	Health services innovation, Global health, Health professions	Module, 8 weeks	Blended-learning
de Jong et al. (33)	2018	The Netherlands	Public health	Module, 8 weeks	Blended-learning
Saqr et al. (30)	2018	Kingdom of Saudi Arabia	Dental medicine	5 days	Blended-learning
Jaiprakash et al. (28)	2019	Malaysia	Medicine	8 days	Online
Erickson et al. (34)	2021	Australia	Speech pathology, Occupational therapy	5 days, plus icebreaker session	Online
Murata et al. (31)	2021	US	Dental medicine	3 weeks	Online
Foong et al. (29)	2022	Malaysia	Medicine	n/s	Online

Note: n/s = not specific.

Most universities involved in the studies had prior experience with PBL; in some universities, PBL was even the principal teaching format (30, 32–34). PBL was implemented according to different models, for example, the seven-step approach was explicitly mentioned as a reference framework for the implementation of DPBL (Table 2) (32, 33). However, most publications did not specify traditional PBL nor did they provide any definitions for DPBL. An exception was de Jong et al. (32, 33) who defined blended DPBL as a digital translation of traditional PBL delivered at the university using the seven-step approach. A similar interpretation was found by Saqr et al. (30).

Characteristics of DPBL Courses

DPBL courses were usually embedded in a learning management system (Table 2), which allowed for posting materials and saving results.

For group work, students were divided into small groups, comprising 6 to 14 people, usually at the beginning and end of the DPBL course. This allowed the process to align with the traditional PBL, which used cases as the central starting point. The group session

was conducted face-to-face or in a synchronous online format, using web conferencing tools. Furthermore, asynchronous course elements, such as forums or social media, were employed to enable interactions between students as well as students and tutors or lecturers. In addition, materials were provided in learning management systems or via additional digital technologies.

Tutors were generally employed to facilitate PBL implementation, which was continued for DPBL. The tasks of the tutors largely corresponded to those in the traditional PBL approach, primarily including supporting group work; providing materials, which in addition to literature also included recordings of lectures; and providing personalised assistance to students (32, 33). To prepare students, tutors and lecturers for DPBL, individual authors planned additional activities, such as social events (32, 33).

Table 2: Synthesis of results regarding the educational approach

First author	PBL-model	DPBL approach	Face-to-face	Online	Small groups (N)	Tutor role	Digital tools	Supporting event	Examination
de Jong et al. (32)	Seven-step approach, three phases	Seven-step approach online, three phases	1st meeting	Tutorial groups (N = 4), Lectures (N = 10 weeks)	n/s	Facilitation of group session	Webcams (Surfgroepen), Skype, Intranet, Blackboard, Elluminate, FirstClass	1st meeting, a one-day face-to-face meeting	End of module test
de Jong et al. (33)	Seven-step approach, three phases	Seven-step approach online, three phases	1st meeting	Tutorial groups (N = 4), Lectures (N = 8 weeks)	7	Facilitation of group session	Web conference tool	1st meeting, a face-to-face meeting, including social event (dinner)	End of module test
Saqr et al. (30)	Analogous seven-step approach, three phases	Analogous seven-step approach online, three phases	Groups session (N = 2)	Discussions, exchange learning resources, during the week	10-14	1 tutor for each group	Moodle		n/s
Jaiprakash et al. (28)		Four triggers (case)		Day 1: trigger sent Day 3: send back facts/definitions Day 4: research to posted guiding Day 6: answer to guiding questions Day 8: mini test	10-11		Google Forms, PowerPoint		Modified essay question end block exam (EBX)
Erickson et al. (34)	Hybrid PBL (2 tutorials, self-directed learning, lecture, practical class)	Analogous seven-step approach online		Online PBL case via black-board, Groups session (N = 2)	10-12	n/s	Hand-rising tool, whiteboard, shared screen, videos by the facilitator (Black-board)	Icebreaker session (one week before)	
Murata et al. (31)	Analogous seven-step approach	Three small group meetings in once a week, corresponding traditional PBL		Small group of students and facilitator met thrice (120 min each session once a week)	6	Facilitators were calibrated on the PBL process	Video-conferencing, collaborative document editing, files sharing, instant messaging	45-min introduction (online)	Online presentation
Foong et al. (29)	PBL on a weekly basis	PBL in virtual learning space		Students and tutors conducted their PBL in a virtual learning space	8	Group session	Virtual learning space (Microsoft Teams), recordings (Microsoft Streams), virtual whiteboard (OneNote)	User manuals training sessions and workshops short session on experiencing virtual PBL	n/s

Blended learning approaches for DPBL

Table 2 provides information on DPBL implementation. de Jong et al. (32, 33) implemented DPBL based on the traditional PBL (i.e., seven-step approach); therefore, the three phases with the corresponding steps can be differentiated here as well. Both studies referred to the same master module, where DPBL was offered with minor variations (32, 33). In de Jong et al.'s (32, 33) study, the DPBL module specified five meetings. Of these, only the first meeting was held face-to-face, supplemented by a social event; the other four group meetings were held online, synchronously, using a web conferencing tool. The social event allowed students to get to know each other as well as to be informed about the course of the event. In addition, 10 synchronous online lectures were offered (32). Saqr et al. (30) also followed traditional PBL, with clearly defined steps in three phases. In the blended DPBL approach, face-to-face group sessions were held at the beginning and end of the week. The first group phase was used to discuss the problem case, to identify explanatory approaches, and to formulate learning objectives. The discussion continued online to share ideas on the determined learning objectives, learning resources, concept maps, and explanations. The learning progress and conclusions were presented and discussed in the second session at the end of the week. A traditional blended learning DPBL format was observed in the studies conducted by both Saqr et al. (30) and de Jong et al. (32, 33) where only the first event, with a different focus, was offered face-to-face.

Fully online approaches to DPBL

Jaiprakash et al. (28) developed a fully online DPBL course in which students worked in small groups, followed a structured scheme, and shared their findings via Google Forms. On the first day, students received a trigger to work on and submitted facts and unfamiliar words with their meanings. They received concrete guiding questions for research on the fourth day and submitted their findings by the sixth day. On the eighth day, the course concluded with a quiz to test their knowledge. Erickson et al. (34) followed traditional PBL in their online DPBL course, beginning with an icebreaker session for the participants to become acquainted with each other and the platform and to troubleshoot technical problems. In the first tutorial, students were given a case (clinical problem) to discuss their ideas. Successively, more written and audiovisual information was provided to students on a shared screen to stimulate discussion and to set learning objectives. In the second tutorial, students accessed discussion notes through the online learning management system, where the results of the learning objectives were discussed in light of the new knowledge and a final clinical interpretation of the case was formulated. However, the authors did not detail whether and how the self-study phase was organised (34). Murata et al. (31) also offered an introductory session on the digital technology used before the start of the DPBL course. The design and goal of the DPBL followed traditional PBL, differentiating seven steps without explicitly referring to the seven-step approach. Small groups of students participated in three synchronous meetings with the tutors, during which they were run through the different steps. No further specification was made. In the last meeting, the small groups presented and discussed the cases. Foong et al. (29) also adopted PBL to DPBL using various digital technologies, although these were not described in detail. The tutors received additional information to prepare for DPBL; students received training on selected functions (e.g., raise hand, initiate chat, share screen, and take notes). To make the synchronous sessions available to students, the tutors recorded them and uploaded them to the learning platform.

Categories Studied in DPBL

The studies that were conducted varied widely in their methodology and content focus. In addition to descriptive studies with quantitative and qualitative study designs, they also included experimental studies (28–33). The cases ranged from 8 to 275 subjects (29, 34). Despite these differences, the following categories were identified: roles of learners, roles and tasks of tutors, social interaction, satisfaction with DPBL, learning outcomes or competency development, and DPBL potential. The results were presented according to these categories (Table 3).

Table 3: Synthesis of results

First author	Study design	Analysed N	Sample	Data collection methods	I/C group	Main variables	Main results	Category for this review
de Jong et al. (32)	Mix-methods study	n/s	Part-time students	Real-world research, questionnaire (students), focus group (students), interview (students faculty staff)		Student roles, student characteristics, tutors' experiences.	Online student roles comparable to face-to-face PBL. Tutor had double task. Collaboration possible. Synchronous and asynchronous PBL feasible.	Student roles, tutor roles and responsibilities. Social interaction. Satisfaction with blended PBL/DPBL. DPBL potential.
de Jong et al. (33)	Practice-based comparative study	22 students; 1 tutor	Full-time and part-time students	Quantitative data (students) Qualitative data (tutors)	Face-to-face = 14 PBL; Online PBL = 8	Tutor performance, student characteristics, Marks on the end of module test, tutors' expectations and experiences.	Tutor activities comparable in PBL and DPBL. Two extra tutors tasks in DPBL. Total duration of the steps were comparable. Discussions in DPBL equally successful.	Student roles, tutor roles and responsibilities. Social interaction. Satisfaction with blended PBL/DPBL. Learning outcomes and/or skill development.
Saqr et al. (30)	Secondary research	215 students; 20 tutors	Second year students; tutors	Metadata online Interaction data (standard data mining technique)		Attributes of individual users, groups, and courses as well as the properties of each post.	Moderate to strong positive correlation between interaction parameters and performance. Students with stronger ties performed better. Negative correlation between tutor interactions and students grades.	Social interaction. Learning outcomes and/or skill development.
Jaiprakash et al. (28)	Experimental study	174 (64 test group; 110 control group)	Year 2 MBBS students	Modified essay question (MEQ) test	64 students of the test group were divided into six groups to ensure that their learning is team-based and collaborative.	Perception of students regarding e-PBL, performance.	PBL and e-PBL nonsignificant differences in both end block and e-PBL MEQs. e-PBL: increased ability to link basic science knowledge with clinical and applied knowledge supported systemic understanding on the topic promoted motivation for self-study improved their information management skills.	Learning outcomes and/or skill development. DPBL potential.

(*Continued on next page*)

Table 3: (*Continued*)

First author	Study design	Analysed N	Sample	Data collection methods	I/C group	Main variables	Main results	Category for this review
Erickson et al. (34)	Qualitative study (Experimental)	8	Students' final year undergraduates	Focus group, survey			Three main themes and eight subthemes: Theme 1: 'I think there is a place for it'. Theme 2: How it feels. Theme 3: Ideas don't flow so easily.	Social interaction Satisfaction with Blended DPBL/ DPBL.
Murata et al. (31)	Case study	Three small group meetings in once a week, corresponding traditional PBL	Year 1 students	Using rubrics, Feedback tutors		Student performance	Positive support for the use of a web-based platform. Positive support for critical skills development.	Learning outcomes and/or skill development.
Foong et al. (29)	Quantitative study	275	Preclinical students (Year 1 and Year 2)	Questionnaire Pre/Post		Instrument consisted of 13 items with 5-point Likert scale responses.	Positive experience towards participating and learning from virtual PBL. Confidence in their abilities to use the knowledge gained during the virtual PBL sessions. Positive towards the use of a VLE for PBL. Lower confidence in passing clinical exams and content acquisition.	Learning outcomes and/or skill development DPBL potential.

Roles of the learners

de Jong et al. (32, 33) found that, in the synchronous online group meetings, the roles of learners in DPBL were comparable to those in traditional PBL. This was also reflected in the execution of each step, where no differences were observed between the face-to-face and blended PBL groups (33). Likewise, the quality of the group discussions remained consistent across PBL and DPBL.

Roles and tasks of tutors

The demands on the tutor have changed as a result of DPBL. de Jong et al. (32, 33) indicated that, in addition to teaching, tutors had to manage technical aspects. Chatting as a way to read and post messages during group sessions proved to be another task for tutors in online sessions. While managing chat posts was not considered disruptive, it was seen as an enrichment; however, it posed a challenge in accurately identifying the participants who posted messages (33). Erikson et al. (34) also highlighted that, to ensure a smooth technical process, tutors may have to invest additional effort.

Social interaction

DPBL presents specific communication challenges due to limitations in nonverbal expressions and restrictions on spontaneous statements (33, 34). This led to the development of a communication style that requires a clear structuring between participants (e.g., clear alternation between contributors) or even making the communication process itself a topic of group discussions (32).

Saqr et al. (30) explored how social networks of online interactions evolve and found that communication occurred essentially between students rather than between students and tutors.

In contrast, Erikson et al. (34) showed mixed results regarding online communication. While some students did not find it challenging to participate in online sessions, others felt inhibited or needed to time to get used to the format, which was partly attributed to the lack of nonverbal communication (34). In addition, the students found it more difficult to establish rapport and sustain discussions in the online format. They noted that limited opportunities to meet in person reduced their social interactions. These limitations may have resulted in less extensive exchange and processing of content than desired.

Satisfaction with DPBL

Ensuring technical functionality and transmission quality (e.g., sound) are key preconditions for satisfaction with blended DPBL (32, 33). Conversely, technical difficulties contribute to dissatisfaction with DPBL (34). In addition to technical difficulties with digital tools, sufficient internet bandwidth also plays an important role in ensuring uninterrupted participation without loss of information. In addition, timely feedback from tutors impacts student satisfaction (32).

Learning outcomes or competency development

No differences in module grades were observed between the face-to-face group and the blended DPBL group (33). Similarly, Jaiprakash et al. (28) reported no significant differences in modified essay question (MEQ) scores between the PBL and DPBL groups. Murata et al. (31) also found no differences in student performance assessments. Students in DPBL indicated that it helped them improve their ability to connect basic science knowledge with clinical and applied knowledge, gain a systemic understanding of the subject, and enhance their motivation for self-study and their information management skills (28). Saqr et al. (30) also demonstrated a consistent moderate-to-strong positive correlation between interaction parameters and performance in blended DPBL courses. In particular, good relationships between students and small interactive and cohesive groups tended to yield better performance. Students self-assessed their acquired skills positively; however, their confidence in passing clinical exams could be improved (29).

DPBL potential

The students in Foong et al.'s (29) study rated DPBL positively. Similarly, in the qualitative study by Erikson et al. (34), students saw potential in DPBL, provided the necessary technical requirements were met. They particularly emphasised the possibility of not being tied to a

specific location, as it involves less time and cost and allows them to perform other tasks and roles more easily. In addition, students perceived DPBL as a better way to pace their learning (28, 29).

de Jong et al. (32) found that offering introductory or additional events to help students learn how to use DPBL, as well as get acquainted with their group, was considered a "good start" for collaboration in DPBL.

DISCUSSION

The results of this study indicated that the core principles and learning approach of traditional PBL can be adapted to DPBL, either in a blended learning format or a fully online format, within health-related study programmes. This conclusion was also demonstrated by Coiado et al. (19). A wide range of digital tools were used for asynchronous (e.g., document management and forums) and synchronous (e.g., web conferencing tools and shared documents) DPBL activities.

Most reviewed courses either explicitly referenced the seven-step approach or aligned with it (30–34). Despite some differences, the three phases and the alternation between the group work and self-study phases were clearly recognisable.

The structured specifications of traditional PBL facilitate the adaptation of PBL to DPBL, as it can be implemented using synchronous and asynchronous digital teaching methods, thus providing lecturers with significant didactic freedom.

de Jong et al. (33) demonstrated that the processing of steps between students in PBL and DPBL was comparable. In contrast, Coiado et al. (19) and Riaz et al. (24) observed that DPBL required more time. It remains unclear whether this increased time demand can be attributed to technical problems, students' inadequate digital literacy skills, or the actual need for additional processing time in DPBL.

Comparable results can also be achieved with DPBL and PBL in terms of grades and intended skill development. This is consistent with the findings from other studies of different digitally supported PBL courses (6, 19), although Foo et al. (23) did not report similar outcomes.

Jaiprakash et al. (28) and Erickson et al. (34) demonstrated that DPBL enables students to use real-life problem scenarios to expand not only their knowledge but also their skills in communication, collaboration, and complex problem-solving. Digital technologies can support these learning processes in special ways, such as saving group discussion results for further elaboration and providing diverse materials (e.g., audio, video, and text) accessible on a structured basis in the learning management system (29–31). For advanced training, Mansholt et al. (20) and Egbert et al. (21) demonstrated that traditional PBL methods (here, 8-step model of the Berlin POL) could be fully translated using different digital technologies (12, 20, 21).

However, the preferred approach involves synchronous group sessions and asynchronous work phases. This direct exchange not only helps participants work on the cases but also facilitates reflection, allowing students to evaluate their specific knowledge by recognising the findings of their peers, which is the main aspect of PBL. Such reflection helps form specific anchor points for autonomous learning via jointly defined learning objectives.

In most study programmes, students had prior experience with traditional or hybrid PBL. In this respect, familiarity with the method facilitated a smoother transition to a digital teaching format. For student groups without PBL experience, an introduction to the PBL/DPBL methodology should be provided, as recommended and implemented, for example, in the 8-step model of the Berlin POL for face-to-face teaching (12).

The findings also indicate that students should be prepared for the specific features of the digital learning methods used in DPBL (24, 29, 31–33). While many have likely developed digital literacy during the COVID-19 pandemic, addressing different levels of digital competency among students in addition to optimal preparation for DPBL is also important for creating equal conditions for participation in DPBL.

Furthermore, convergence is anticipated between social interaction within PBL and DPBL. Nevertheless, digital communication has inherent limitations, as evidenced by a lack of spontaneity and an inability to receive non-verbal expressions (34). Future DPBL should address and develop new approaches to digital exchange. Coiado et al. (19) demonstrated that the roles established in PBL can be transferred to DPBL, with adaptations using digital technologies. This approach could be beneficial for implementing DPBL by defining students' roles in the context of digital teaching and learning methods as well as identifying any additional roles required, such as those on collaboration in group sessions.

Similarly, the results showed that tutors play an important role in DPBL, who perform their tasks in PBL in a digital context. However, in terms of moderation, they may face new challenges when group rapport and the progression of discussion falter (33, 34). Here, solutions must be found where tutors support the discussion without compromising the restraint required according to the PBL model. This indicates the need for content-specific adaptation in DPBL. In addition, de Jong et al. (33) demonstrated that tutors may be faced with additional tasks that revolve around securing digital technology, potentially overburdening them, which may require extra staff.

Certain limitations need to be considered. Despite a thorough search approach, some relevant studies may have been missed, and not all aspects of DPBL approaches may have been recognised due to the limited descriptions in the reviewed studies.

CONCLUSION

This scoping review aimed to ascertain whether and to what extent the principles and structure of PBL can be adapted to online learning. The findings demonstrated that the online environment is not only conducive to PBL but also presents opportunities for further advancement of this approach. Furthermore, they indicated that DPBL is an effective method for developing competencies in healthcare and medicine.

In summary, DPBL is more than simply enriching PBL with digital technologies. The present results suggest that DPBL holds greater potential, as digitalisation can provide different and even new competencies in collaboration and problem-solving, which prepare students for the challenges of a digital society. For example, it allows students to develop competencies of interactive exchange using digital information in real-time or digital communication or collaborative documentation of project results.

Despite a large number of publications on this topic, only seven papers could be identified in which DPBL (blended or fully online formats) was conducted as a regular course in a health-related study programme. Unfortunately, most of these publications insufficiently differentiated descriptions of didactic implementation, resulting in gaps in detailed understanding of the implementation. Consequently, a "black box" is created that requires further investigation. By addressing these limitations, the full potential of DPBL can be exploited.

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APPENDIX

Search Strategies

PubMed (last search date: 22/03/2022)

("Digital problem-based Learning" OR "Digital problem based Learning" OR "online problem based learning" OR "online problem-based learning" OR "EPBL" OR "e-PBL" OR "online PBL" OR "electronic problem-based learning" OR "electronic problem based learning" OR "DPBL" OR "digital education in problem-based learning" OR ("Problem-Based Learning" [MeSH Terms] AND ("Education, Distance"[Mesh] OR online[Title] OR digital[Title] OR electronic[Title])) AND (university* OR "Universities"[MeSH Terms])

Web of Science Core Collection (last search date: 22/03/2022)

ALL=("Digital problem-based Learning" OR "Digital problem based Learning" OR "Digital problem based Learning" OR "online problem based learning" OR "online problem-based learning" OR "online problem based learning" OR "EPBL" OR "e-PBL" OR "online PBL" OR "electronic problem-based learning" OR "electronic problem based learning" OR "DPBL" OR "digital problem-based learning" OR "digital education in problem-based learning") and 2016 or 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 or 2007 or 2006 or 2005 or 2004 or 2003 or 2002 or 1999 or 1997 or 1995 or 1994 or 1993 or 1992 or 1987 or 1985 (exclude – publication years)

SCOPUS (last search date: 22/03/2022)

(ALL ("Digital problem-based Learning" OR "Digital problem based Learning" OR "Digital problem based Learning" OR "online problem based learning" OR "online problem-based learning" OR "online problem based learning" OR "EPBL" OR "e-PBL" OR "online PBL" OR "electronic problem-based learning" OR "electronic problem based learning" OR "DPBL" OR "digital problem-based learning" OR "digital education in problem-based learning")) AND (university*) AND (PUBYEAR > 2016)

CINAHL (last search date: 22/03/2022)

("Digital problem-based Learning" OR "Digital problem based Learning" OR "Digital problem based Learning" OR "online problem based learning" OR "online problem-based learning" OR "online problem based learning" OR "EPBL" OR "e-PBL" OR "online PBL" OR "electronic problem-based learning" OR "electronic problem based learning" OR "DPBL" OR "digital problem-based learning" OR "digital education in problem-based learning") OR ((MH "Problem-Based Learning") AND (MH "Online Education" OR TI online OR TI digital OR TI electronic)) AND (universit*)

Cochrane Library (last search date: 22/03/2022)

("Digital problem-based Learning" OR "Digital problem based Learning" OR "Digital problem based Learning" OR "online problem based learning" OR "online problem-based learning" OR "online problem based learning" OR "EPBL" OR "e-PBL" OR "online PBL" OR "electronic problem-based learning" OR "electronic problem based learning" OR "DPBL" OR "digital problem-based learning" OR "digital education in problem-based learning") OR ("Problem-Based Learning") AND (MeSH descriptor: [Education, Distance] explode all trees OR (online OR digital or electronic):ti) AND (universit*)