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**Parton, Graham ORCID logoORCID: <https://orcid.org/0000-0002-5192-0849> and Bailey, R. (2008) Problem-based Learning: A Critical Rationalist Perspective. *London Review of Education*, 6 (3). pp. 281-292.
doi:10.1080/14748460802528475**

Official URL: <https://www.ingentaconnect.com/content/ioep/clre/2008/00000006/00000003/art00008>

DOI: <http://dx.doi.org/10.1080/14748460802528475>

EPrint URI: <https://eprints.glos.ac.uk/id/eprint/8103>

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Problem-based learning: a critical rationalist perspective

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Although problem-based learning is being adopted by many institutions around the world as an effective model of learning in higher education, there is a surprising lack of critique in the problem-based learning literature in relation to its philosophical characteristics. This paper explores epistemology as a starting point for investigating the theoretical underpinnings of problem-based learning as a learning model. Criticisms of empiricism are analysed in terms of the perceived learning outcomes of learners undertaking a problem-based learning curriculum. It is argued that models of empiricism theorised by philosophers such as Bacon, Locke and Hume cannot fully account for the learning model found in problem-based learning curricula. It is proposed that an alternative epistemological approach is needed. The work of Karl Popper is discussed, whose critical rationalist epistemology emphasises the generation of bold conjectures and criticism. Popper's work shows a positive contribution to the demands of higher education, characterised by learners who are serious about making professional progress. The paper concludes by critically analysing the tensions and contradictions of problem-based learning in light of Popper's epistemological theory of critical rationalism. It is argued that a critical rationalist perspective has educational benefits for students as it creates an environment rich in critical thinking, reading and writing and values disjunction and challenge.

Keywords: problem-based learning; critical rationalism; higher education; Popper

Introduction

A genuine higher learning is subversive in the sense of subverting the student's taken-for-granted world, including the world of endeavour, scholarship, calculation or creativity, into which he or she has been initiated. A genuine higher education is unsettling; it is not meant to be a cosy experience. It is disturbing because, ultimately, the student comes to see that things could always be other than they are. A higher education experience is not complete unless the student realizes that, no matter how much effort is put in, or how much library research, there are no final answers. (Barnett 1990, 155)

This quotation encapsulates the central idea of the paper. It has been argued that university teaching has stagnated and methods of teaching are out of date, due to the changing needs of learners (Biggs 2003). Biggs claims that university classes used to contain highly selected individuals and were taught using transmission methods of teaching. Transmission methods, for the purpose of this paper, are defined as methods of teaching which hold the teacher as knowledge giver and the student as the recipient of the knowledge. Examples of this method of teaching are the traditional mass lecture seen in many universities. These transmissional methods of teaching and learning produced effective learning experiences for learners 20 years ago, but Biggs argues that times have changed: 'Universities now have a much more diverse student population and these methods now no longer seem to be working' (2003, 2). It is not just the diversity of students but also the huge increase in the number of students in higher education which have given rise

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to a call for a more individualised curriculum which does not involve transmission-based delivery (Prosser and Trigwell 1999). Also transmission-based methods of delivery can, as argued by Ramsden, have an emphasis on factual knowledge and teacher-defined goals. Work is dominated by assessment considerations and this leads to the promotion of 'surface' approaches to learning rather than deeper understanding (Ramsden 1992).

We have to adjust our teaching decisions to suit our subject matter, available resourcing, our students, and our own individual strengths and weaknesses as a teacher. (Biggs 2003, 2)

This is supported by Haggis, who argues that transmission-based learning models used in higher education are problematic and new ways are needed to conceptualise learning in higher education in order to 'become truly accessible to the widest possible range of lifelong learners' (Haggis 2003, 89).

One such popular and relatively new model of learning in Higher Education is that of problem-based learning. Problem-based learning has been a very popular learning model in medical and health degrees and research has shown that it can be an effective method of learning (Biggs 1991; Marton and Saljo 1976; Ramsden 1992). Unfortunately, there is limited research to support its theoretical position (Scaife 2000). It is therefore problematic to claim, as some research has argued, that problem-based learning can be hailed as the new model of effective learning in Higher Education (Barrows and Tamblyn 1980; Camp 1996) especially when it has been stated that the theoretical concepts supporting problem-based learning are:

imprecise, lacking explicit descriptions of their interrelationships and of their relationships with observables, such as interventions and outcomes. In addition, the basic research is contrived and adhoc, using manipulations that seem to ensure the expected results, regardless of the theory. (Colliver 2000, 264)

This has led to the central question of this paper: Is there a philosophically robust theory which can support problem-based learning? To answer this challenging question the empiricist and rationalist schools of philosophy will be highlighted and the work of Karl Popper will be investigated as, at first glance, Popper's philosophy of the growth of knowledge seems to be very close yet extends the fundamental principles of problem-based learning.

What is the 'traditional' model of problem-based learning?

Problem-based learning was initially developed in response to concerns that the academic discipline focus of a conventional university education might not be the most effective preparation for future professionals (Albion and Gibson 2000). One of the first university courses formally designed as problem-based learning was launched by McMaster University, Canada in the late 1960s (Barrows and Tamblyn 1980; Neufeld and Barrows 1974). Subsequently many medical schools worldwide took this model of learning into their own courses and problem-based learning grew as an effective way to train medical and health-related learners.

A problem-based learning encounter typically begins with an authentic problem of practice, without any prior preparation by learners, followed by a systematic, student-centred inquiry process. Following initial analysis of the problem, which is usually undertaken in a small group, areas of learning are identified for individual study and the knowledge and skills acquired in this way are applied back the problem. The final reflective phase provides opportunity to summarise what has been learned and to integrate it with the student's prior knowledge. This can be expressed in a process of stages (Schwartz, Mennin, and Webb 2001; Tzannes 1997):

- (1) The problem is first encountered 'cold' without any prior preparation or study.
- (2) The students in a group interact with each other to explore their existing knowledge as it relates to the problem.

- (3) The students work with the problem in a way that permits their ability to reason and apply knowledge to be challenged and evaluated appropriate to their level of learning.
- (4) Learners identify further learning needs in order to make progress with the problem.

Problem-based learning is seen as an effective context for preparing independent lifelong learners (Newbie and Clark 1986), especially in the area of professional education, which requires competencies in integrating and applying theory to professional practice (Tang et al. 1997). This has led problem-based learning to be adopted in many disciplines other than medicine; these include agriculture, business, architecture, social work and teacher education. Among the advantages claimed within problem-based learning are increased motivation and better integration of knowledge across disciplines (Boud and Feletti 1985). The problem seems to act as a trigger to motivate learners to find out for themselves (Martin 2000). As Schmidt and Moust state, problem-based learning encourages authentic learning which can be defined as 'an in-depth understanding of the field of study, the ability to transfer knowledge to other domains and the ability of learners to reflect on their learning processes' (Schmidt and Moust 1998, 6). Problem-based learning is associated with optimal learning performance, particularly in the area of knowledge retention (Norman and Schmidt 1992). It is the integration and application of this knowledge retention which is seen by the literature as a key outcome of problem-based learning (Barrows and Tamblyn 1980; Norman and Schmidt 1992). Collaboration is also seen as a key factor of impact (Savin-Baden 2000). As a result of small group collaboration, Engel et al. (2007) argue, students are able to receive feedback from their peers on how well they have learned and also receive feedback on the clarity of their arguments. Students are able to develop competencies in critical appraisal of the research sources used in order for them to check the validity of their arguments.

The role of the tutor in problem-based learning (or PBL) has marked differences over more traditional teaching roles (Chaves, Lantz, and Lynch 2001). Rather than being an expert in the field and transmitting knowledge to students, a PBL tutor is seen more as a facilitator, responsible for guiding students through the scenario. It is claimed that PBL encourages generic learning competencies (Norman and Schmidt 1992). However, these competencies, by their very nature, are developmental and need to be introduced and revisited during the PBL programme. It is therefore the role of the tutor to implement structured experiences where students can be introduced to these generic competencies such as critical reading, critical writing and collaborative skills, rather than allowing them to happen as a given consequence of PBL.

Investigating epistemology and problem-based learning

Problem-based learning is based on assumptions about learning. In turn, these assumptions arise, explicitly or implicitly, from epistemological claims. As Winch (1974) and others have demonstrated, it is very difficult and probably unwise to ignore philosophical concerns regarding the nature and growth of knowledge in our conversations about learning.

There does not seem to be a current consensus regarding the philosophical foundations of problem-based learning. For example, Schmidt (1993) locates it firmly within the rationalist philosophical tradition. Savin-Baden and Major (2004), on the other hand, associate problem-based learning with empiricism. This distinction reflects the classic characterisation of epistemological schools into two dominant camps: rationalism or, as it is sometimes called, intellectualism, and empiricism (Musgrave 1993). Russell (1945) has suggested that the origin of this distinction lies in the Cartesian separation of the world into mind and matter. Consequently, answers to questions of the sources of our immediate knowledge of the world often fall into one of two broad groups: those asserting that it is experience (empiricists) and those that it is reason or intellectual intuition (rationalists) that offers immediate knowledge of first principles. Claims for

an empiricist or a rationalist character of problem-based learning are premised on significantly different assumptions about the learning that takes place.

Empiricism, associated with the likes of Bacon (1561–1626), Locke (1632–1704) and Hume (1711–1776), can very briefly be summarised as the view that it is through our senses that we gain knowledge. Truth is recognised through clear perceptions. The veracity of such perceptions was linked by Bacon to the process of induction, in which discrete observations are generalised into theories.

Within the history of empiricist philosophy it can be seen that the central theme that the growth of knowledge comes from experience is still held, but the theory of induction which is the method used to gain knowledge has been claimed to be flawed by philosophers since David Hume. Hume's (1739) critique of induction states that it is not logical to assume that what has happened in the past, however many times it happens, will necessarily happen again. However, even with the critique of induction, Burgess argues that Higher Education still 'rests upon an implicit acceptance on induction' (Burgess 1977, 131). This is something of a worry in education as inductivism fails as a theory for the advancement of knowledge.

Milne and Noone (1996) have argued that problem-based learning is best exemplified in Kolb's (1984) four types of learning tasks that make up the experiential learning cycle:

- concrete experience;
- reflective observation;
- abstract conceptualisation;
- active experimentation.

This model clearly shows an empiricist or inductivist stance. If problem-based learning really does follow an inductivist method, a student would come to the problem scenario without theories of the issues behind the problem; the research done by the students would be starting from nothing and because of this the research undertaken would seem destined to become undirected and result in confusion and miscomprehension. Within the problem-based learning process it is important for the learners to bring their own experience and theories to the problem (Savin-Baden and Major 2004). In this way knowledge is built upon from existing evidence and not discovered. These experiences are vital as the experiences of the group will help shape the learning process and the research which is completed will have the potential to possess greater focus and direction and ultimately finish with lucid and educated outcomes. This argument is also relevant for the role of tutors in the problem-based learning process. Their role in the process is to act as a facilitator; put more simply, their role is to guide and scaffold the group work and research. If this role was seen in an inductivist stance, the tutor would be the knowledge giver and the learners would be seen as the blank slates. Swann and Burgess (2005) support this view, arguing that the very act of approaching the student–teacher relationship in terms of an active, knowledgeable teacher giving something to the passive, ignorant student assumes the first stage of inductivism, which is unprejudiced observation.

Another problem with inductive theory is its implicit avoidance of mistakes. In this way knowledge must be acquired without making mistakes and these mistakes or errors are seen as negative. This can be seen in many educational practices today; the strict avoidance of error in scientific subjects in order to purify the learning experience, an example being in secondary school science experiments which are designed to eliminate errors which might confound the desired result. Problem-based learning sees mistakes or errors as a positive part of learning. This is embodied in the concept of reflection where learners undertaking a problem-based learning course are required to reflect on the scenario and the role they have played in the process. The learners use errors to learn from and develop professionally. It is only through these errors that

skills used in the problem-based learning process can be improved and developed. Therefore, it can be argued that in terms of the importance of past experience, and allowing students to be confident in making mistakes, problem-based learning as a model of learning cannot fully be explained using an inductivist stance.

The rationalist tradition was characterised by an ultimate appeal to reason, or intellectual intuition, as the source of knowledge. That is, knowledge is innate and it is held that through reason all knowledge can be found. The theory distinguished itself from empiricism by the way knowledge was understood to be acquired, through intellect and deduction rather than experience and induction. Whilst empiricists spoke of the truthfulness of the natural world, rationalists, such as Descartes (1596–1650), spoke of the truthfulness of God. So, first principles of knowledge were believed to be rationally self-evident, and once a rational person understands these principles, it would become obvious and beyond any doubt that they are true. Building upon these principles, the rational individual can establish the truth in other propositions. In this way, knowledge grows. This connects with ideas like metacognition and learning to learn (Biggs 1991), in terms of knowledge being an individual construct which is subject to questioning and dialogue in order to probe the individual's understanding and lead to clearer and more refined knowledge. Savin-Baden and Major (2004) suggest that this can be related to problem-based learning as students should use metacognitive skills and complex reasoning skills to solve problems. Prior knowledge is central to rationalist perspectives and Schmidt (1993) argues that problem-based learning provides an environment in which learners can draw upon prior knowledge. He extends this by stating that the use of scenarios prior to reading has the effect of activating prior knowledge and that this prior knowledge is then used to assimilate and comprehend new information.

It can be argued that there is a tension between strictly empirical and strictly rationalist conjectures of problem-based learning and that a better explanation could be found in an approach that addresses the problems evident in both empirical induction and rational deduction, and that there is a role for both reason and experience, a deductive-inductive dualism. Problem-based learning as argued by Huey (2001) involves a central process of inductive reasoning, inferring a generalised conclusion from the problem statement. This conclusion, a hypothesis, is then tested on other data, which reflects deductive reasoning. This combination of induction and deduction is often referred to as hypothetico-deductive reasoning (Bisanz, Bisanz, and Korpan 1994).

Critical rationalism

The debate between rationalists and empiricists is often presented as that between two mutually exclusive stances (Musgrave 1993): *either* knowledge grows through experience, *or* it grows through reason. The philosopher Karl Popper, however, challenged this presentation by arguing, firstly, for the importance of both reason and experience in learning and the growth of knowledge, and secondly, that neither empiricism nor rationalism offers a wholly satisfactory explanation. From the perspective of problem-based learning, our suggestion is that the Popperian critique of traditional views of knowledge – and his alternative, critical rationalism – raise some searching questions regarding the nature of learning and of problems, and, therefore, of problem-based learning itself (see Popper 1963).

As stated, Popper acknowledges to certain appealing elements within the empiricist and rationalist traditions: 'I am myself an empiricist and a rationalist of sorts' (Popper 1963, 4). Both reason and experience play important roles in learning and the growth of knowledge, he claims, although neither has the central roles with which they have been attributed. But Popper's most fundamental criticism of both empiricism and rationalism is that they begin with shared mistaken

presumptions about knowledge and learning. Indeed, he suggests the differences between empiricism and rationalism are smaller than their similarities.

Popper's criticism of both rationalism and empiricism centred on his rejection of a number of their shared characteristics. For example, he rejected the assumption that there are any infallible foundations of knowledge, endorsing the common criticisms that neither the senses can provide an infallible source of knowledge, nor can self-evidence act as a criterion of truth (Musgrave 1993). He suggested that the search for authoritative foundations is logically incoherent, since these foundations cannot adjudicate that which is authoritative; an authority cannot be self-authenticating, so acceptance must ultimately rest on an act of faith (Parekh 1982). A related difficulty with traditional epistemologies, according to Popper, was their unwarranted emphasis on the origins of knowledge, which conflated questions of origin with questions of validity (Popper 1963). That is, they assume that knowledge derives its validity from its source – experience or reason – and is only valid if the source is infallible. Popper offered another view: 'there are no authoritative sources of knowledge, and no "source" is particularly reliable' (1972, 134). Every potential source is welcome, he argued, be it experience, intellect, tradition or hunches, it is admissible, but none has authority, as all can lead to error. So, Popper proposed an alternative to traditional epistemological questions, like 'How do you know?' and 'What is the source of your assertion?', with a fallibilistic version, 'How can we detect and eliminate error?' (Popper 1963, 25). And his answer to that question is *criticism*:

Knowledge can grow ... just because we can learn from mistakes. The way in which knowledge progresses ... is by unjustified (and unjustifiable) anticipations, by guesses, by tentative solutions to our problems, by conjectures. These conjectures are controlled by criticism; that is, by attempted refutations, which include severely critical tests. They may survive these tests; but they can never be positively justified. (Popper 1963, vi)

Popper's view of knowledge as 'provisional and permanently so' (Magee 1973, 26) highlights its relevance for problem-based learning. According to his view, learning – indeed, any knowledge-generating activity – can be best understood in terms of problem solving (Popper 1972).

Can a critical rationalist model of PBL offer improvements over 'traditional' methods of PBL?

In the final section of this paper it is intended to examine critical rationalism in terms of a philosophical basis of problem-based learning. In principle it can be argued that critical rationalism can offer an improvement on the traditional model of PBL and also offer a tentative philosophical explanation for problem-based learning. The central themes are detailed below:

- (1) PBL has problem solving at its heart and encourages students to see knowledge as fluid and not predetermined.
- (2) Within the PBL process new problems are found all the time, it is open-ended and there are no definitive answers.
- (3) PBL encourages students to be critical of each other's views and experiences with reference to literature in order to clarify their reasoning and position.

The critical shift from a transmission model of knowledge growth to an increasing need to use critical methods to judge the validity of theories and ideas can be seen within a problem-based learning curriculum, as the methods used within problem-based learning encourage the process of critical thinking (Biley and Smith 1998). This is also supported by Wettersten, who states:

Individuals do not primarily learn by imbibing information unrelated to problem solving activity ... All attempts to act as if there is such a body of truths lead to some form of deception and some form of disregard for students. (Wettersten 1999, 106)

Barnett (2000) states that the development of a 'critical being' is crucial for higher education. Barnett (1994) argues that approaches such as problem-based learning help learners to develop independence in inquiry and to take up a critical stance towards knowledge. It has been argued that there is a theoretical basis for using problem-based learning to promote students' critical thinking (Biley and Smith 1998; Moore, Block, and Mitchell 1990). However there have been only a few studies which claim that problem-based learning increases critical thinking (Celia and Gordon 2001; Tiwari 1999). Problem scenarios within problem-based learning can develop criticality in learners and Barnett (2000) argues that this should be completed in stages: critical thinking, critical thought and critique. Features of 'critical thinking' include the development of autonomy and the use of reasoning skills, analysis and synthesis. 'Critical thought' includes collective learning and action and critical dialogue. Finally, 'critique' involves the criticism of the discipline and taking a stance towards knowledge. Savin-Baden and Major (2004) argue that when problems are designed in problem-based learning, thought should be given to engage learners in different levels of criticality according to their development in order to promote and develop the critical thinking skills of learners.

In many variations of problem-based learning, a critical method is used as a vehicle to allow learners to discuss their interpretations and understandings of theories. Through discussion within small groups, learners are encouraged to be critical of other learners' conjectures and to support their criticisms with reference to literature. If a critical rationalist philosophy is followed, it can be argued that the theoretical frameworks or knowledge utilised in a problem-based learning curriculum are tentative and open for critical analysis. Therefore, if a critical rationalist stance is taken to underpin problem-based learning, learners should be encouraged to follow implicitly Popper's schema, in order to elicit mismatches in their interpretation of theories, which will result in an environment of critical engagement. Savin-Baden and Major (2004) support this by stating that if critical thinking is used throughout a problem-based learning curriculum, learners will see that engaging with a problem will not merely involve the application of a narrowly defined problem-solving skill, but a means of developing a deep understanding of the subject through critical analysis of their own theories and conjectures.

Perkinson (1993) argues that any learning model which starts with a problem for a student to explore encapsulates a progressive approach to teaching. The term progressive education is used to describe educational ideologies that are child centred and allow learners freedom and independence to learn without formalised learning curricula. It is widely acknowledged that problem-based learning is a progressive model of teaching and learning (Savin-Baden 2000) and has its roots in Dewey's theories of progressive and democratic education. Within this context it is claimed that the progressive approach to teaching is concerned with the 'discovery' of new knowledge. This is supported by Margetson (1997), who argues that problem-based learning puts the learner in the position somewhat similar to that of a scientist tackling a problem and making a discovery in the process. It could be argued, therefore, that problem-based learning as described by Margetson (1997) follows a more empirical philosophy in terms of seeing knowledge coming from without or outside the knower and, therefore, allowing discovery of new knowledge through experience. This is incompatible with the critical rationalist philosophy, which argues that knowledge comes from an interaction between prior ideas and experience and is actively constructed and refined. Knowledge, as argued from a critical rationalist perspective, is not predetermined and therefore not discovered, as this implies a foundational and fixed body of knowledge. When a progressive teacher who is employing a discovery approach like this intervenes, it is not to help students uncover inadequacies in their understanding but to give

students help and guidance which will allow them to empirically discover the pre-existing solution to the problem. Also, when a progressive teacher is supporting students, praise will come when the correct solutions are given (Perkinson 1993), again a typical empiricist teaching method. From the critical rationalist perspective there are no certain answers but plausible conjectures at a moment in time. It can be seen, therefore, that a progressive approach to learning, such as problem-based learning, seems not to facilitate the process of trial and error elimination and the critique needed to allow an uncovering of the inadequacies learners hold. This subsequently does not allow them to refine their knowledge in light of critique and does not allow them to follow a critical rationalist approach to learning.

By creating environments wherein students seemingly discover knowledge and where they perform experiments that confirm that knowledge, the progressive educator strengthens the student's belief in that knowledge; but this does not facilitate continual growth; in fact it actually hinders it. (Perkinson 1993, 45)

Unasked questions

If I thought of a future, I dreamt of one day founding a school in which young people could learn without boredom, and would be stimulated to pose problems and discuss them; a school in which no unwanted answers to unasked questions would have to be listened to. (Popper 1976, 40)

This quotation from Popper highlights the argument that for knowledge to grow, learners need to ask their own questions rather than having to answer questions from other people such as teachers. The problems have to be owned by the learner in order for true learning to take place. It is argued that the traditional model of problem-based learning does not follow a critical rationalist philosophy.

Problem-based learning requires the formulation of problem scenarios for the learners to analyse as a basis for their research and discussions. Critical rationalism requires problems to be formulated by the learner as a result of a mismatch in expectations. In many PBL curricula, the problems are designed by tutors rather than the learners. The key question therefore is who owns the problems. Problem-based learning is characterised by Stepien, Gallagher, and Workman (1993) as an 'apprenticeship for real-life problem solving, that is undefined problems, incomplete information and unasked questions' (340). This is interesting in terms of traditional models of problem-based learning as the initial scenarios that are created come from the tutors rather than the students, in essence it is the tutors' questions and not the students'. It is difficult, however, to see any problem-based learning curriculum allowing learners to choose on an individual basis the areas of knowledge they would like to research. For problem-based learning to be effective it is important to frame areas of knowledge so that a basis can be established which then allows learners to start to test their ideas or conjectures. Learners are only able to identify unexpected and unexplained ideas when they have had time to research literature which is at odds with their expectations and discuss these unexpected experiences with their peers. This will then lead to a problem which is owned by the learner, their own question. It can be argued, therefore, that the problems faced by the learners are not initially owned by themselves, but once a subject has been framed a critical rationalist approach to problem-based learning can provide learners with an environment where they can make trial solutions to their own questions, rather than answering unasked questions which is common in more traditional learning environments. This is supported by Popper, who states that traditional teaching of knowledge has its place to stimulate the interest of learners, and that learners need a degree of dogmatism before they can highlight mismatches in their learning and experience and become critical beings:

Up to a certain stage, the teacher has to be quite dogmatic with many things. And one can say that the children need a certain degree of dogmatism. They want to be taught something. But there will

Table 1. A critical rationalist model of problem-based learning.

Traditional model of problem-based learning	Critical rationalist model of problem-based learning
Knowledge is	
predetermined, and accessed from without.	determined by the individual, and generated from within.
And problems are	
to be solved, as students' answers converge on a specific solution	the starting point, which accepts divergence and exploration of theories
by using	
inductive methods of reasoning.	conjectures and refutations.
So problem-based learning should be concerned with	
teaching of students towards set goals and order within knowledge.	teaching of students to allow for multiple meanings and ambiguity.

come a time when the children ask intelligent questions. So the questions of where and when to be dogmatic – all of these depend on the child, on the way the child asks questions. It is an advanced stage at which you can begin to be really critical. (Popper, cited in Bailey 1995, 187)

Perhaps problem-based learning cannot be fully explained by a critical rationalist perspective. However difficult, it seems worthwhile to begin to reframe problem-based learning to convey a more critical rationalist form which follows more closely the ideals set by this philosophy, such as critical thinking, deductive methods of reasoning, freedom to think, read and discuss and ask questions in order to allow them to be criticised. This tentative step to reframe problem-based learning is illustrated in Table 1 above.

Conclusion

The intention of this paper has been to explore the philosophical basis of problem-based learning. As claims for different interpretations of problem-based learning are premised on significantly different assumptions about learning, both empirical and rationalist traditions were investigated. It was concluded that neither of these approaches could explain fully the practice of problem-based learning. Karl Popper's theory of critical rationalism was then examined as it could be argued that problem-based learning closely follows a critical rationalist philosophy.

There are practical implications for a model of PBL, as argued in this paper, that is rooted in a critical rationalist philosophy. One of the most important is the change from a positivistic medical model of PBL to a model which allows for multiple problems and multiple conjectures which lead to ambiguity in students' learning. This ambiguity allows for disjunction in the learning process, a state where there is a mismatch between expectation and experience and a desire to resolve this mismatch (Popper 1934). Savin-Baden (2000) sees this mismatch as crucial to the learning process and believes it should be promoted in any higher education programme that is PBL based. This in turn has implications for the tutor, who should be prepared to facilitate and promote this state of disjunction and reject a learning environment which does not promote uncertainty and anxiety.

Critical thinking has been shown to be one of the main skills or competencies developed by PBL but it is argued that with a critical rationalist model, critical thinking, reading and debate need to have an even greater emphasis. This skill is developmental and it is argued that with any

design of a PBL programme this is taken into consideration. Many programmes place skill sessions early on in the year in order to prepare the student for PBL. This can then be forgotten as it is felt that critical thinking is implicit to PBL and will develop without help from the tutors. If critical thinking is at the heart of a critical rationalist model of PBL then this skill should be made more explicit. Critical thinking should be developed throughout the PBL programme and tutors need to be aware of the progressive stages found in critical thinking and ways to facilitate students' capacity in this skill. It is argued therefore that a systematic programme of professional development is needed for new and established tutors to develop critical thinking, reading and writing competencies, in a structured and coherent way. It is very easy to start a PBL programme with a number of sessions on the core developmental competencies such as critical reading and writing and then to presume they will be developed naturally. It is argued that throughout the programme tutors need to revisit these competencies and design experiences which explicitly integrate these into the sessions. Without formal training in critical thinking students will find it particularly hard to engage in debate, writing and reading. One important tool in the development of critical thinking can be through the assessments the students complete during a PBL programme. Therefore it is important to be mindful of the reason for assessment in PBL; in a critical rationalist model of PBL, assessment should be seen not as a summative snapshot of the students' capability but a formative process which will enable the student to develop and refine critical skills which can then be transferred to lifelong learning.

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Richard Bailey is Professor of Sport and Education at Birmingham University. His main research interests relate to philosophical aspects of education and sport. Recent work has examined the development of expertise in ballet and in physical education, elite players' attitudes to drugs and doping, and the concepts of well-being and human flourishing in sport and education. Richard has also engaged in numerous quantitative and qualitative studies, including topics such as perceptions of play, health and well-being, socialisation into sport and dance, and outcomes of participation in physical education.

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