Title– Problem Based Learning in Radiography Education: A Narrative Review

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Abstract

Objectives: Radiography practice is fast developing with new imaging updates and challenging scenarios to deal with on a frequent basis. There is a need to equip students with the skill to be independent learners and develop critical thinking skills, so they can change their practice as the profession evolves. Problem Based Learning (PBL) has widely been adopted in medical and nursing training worldwide as a result of its desirable benefits. In order to ascertain the efficacy of the technique, this paper presents a review of the essential aspects of PBL, such as the theories, process, key roles and implication for radiography education and practice.

Key Findings: The use of a defined model provides a useful structure to the PBL exercise with the addition of reflection, which is a pertinent inclusion within the process. The role of the facilitator in PBL is significant to students' learning as they help guide the students to the learning outcomes and provide support to the group; however, their skills development is an important factor to consider in PBL.

Conclusion: This teaching approach has key benefits in radiography education and training in particular, its impact on preparing students for autonomous clinical practice.

Implications for practice: The application of PBL in developing students' critical thinking and decision-making abilities support the narrowing of the spoon-feeding expectation of students and render it a useful pedagogical implementation within radiography programmes.

Introduction

In 1969, the Problem Based Learning (PBL) technique was first introduced to medical training programme at the McMaster University in Canada[1]. PBL is a student-focused approach that involves a group of students researching to solve a real-world problem[2]. It is different from the didactic or traditional method of teaching which involves the tutor giving a lecture on a topic and then discussing the real-life application. In PBL, students use a real-life problem to identify the relevant topic to learn to solve the problem. PBL has been shown to be a more effective approach compared to traditional teaching methods [3,4] and has the advantages of aiding the development of the students' critical thinking, communication and team-working skills[5,6].

Critical thinking in medical imaging requires the use of ethically sound professional reasoning in making justifiable decisions in relation to examinations, diagnosis, and management of the patient[7]. The process of critical thinking involves the application of both cognitive and affective skills in order to provide not just a logical thought pattern but also an empathetic approach to patient-centred care and management in radiography practice[7].

PBL offers the opportunity for students to develop these skills through solving a clinical problem by critically examining different interventions and their impact on patient management and outcomes. Students work as members of the team to solve the problems, thus also improving both their communication and team-working skills[7]. In addition, they learn the value of reflecting on their decisions and subsequent outcomes; this helps to enhance their commitment to lifelong learning. However, it is recognised that if the actual answers are not presented then an element of learning has not taken place, and this has been noted in some medical programmes where a lack of foundational knowledge has been highlighted [8].

The key to successful PBL is the recognition that students are active participants in the own learning, they are effectively 'learning to learn', and this gives them a strong sense of ownership of their learning At the same time the lecturers have to learn how to 'surrender the seat of authority' and change from being the 'knowledge giver' to 'the knowledge broker'[9].

While the approach has been in use for some time in medical and nursing training worldwide, PBL was adopted in radiography education in the United Kingdom in early 2000[10]. Its adoption in radiography education was because of the extending roles of the Radiographers that meant that they were more independent and autonomous[11,12]. Autonomous practitioners' thinking and decision-making skills have to be of a higher order. However, despite PBL being a well-established teaching and learning pedagogy, students still struggle with developing higher-order thinking skills, i.e. the skills of critical thinking [7]. PBL emphasises the need to train student radiographers to develop the critical thinking and team working skills required in autonomous radiographic practice.

Furthermore, the imaging equipment used by radiographers is advancing rapidly, and students need to possess the knowledge and skills to apply these advancements to their practice actively [13]. Nesargikar[12] asserted that the fear of change is a factor that influenced tutors' adoption of this approach in radiography education, as they believe it might make them irrelevant. In addition, the limitations of using this approach are that it requires a well-trained staff to facilitate the learning to guide the students through the activity and manage the group dynamics[14].

This paper aims to review the process, theories of PBL, key roles in PBL and implication of the PBL in radiography education.

The PBL Process

The approach in PBL can vary from an unstructured to structured approach [15]. The former does not require much support from the facilitator for the students when attempting to solve the problem [16]. However, the students must be experienced in using the PBL approach in their learning; thus, this approach might only be used for postgraduate radiography training with previous experience in the PBL process. The structured approach is the process where PBL is guided using a predefined model, such as the process highlighted in Table 1. This table was adapted from Maastricht seven steps process[17]. Undergraduate radiography students are at the beginning of their learner journey at university; hence the structured approach might be preferred to guide them due to their inexperience at that level.

The PBL processes developed by the McMaster and Maastricht universities are most popularly adopted in the PBL curriculum in health education programmes around the world [18,19].

The features of the McMaster's PBL approach are the use of patient-based problem, student-centred activity and small group learning [20]. The Maastricht's method provides a clear step by step process to guide the students; however, this can be restrictive and might discourage creativity. In a study conducted with medical students at the University of Manchester, the results showed that there was need to include a new step – *Elaboration* – to the Maastricht process as they believed it might help students to actively connect their learning to clinical experience[21]. In addition, Rideout and Carpio [19], in their book, included a similar step referred to as '*reflection*' in order to encourage the students to think about the content and process of the PBL activity. Therefore, due to the desirable feature of this step to radiography education, it has been added to the Maastricht process in Table 1, giving us an eight-step process to the structured PBL exercise. The theoretical concept in PBL that supports this element will be explored further in the subsequent section. Steps 1-5 should be performed at the first meeting, while steps 6-8 at separate times [22].

Table 1: The PBL model adapted from the Maastricht seven-step process[17].

Steps	**Elements**	**Descriptions**
1.	Explain the problem	Ensure everyone understands the problem.
2.	Define the goals	Identify the questions that need to be answered.
3.	Analyse and evaluate the problem	Deconstructs the problem to identify specific issues and potential solutions.
4.	Assess any alternatives	Evaluate the potential solutions identified in the previous step.
5.	Work out the learning objectives	Provide the learning outcomes in a form that is concise and precise, as identified in Step 2.
6.	Individual or group study	Provide directed reading and fixed resources to acquire knowledge on the learning objectives.

7.	Discuss findings	The entire group comes together to present new information, and the facilitator provides feedback.
8	Reflection	Reflection on the content and process of learning.

PBL– Underlying Theories

The main education theories that can be applied to PBL, according to Gewurtz et al.[22], are constructivist theory, contextual learning theory and cooperative learning theory.

The development of students' learning over a period of time can be likened to the construction of new knowledge based on individual interpretations of reality. It involves descriptions of how a learner constructs or builds knowledge from past experience. The theory that underpins the construction of new knowledge from previous learning and experience is called constructivism [24,25,26].

Vygotsky's theory focused on the dialectic between an individual and society, and the effect of social interaction, language, and culture on learning, i.e. internalisation and externalisation whereby the transition from external operation to internal development leads to qualitative changes[25]. He believed that learning is a continuous movement from one level to the next higher level which more closely approximated a learner's potential. This movement occurred in what he called the zone of proximal development as a result of social interaction. According to Ardichvili [27], Vygotsky defined the zone of proximal development as the distance between a person's actual independent developmental level in relation to the problem-solving skills and their level of potential development derived through problem-solving under supervision or guidance of a tutor or peer. In this way, Vygotsky professed that learning occurred through scaffolded support, where learning developed from one stage to another[7].

Similar to Vygotsky, in Bruner's theory[28], knowledge is an active process; construction of new ideas or knowledge is based on current and past knowledge. Learners select information and make decisions in the process of integrating experiences into their existing mental constructs, known as discovery learning [29]. Learners build knowledge hence the constructivist approach. He introduced the idea of a spiral curriculum where complex learning is presented in a

simplified way first and when the learner grasps this, they then move onto more complex levels of learning. In this way students are taught through increasing levels of difficulty which teaches them to problem-solve independently[30]. During the process of 'scaffolding', an individual is prompted to move past current levels of performance following external support and develop new abilities as they construct knowledge [31]. The concept of scaffolding and the zone of proximal development fit closely with the learning experiences of radiography students where they learn and develop through the social interaction and guidance from university tutors and clinical placement mentors[7].

The constructivist theory forms the basis of PBL [16] and outlines how learners process information about the world [22]. It has three key elements: knowledge activation, encoding specificity and elaboration. The elements are highlighted as follows:

1. Knowledge activation: This is a framework developed by the students, and on which they add new knowledge. New information is more likely to be retained by students if prior knowledge is reflected upon, and actions are taken to improve on the knowledge acquired [16]. However, in the Maastricht process, there is no element that encourages students to do a personal reflection on their learning. Therefore, the inclusion of 'reflection' as an element (i.e. step 8) in the Table might be useful for knowledge activation.
2. Encoding specificity: Students are more likely to retain new information if the situation which it will be applied is similar to the situation in which it is learned. It is identical to the contextual learning theory described later.
3. Elaboration: By allowing students to discuss a subject and ask questions, they can develop a conceptual framework to link the different pieces of information. Consequently, they are more likely to understand and remember the information. This is an important step towards developing independent thinking skills in a student-centred and focussed manner.

The second learning theory is the contextual learning theory which assumes that the context of how knowledge will be used should determine the process in which it is acquired [22]. In radiography practice, one requires knowledge of the use of patient positioning and imaging techniques, radiation safety, patient care, diagnoses, likely treatment options and

management of disease processes [31]. In PBL, clinical scenarios are used to set a real-life problem into context for students to gain relevant information and understanding of the topic [16].

The third theory is the cooperative learning theory where students work together in a team and believe that when the other members of the group reach their goals, they can also reach their own goal [32,33]. Due to Higher Education HE having a mix of culturally diverse students, using PBL as a learning and teaching tool can encourage sharing of information where students learn from each other. This is a useful characteristic of PBL which might help to lower the Black, Asian and Minority Ethnic (BAME) attainment gap in University programmes such as radiography. According to the Advance HE [34], the BAME attainment gap – the difference between the good degrees awarded to white students and BAME students is 15.6%. This difference is greater when white students are compared directly to black students, which is 28.3%. There are a number of factors attributed to this gap, one of which is the lack of an inclusive curriculum. Given the extensive range of learning and teaching resources we now have at university, it is "increasingly possible to diversify perspectives and representation within the curriculum whilst maintaining academic values" [35].

Therefore, the PBL approach has the potential to make the radiography curriculum more inclusive, and consequently contribute to lowering the BAME attainment gap, which is a priority for HE.

Lastly, students have the opportunity to take responsibility for their learning and are internally motivated as they engage with topics which are relevant and exciting [36]. PBL is student-focused, and it is crucial for students to feel motivated to learn [23]. Also, because the undergraduate curriculum aims to help students become independent learners, PBL should be introduced to help students develop this ability. To avoid novice students in PBL from being discouraged from learning, a well-structured approach– for example, the adapted Maastricht process– should be used to guide both the learners and facilitators.

The roles in PBL

PBL has distinct roles which need to be agreed and understood in advance. The academic takes the role of facilitator and the students' elect a chair and scribe. It is important that the student roles are rotated for each scenario, giving all students the opportunity to participate in the roles. A group would typically comprise of 8-10 members, but slightly larger groups can still be effective.

The Facilitator– Once a comfortable and safe learning environment has been created, the facilitator should commence with a short icebreaker to engage the students in some informal conversation [36]. Once the session commences, they should guide the discussion and ensure the other roles are being adhered to [37]. The facilitator can test knowledge at appropriate stages to prevent side-tracking, but their role should be secondary to the group discussion [38].

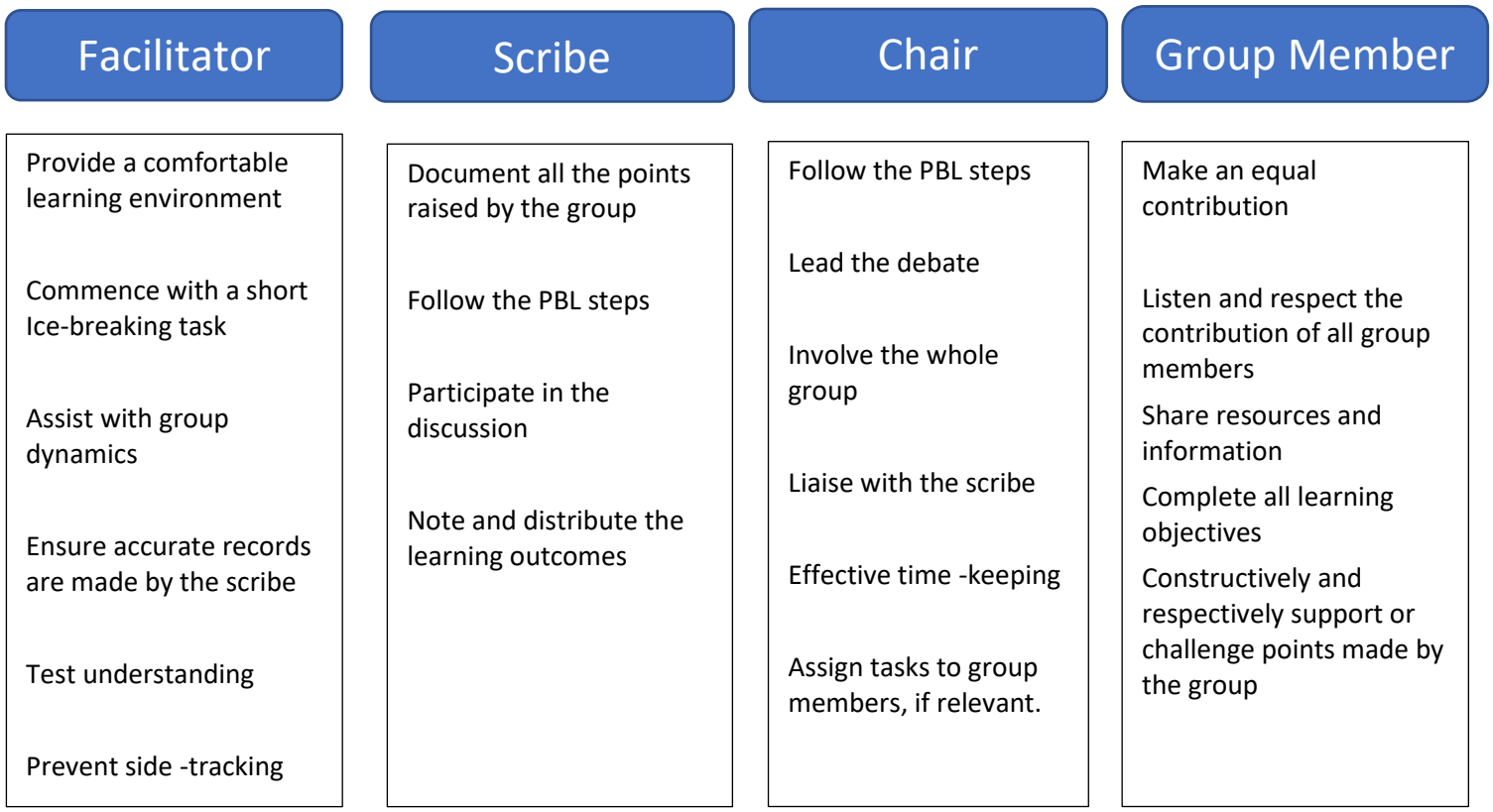
Expertise in facilitation is a more suitable characteristic of a PBL facilitator compared to being a content expert, as evidence suggests that content experts are more likely to revert to the traditional teaching methods [39,40]. Therefore, training and experience in PBL learning might influence the facilitators' ability to coordinate the PBL session effectively [14].

The Scribe– The scribe has an important role in accurately recording the points raised at each stage. It is important that they record this verbatim so that nothing is missed at teach stage. The documentation can be recorded on flip charts, whiteboards or electronically. The scribe ensures that all the notes and the learning outcomes are available to the group after the session[38].

The Chair– The role of the chair is to lead the group through the PBL stages, trying to engage all members in the discussion. They should also move the discussion forward according to the time allocated for the session. Once the learning outcomes have been agreed, the chair should ensure that all members are clear about the research and feedback required for the next session.

The group members– It is vital for all group members to make a good contribution but also to listen and respect the points raised by others. This should not inhibit constructive support or challenging of points raised but should avoid members being too dominant within the group. Members should be prepared to share their resources with each other [38]. Further details of the roles are summarised in Figure 1 below.

Figure 1 The Roles in PBL



Facilitator training on PBL. The role of the PBL facilitator changes in the course of solving the problem, and it is pertinent for the facilitators to understand this challenge. In addition, the facilitator should have a good understanding of the common approaches that could be used to solve the problem; thus, it is essential that they are involved in the creation of the PBL material [40]. Moore & Kain provided strong evidence that tutor training on their role and the purpose of PBL significantly affects students' experience [41]. Therefore, a structured training approach should be designed by radiography educator**s** to help tutors develop skill in facilitating PBL sessions.

There are various methods to help develop the skills of the PBL facilitator. In the past observation of more experienced facilitators was the quickest and most successful method of training. This involved the facilitator observing an experienced facilitator and then conducting their own PBL session soon after

watching an expert[37,39,42,43]. Watching interactive videos also contributed to facilitator training. However, no study has been conducted to show which approach is the most effective method of training facilitators.

Implications of PBL in Radiography Education

Negative implications include time constraints, inadequate resources and student motivation[44]. Inadequate resources consist of poor students to staff ratio (higher than 10:1), tutors lack of PBL process expertise and learning environment[45]. Poor students motivation can be influenced by lack of support when students are unable to identify what to do. Also, a dysfunctional group dynamic might affect students' motivation. A well-designed training exercise for facilitators might help them identify their role in supporting and managing the group dynamics.

One of the biggest challenges in supporting student learning is managing student expectation[7]. Students expect tutors to be giving them all the information, which is relatively easy for tutors to do, however, the knock-on effect is that students are becoming less and less autonomous in their approach to learning to the extent that their motivation and engagement suffers [46]. Kowalczyk et al. [47] state that diagnostic radiography lags behind other professions, such as nursing and medicine, in adopting critical thinking approaches to teaching, such as PBL. This could be due to the large amount of content that needs to be taught hence less emphasis on analysis, synthesis, and application of knowledge. In addition, they report that radiography tutors find it difficult to develop teaching methods that cultivate critical thinking skills in students and are somewhat resistant to change their teaching style. Castle[48] advises that tutors should carefully consider their teaching philosophy in order to positively influence students. In so doing as tutors we will be shifting the focus from a tutor–centred teaching to student-centred focus, as mentioned earlier. Tyler[49] assures tutors that "learning takes place through the active behaviour of the student: it is what *he* does that he learns, not what the teacher does", where '*he*' is the student. Students need to be properly briefed on the nature and process of the PBL learning tasks, the skills, the tasks are designed to develop and a clear expectation of their engagement to enable them to get the most of out of the exercise. This preparatory approach can be added to the PBL process to make

learning objectives more specific and focussed on guiding them through the exercise, thus keeping them engaged on the task at hand.

The literature consistently highlights the benefits of PBL from the perspective of academics and students. The active involvement of the students appears to be a significant factor and confidence gained from giving presentational feedback can make them feel secure and motivated. In addition, some students noted that researching materials for themselves, meant they learnt more than they would in a traditional lecture [50]. From a clinical perspective, the development of competence was noted in nursing studies and in particular the ability for new graduates to take on leadership roles at an early stage [51], and the potential to develop other domains of practice. Furthermore, important cognitive and social skills were also reported to be enhanced in medical students on PBL programmes [52].

Conclusion

Radiography practice has significantly evolved over the years due to advancement in technology and role development, and in response radiography training has had to evolve to address these emerging trends. That is, these developments need to translate into changes in the approach of radiography education. This review has highlighted the underlying theories of PBL - a student-centred learning approach, it merits over traditional teaching method and its relevance and possible application to and/or adoption for the delivery of radiography education.

This article has discussed the relevance of including the reflection in the PBL process, as it helps students understand how they have acquired the new knowledge. The paper posited that some of the training modules, which could be better delivered using case studies/scenarios were problem-solving in nature for smaller groups of learners would be better taught using the PBL approach. However, experienced and skilled facilitators are required for the deployment of the learning technique. The role of the facilitator, chair and scribe are central to the smooth and successful management of a PBL session. More effort needs to be made to help students engage with learning tasks and narrow the spoon-feeding expectation to create autonomous learners. As the demand on practice continues to place emphasis on radiographers' clinical decision-making abilities, the role of PBL in learning and teaching at the undergraduate level cannot be over-emphasised.

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