

Experiencing the Process of Knowledge Creation: The Nature and Use of Inquiry-Based Learning in Higher Education

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Inquiry-based learning (IBL) is a pedagogy which best enables students to experience the processes of knowledge creation and the key attributes are learning stimulated by inquiry, a student-centred approach, a move to self-directed learning, and an active approach to learning. Students should develop research skills and become life-long learners. There is strong educational theoretical support for the use of inquiry approaches and IBL is being adopted across the full spectrum of disciplines at all levels from within-class activities, through to inquiry courses and even inquiry degree programmes. Evidence is gradually accumulating that shows IBL can enhance student engagement, academic achievement and higher order learning outcomes. Benefits can also accrue for teachers through the integration of teaching and research, increased enjoyment and interaction with students and the rewards gained from enhanced learning outcomes for students.

KEYWORDS: inquiry, enquiry, inquiry-based learning, research-based teaching, undergraduate research

Introduction

“Tell me and I forget, show me and I remember, involve me and I understand.”

This well known adage signifies the value of engaging the learner in a task as a more meaningful way to learn. One such teaching approach is learning through inquiry (or inquiry-based learning, IBL). Elements of this approach have their origins in antiquity, and are discernible in the teaching of Confucius and Socrates. Philosophers as early as Spinoza in the 17th century purported that knowledge is found in the manipulation of ideas rather than the transmission of facts. It is the American educator and philosopher John Dewey (1859-1952), however, who was largely responsible for promoting ‘learning by doing’ (Dewey, 1933). Influenced by Dewey, inquiry-based learning was adopted by many school teachers in the 1970s and began to appear about the same time in tertiary institutions. One example of this is Hampshire College in the United States, where an inquiry curriculum has been used since its establishment in 1970 (Weaver, 1989), while McMaster University, Canada, has been teaching using IBL for over twenty years (McMaster University, 2007). Despite a lengthy history, the literature base for IBL is at best patchy and diffuse, and although there are several recent volumes that describe the teaching approach and provide readers with a range of examples (e.g. see Alford, 1998; Bateman, 1990; Lee, 2004; and Weaver, 1989), most literature appears in pockets amidst educational and disciplinary journals, usually due to enthusiasts attempting to encourage others to try the approach.

The nature of inquiry-based learning is contested and even the term itself is not in widespread use throughout the educational literature. A search for studies on IBL must necessarily include such terms as ‘inquiry’ (or enquiry), ‘inquiry-based learning’, ‘guided-inquiry’, ‘undergraduate research’, ‘research-based teaching’, ‘discovery learning’, ‘teaching research links/nexus’ and ‘inductive teaching and learning.’ Although the teaching approach is becoming pervasive throughout all levels of education (from primary to tertiary), there is a

paucity of research that provides a clear overview and synthesis of IBL. This review aims to address this observation, by providing such an overview and synthesis of IBL. Thus this integrative review will explore the nature of IBL, outline the theoretical support for the approach, describe a range of examples in higher education and examine the effectiveness of IBL for learning outcomes. A secondary aim is to determine where there are gaps in understanding of this approach.

What is Inquiry-Based Learning?

Inquiry-based learning falls under the realm of ‘inductive’ approaches to teaching and learning, an excellent review of which is provided by Prince and Felder (2006). Inductive approaches to teaching and learning begin with a set of observations or data to interpret, or a complex real-world problem, and as the students study the data or problem they generate a need for facts, procedures and guiding principles. Prince and Felder (2006:123) state that inductive teaching encompasses a range of teaching methods including “inquiry learning” (hereafter referred to as IBL), problem-based learning (PBL), project-based learning, case-based teaching, and discovery learning. They classify the teaching methods by considering the context for learning and other features, such as the amount of student responsibility for their learning and the use of group work (Table 1). As Table 1 shows, common to all these inductive methods of teaching are several characteristics:

- 1) a student- or learner-centred approach (Kember, 1997) in which the focus of the teaching is on student learning rather than on communicating defined bodies of content or knowledge;
- 2) active learning is about learning by doing (Gibbs, 1988, Healey & Roberts, 2004) and may involve, for example, students discussing questions and solving problems (Prince & Felder 2006);
- 3) the development of self-directed learning skills in which students take more responsibility for their own learning;
- 4) a constructivist theoretical basis (e.g. see Bruner, 1990) which proposes that students construct their own meaning of reality; it is the students who create knowledge rather than knowledge being imposed or transmitted by direct instruction.

Many of these inductive methods also utilise collaborative or cooperative learning with much work both in and out of formal class time being done by students working in groups.

One of the early tertiary institutions to adopt an explicit inquiry curriculum was a private liberal arts college in Western Massachusetts - Hampshire College, established in 1970. The inquiry approach drew heavily on Bell’s (1966, cited in Weaver, 1989)) research and thus

“the organising approach for Hampshire’s academic program will be conceptual inquiry...exercising the intellect to learn, use, test and revise ideas, concepts, theoretical constructs, propositions and methodological principles in active inquiry” (Weaver, 1989: 5).

Themes running through the curriculum congruent with inquiry at Hampshire included:

- student work being cumulative and coherent
- a student-centred approach to teaching involving ‘active teaching’
- students as active learners
- the reduction of competitiveness and the encouragement of collaborative learning
- students developing skills in reflective practice.

TABLE 1: *Features of common inductive instructional methods (adapted from Prince and Felder, 2006).*

Feature	IBL	PBL	Project-based	Case-based	Discovery
Questions or problems provide context for learning	1	2	2	2	2
Complex, ill-structured, open-ended real-world problems provide context for learning	4	1	3	2	4
Major projects provide context for learning	4	4	1	3	4
Case studies provide context for learning	4	4	4	1	4
Student discover course material for themselves	2	2	2	3	1
Primarily self-directed learning	4	3	3	3	2
Active learning	2	2	2	2	2
Collaborative/cooperative (team-based) learning	4	3	3	4	4

Note: 1 – by definition, 2 – always, 3 – usually, 4 – possibly

Weaver (1989:12) comments that there are a “plurality of substantive questions, techniques and styles” consistent with successful inquiry teaching and that there are “no formulas or party lines”, so that the ultimate course design will depend on factors such as the structure and aims of the course, the pattern of assessment, the background of the students and the personality and ability of the teacher.

Similar to Hampshire College, McMaster University in Canada has been teaching inquiry for over 20 years. They define inquiry as a form of self directed learning in which students take more responsibility for:

- determining what they need to learn
- identifying resources and how best to learn from them
- using resources and reporting their learning
- assessing their progress in learning (McMaster University, 2007).

They recognise that first year students may require more teacher direction and may only develop two or three of the above skills, while by the end of their degree students should be able to take the initiative and be largely responsible for completing their learning in a given area. They define inquiry courses as being question driven, rather than topic or thesis driven and beginning with a general theme to act as a starting point or trigger for learning. They emphasise asking good researchable questions on the theme, and coaching students in doing this, as well as providing students with training in development of valuable research and communication skills. A group of McMaster teachers (Justice et al., 2002) involved in IBL developed a model of the inquiry process (Figure 1). This model clearly shows a cycle in which students become engaged with a topic, develop a question to explore, determine what information needs to be found, gather data, synthesise findings, communicate findings and then evaluate the success. Further the process is seen as circular since the inquiry leads to new interests and more questions. Core to the process is an attitude of self-reflection and

evaluation, which are seen as “both a product of the inquiry process and an enabler of success at every stage” (Justice et al, 2002:19).

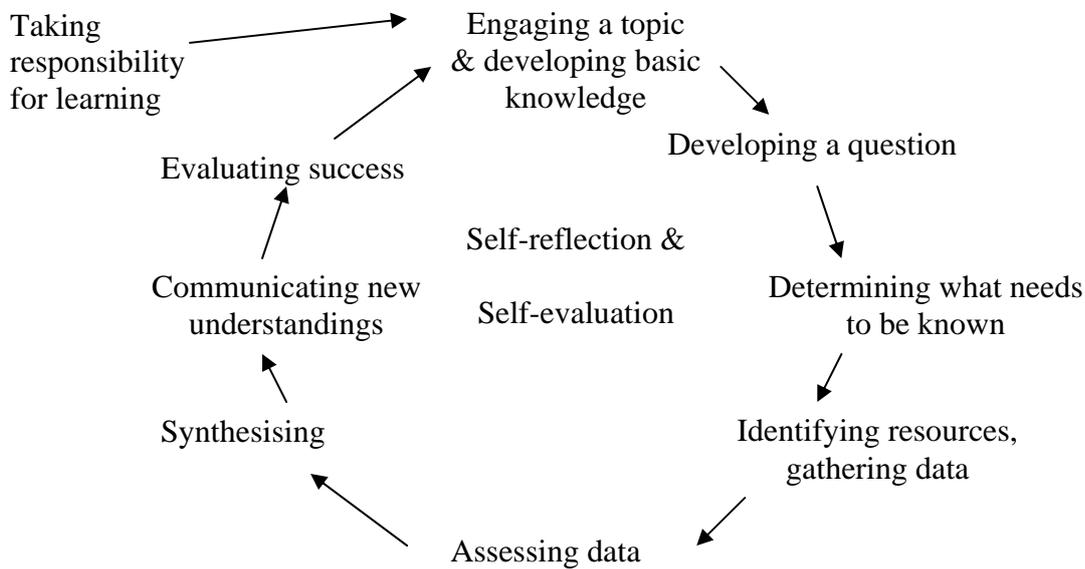


FIGURE 1: *Model of the inquiry process (Justice et al., 2002:19).*

Defining the relationship between IBL and problem-based learning (PBL, which has a more coherent and well-developed literature base) has been fraught with difficulty. Most researchers acknowledge an overlap in the approaches but there are conceptual differences in distinguishing the two. For example, as shown in Table 1, Prince and Felder (2006) suggest that the major difference between IBL and PBL lies in the type of question with PBL *by definition* involving complex, ill-structured open-ended real world problems, while IBL may *possibly* use such problems. This distinction is in contrast to many researchers (e.g. Plowright & Watkins 2004; Elton 2006; McMaster University, 2007) who suggest that PBL *usually* focuses on questions to which answers already exist, while IBL *often* involves open-ended questions. A further difference postulated by McMaster University (2007) is that PBL has a shorter timescale (one class to a few weeks), while IBL can be for a sustained period. Kahn and O’Rourke (2004) suggested that PBL was a subset of IBL, along with other pedagogies such as project work and small scale investigations (Figure 2). Spronken-Smith et al. (2008) used the notion of collaboration to distinguish. While IBL *can be* done in collaborative groups, PBL is *usually* done this way. In considering the debate Spronken-Smith et al. (2007:3) concluded that “as a guide, it appears that PBL is a more prescriptive form of IBL, and thus PBL is seen to be a subset of IBL, and both IBL and PBL are subsets of active learning” as shown in Figure 3.

Towards a Definition of IBL

Clearly IBL is a contested term – even the phrase itself has many permutations and alternatives. However, there is a commonality of opinion about what constitutes IBL. Spronken-Smith et al., (2007: 2) drew on this commonality to define IBL as a

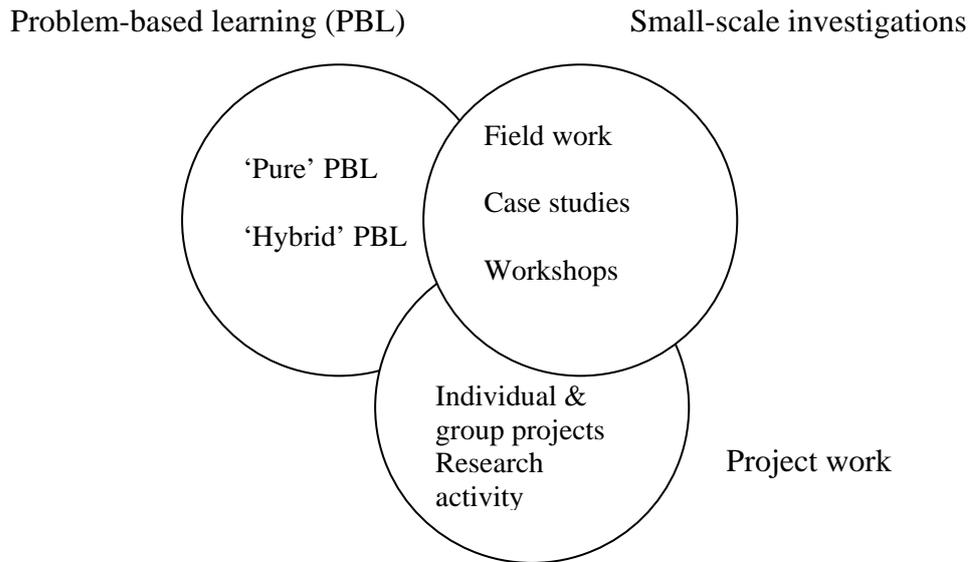


FIGURE 2: *Approaches to learning covered by IBL (Kahn and O'Rourke, 2004).*



FIGURE 3: *The relations between inquiry-based learning, problem-based learning and active learning (Spronken-Smith et al., 2008).*

“pedagogy which best enables students to experience the processes of knowledge creation. The core ingredients of an IBL approach that most researchers are in agreement with are:

- learning stimulated by inquiry, i.e. driven by questions or problems
- learning based on a process of seeking knowledge and new understanding
- a learning-centred approach to teaching in which the role of the teacher is to act as a facilitator
- a move to self-directed learning with students taking increasing responsibility for their learning and the development of skills in self-reflection
- an active approach to learning.”

The central goal of IBL is for students to develop valuable research skills and be prepared for life-long learning. Students should achieve learning outcomes that include critical thinking, the ability for independent inquiry, responsibility for own learning and intellectual growth and maturity (Lee et al., 2004).

Inquiry-based learning ranges from a rather structured and guided activity, particularly at lower levels (where the teacher may pose the questions and give guidance in how to solve the problem), through to independent research where the students generate the questions and determine how to research them. Furthermore, IBL can occur at a range of scales within the curriculum from a discrete activity through to the design principle for the whole degree (University of Sheffield 2007; Spronken-Smith et al., 2007b).

Theoretical Support for IBL

The theoretical support for IBL stems from widely accepted research on student learning. The approach has its roots in constructivism and is in line with research on motivation, intellectual development and approaches to learning. Inquiry-based learning also finds favour with learning cycle-based teaching since many elements are similar. Finally, in recent years there has been a renewed call for inductive approaches such as IBL as a means to strengthen teaching-research links in universities. This section will explore each of the theoretical underpinnings that support and strengthen the case for tertiary teachers to use IBL.

Constructivism

In constructivism, the key tenet is that an individual learner must actively construct knowledge and skills (Bruner, 1990). Thus despite whether or not there is an objective reality, it is the individual who constructs their own reality through their experience and interaction with the environment. As an individual experiences something new, he or she filters this information through mental structures (schemata) that incorporate prior knowledge, beliefs and preconceptions to make sense of the information (Prince & Felder, 2006).

This theory of learning goes back many centuries, but in more recent times the research of John Dewey (1933), Jerome Bruner (1990) and Lev Vygotsky (1978), together with Jean Piaget's (1972) work on developmental psychology, has resulted in the broad approach of constructivism. There are two main forms of constructivism: cognitive and social. Cognitive constructivism draws mainly on Piaget's (1972) theory of cognitive development. Piaget proposed that individuals must construct their own knowledge and that they build knowledge through experience. These experiences allow creation of schemas or mental modes and thus lead to learning. In contrast to cognitive constructivism, social constructivists place more emphasis on the social context of learning. Vygotsky is the main proponent of social constructivism and suggested that cultural history, social context and language play an important role in the pattern and rate of development of children. Vygotsky's concept of the zone of proximal development argues that individuals can, with the help of a more experienced peer, master concepts and ideas that they cannot understand on their own (Vygotsky, 1978).

Thus, according to the constructivist theory of learning, effective teaching must offer experiences that:

- build on what students already know so they can make connections to their existing knowledge structures
- encourage students to become active, self-directed learners

- provide authentic learning opportunities
- involve students working together in small groups (i.e. in collaborative or cooperative learning).

Rather than being the “sage on the stage” in a transmission mode of teaching, constructivist teachers should act as a “guides on the side”, providing opportunities to test the adequacy of students’ current understandings (Hoover, 1996). Hoover also argues that because new knowledge has to be actively built, it takes time to do so. This means that any constructivist courses should allow ample time for student reflection about new experiences and how these fit (or not) with current understandings.

Motivating Learners

One of the primary reasons for advocating an inquiry approach is because it is thought to motivate learners more strongly. Bransford et al. (2000) provide a comprehensive review of cognition research. They discuss studies which find that motivation affects the amount of time and energy that people are willing to devote to learning. Further they suggest that tasks must be challenging but at the proper level of difficulty to remain motivating – if they are too easy students will be bored, while if they are too hard, students will become frustrated. As Ciardello (2003) argues, learners will be better stimulated and motivated to learn by sparking their curiosity. Thus by confronting students with a state of perplexity, students are prompted to seek questions and evidence that will help them resolve the discrepancy or problem. Learners are also motivated when they can see the usefulness and relevance of what they are learning – especially in their local community (Bransford et al., 2003). The implications for IBL are clear: students can be strongly motivated by complex, personally relevant questions.

Intellectual Development

Perry (1970) described nine stages of intellectual development of college students from basic duality through complex duality to relativism and a commitment in relativism. Students should progress from a belief in the certainty of knowledge to a stage where they see knowledge as uncertain and contested. Perry argued that by graduation students should achieve the highest developmental level of contextual relativism in which students can think like experts in the field. Inquiry-based learning provides a means to assist students to make the transition from dualism to contextual relativism as the inquiry process involves students questioning knowledge and developing their skills in critical thinking. This is in direct contrast to more traditional, didactic teaching approaches in which knowledge is often presented as facts that students have to learn and regurgitate for assessment.

Approaches to Learning

Several researchers have tried to tease out how students learn. A Swedish researcher Saljo (1979, reported in Ramsden, 2003:27-28), interviewed adults to find out about their conceptions of learning and subsequently identified five hierarchical categories. At the lower end were “surface approaches” including 1 - learning as a quantitative increase in knowledge (acquiring information), 2 - learning as memorising (storing information that can be reproduced) and 3 - learning as acquiring facts, skills, and methods that can be retained and used as necessary. At the other end of the continuum was 4 - learning as making sense or abstracting meaning (involves relating parts of the subject matter to each other and to the real world) and 5 - learning as interpreting and understanding reality in a different way, which characterise “deep approaches”.

Similar to Perry (1970), Ramsden (2003) suggests that the higher order deep approaches should be gained by university students. Teachers can encourage students to take

a deep approach to learning by teaching to bring out the structure of the topic; by actively involving the students through questioning or giving problems rather than teaching a rigid body of facts; by building on what students already know; by emphasising depth of learning rather than coverage and by using teaching methods and assessment strategies that support the learning outcomes of the course (Biggs, 2003). Inquiry-based learning, if carefully constructed and implemented, provides an excellent avenue for the development of deep approaches to learning.

Learning Cycle-Based Teaching

Another plug for an inquiry-based approach to teaching comes from the research on learning cycles. One of the most well known models of learning in higher education is Kolb's (1984) experiential learning model (Figure 4). Kolb built on the work of Dewey and Lewin and advocated a four-stage cycle involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. Learners can enter the cycle at any stage but the stages should be followed in sequence. Kolb argued that reflection was a key experience that would lead to new understanding. He also theorized that learners have different styles - divergers, assimilators, convergers or accommodators - with an associated array of characteristics (Kolb 1981, 1984). While aspects of inquiry-based learning are recognisable in each category, the accommodators are the group most comfortable with experiential approaches (Healey et al., 2005). Teachers should encourage students to engage with all four stages of the learning cycle and it is important for students to be taken out of their comfort zone so they can develop a range of learning styles which are seen to be important for effective professionals (Prince & Felder, 2006). Teachers using IBL should be aware that this may not be the preferred learning style for many students (e.g. see Healey et al., 2005) and thus they should be offering appropriate support when undertaking inquiry activities.

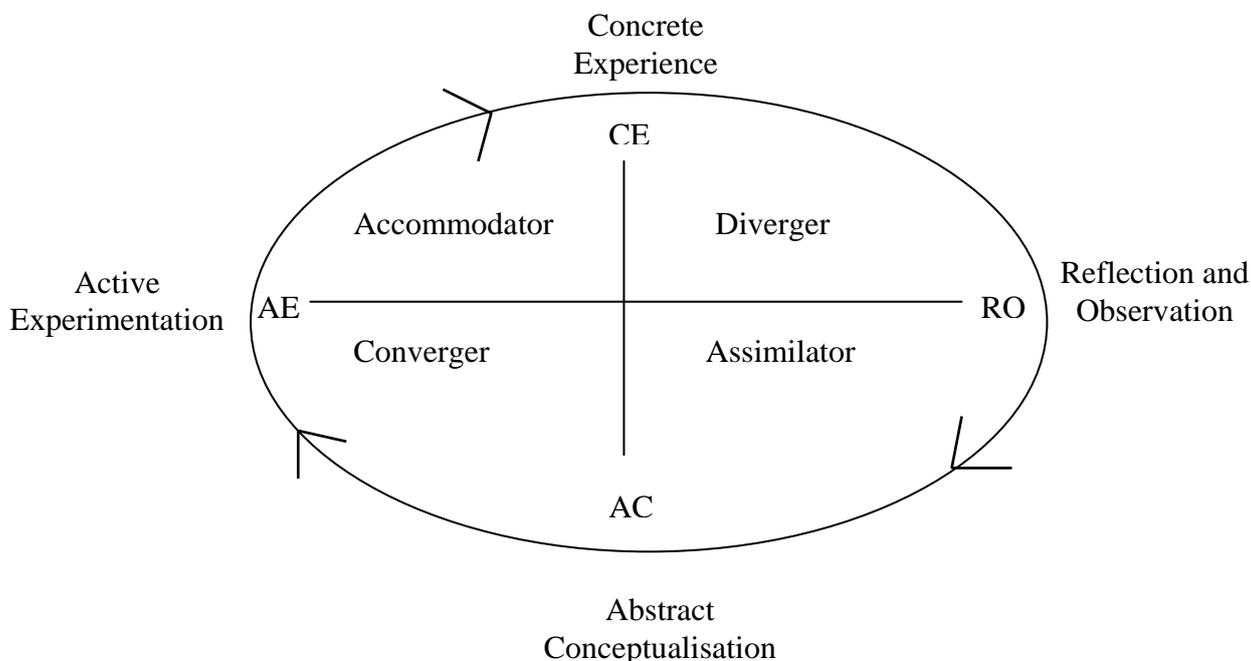


FIGURE 4: *The experiential learning model and associated learning styles (Healey et al., 2005 after Kolb 1981, 1984).*

Strengthening Teaching-Research Links

Ernest Boyer and his colleagues at the Carnegie Institute challenged the teaching-research dualism and lamented the lack of research experience for undergraduates that was genuine and meaningful (Boyer, 1990; Boyer Commission, 1998). Since the work of Boyer there has been an emergent literature that has examined the teaching-research nexus. While some researchers have called for a new definition of scholarship (e.g. Boyer, 1990), others have advocated for a reshaping of teaching to explicitly and implicitly incorporate research and this is where inquiry approaches have been advocated (e.g. Boyer Commission 1999; Rowland 2000; Brew 2003; Badley 2002; Healey 2005a, b; Jenkins et al., 2007; Kreber, 2006; Spronken-Smith et al., 2007; Jenkins et al. 2003). Badley (2002:451) argues for a “really useful link” to help build a bond “between research and teaching through the crucial academic process of inquiry”. Similarly, Justice et al. (2007a) comment that IBL refers to both a process of seeking knowledge and new understanding as well as a method of teaching based in this process. Thus they see IBL as similar to research, and see it as a way to integrate research and teaching as both students and teachers are “compatriots in the search for knowledge” (p2).

Healey (2005b: 69) drew on Griffith’s (2004) research-teaching nexus classification and made links to aspects of teaching arguing that it is “possible to design curricula which develop the research-teaching nexus according to whether:

- the emphasis is on research content or research processes and problems
- the students are treated as the audience or participants
- the teaching is teacher-focused or student-focused.”

as shown in Figure 5. Healey (2005b) suggested that most traditional university teaching occurs in the bottom left (research-led) quadrant, although he recognised that some disciplines have relatively more activity in the other quadrants. He argued that higher education should place more emphasis on pedagogies in the top half of Figure 5 – i.e. those that are either research-tutored (the Oxbridge tutorial system) or research-based (inquiry-based learning) – since these models have the most benefit for student learning.

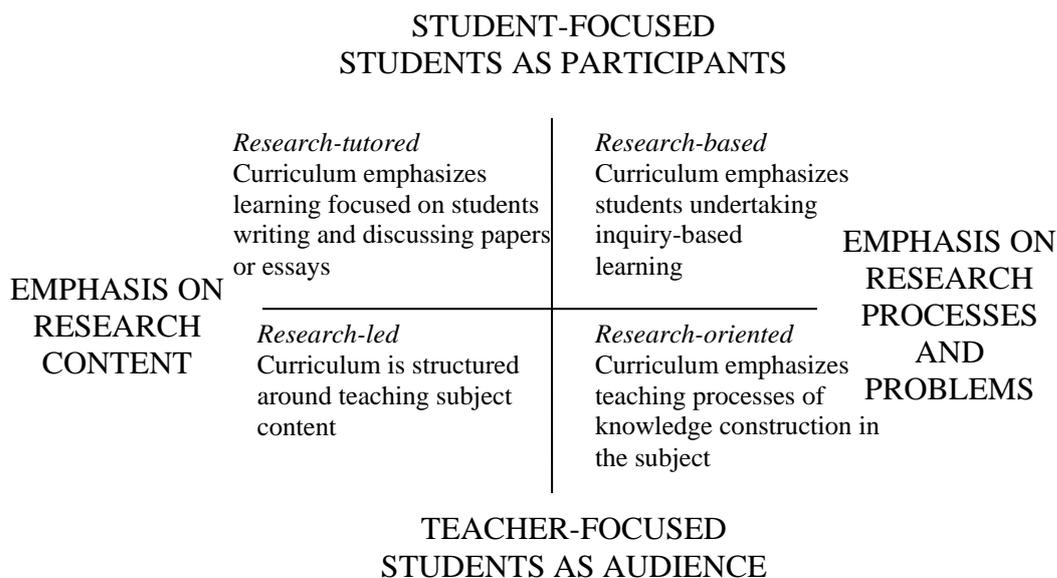


FIGURE 5: *The links between curriculum design and the research-teaching-nexus (Healey, 2005b).*

Another compelling argument for adopting an IBL approach, that is closely tied into the literature on the teaching-research nexus, is the notion that tertiary teaching and learning should occur in communities of inquiry in which teachers and staff are co-learners (Brew, 2003; Le Heron et al. 2004; Rowland, 2000). Brew (2003) argues that such communities of inquiry should be accessible to all undergraduates, not just the high achievers or elite institutions.

Examples of IBL in Higher Education

Gaining a comprehensive overview of the examples of IBL in higher education is beyond the scope of this review. Rather, this section aims to give the reader an appreciation for the extent and type of IBL activities that are being employed in curricula around the world. Table 2 presents a range of examples where IBL is the focus of undergraduate courses. Although problem-based learning is seen as a subset of IBL, examples of PBL are not given here.

In addition to the cases in Table 2, there are several recent volumes that discuss the approach and provide a range of examples. Jenkins et al. (2007) provide a series of short cases and links to fuller reports in their Higher Education Academy paper *“Linking Teaching and Research in Disciplines and Departments.”* The proceedings of a symposium at McMaster University in 2004 on *“Experiences with Inquiry Learning”*, edited by Christopher Knapp (2007), provides a very useful overview of the origins and scope of inquiry, as well as examples of implementation, evaluation and political and organizational issues. The book edited by Virginia Lee (2004) *“Teaching and Learning Through Inquiry: A Guidebook for Institutions and Instructors”* contains a range of cases including disciplines such as history, foreign languages, psychology, microbiology, chemistry, engineering and design. These cases are very accessible as they consist mainly of narrative accounts of teachers as they transform their usually traditionally taught (lecture format) classes to take an IBL approach. Thus they are grounded in practical advice that is of immense help to other teachers contemplating making such a shift. Another useful source is the Proceedings of the 2003 Conference *“Learning Based on the Process of Enquiry”* (Kahn & O’Rourke, 2004b). The conference was part of a programme to build capacity for IBL in UK universities, but institutions in Australia and the USA were also involved. The conference papers span the disciplines to include cases from law, social sciences, history, languages, health sciences, zoology and engineering.

As can be seen from Table 2, IBL is used over the full range of academic disciplines from humanities to sciences and health sciences, and applied subjects such as communications. Several of the studies seek to determine whether technology is effective in assisting learning in IBL courses. Most studies in the literature begin by grappling with the issue of defining IBL and then go on to describe how IBL is implemented in their course of programme. Many studies also undertake some form of evaluation to elicit feedback from students and/or teachers. However, often this feedback is anecdotal, rather than a systematic attempt to triangulate evidence regarding the success or otherwise, of the approach. Contrary to the commonly held belief that IBL courses are best suited to more advanced students (once they have mastered some fundamental knowledge in the subject area), Table 2 presents several examples from first year teaching (e.g. Oliver 2006; Justice et al., 2002; Plowright & Watkins, 2004; Zoller, 1999) as well as others who use the approach for introductory courses at a higher level (e.g. Yarger et al., 2000). Those teachers who advocate the use of IBL at first year or freshman levels, strongly believe that it is important to enculturate students to a student-centred learning environment as soon as they enter university, so that they can

continue to use the range of skills developed throughout their university study. While many case studies are apparent for a range of courses, the literature is lacking in studies that discuss how to progressively develop inquiry skills throughout a degree programme.

TABLE 2: *Examples of IBL for a range of disciplines and topics.*

Discipline or topic	Source	Overview of research focus
Communications	Oliver (2006)	Describes and evaluates an optional IBL project as part of a large first year class in communications and digital technology.
Literacy	Hutchings and O'Rourke (2003)	Describes the design of an IBL literacy course embedded in an otherwise traditional curriculum. Students work in groups. Observations from the research team are given about student reactions and learning.
Foreign languages	Luke (2006)	Describes and evaluates a fourth semester (intermediate) level course in Spanish using an IBL approach
Social Science	Justice et al. (2002)	Describes a model – a “grammar for inquiry” for a first year social science inquiry course and evaluates the success of the course.
Geography	Spronken-Smith et al. (2007a)	Describes IBL approach and gives examples of use of IBL in geography curricula from in-class activities to whole degree programmes. Outlines benefits and challenges for teachers and students.
Psychology	Muukkonen et al. (2005)	Uses an IBL cognitive psychology course as a basis for study. Compares non-mediated and technology-mediated inquiry processes with the latter being both tutored and non-tutored.
Social work	Plowright and Watkins (2004)	Describes and evaluates an introductory IBL course in social work as part of a Diploma in Social Work.
Medicine	Houlden et al. (2004)	Study of an IBL elective in the medical undergraduate curriculum to explore students perceptions of the value of this research experience and whether it impacted their decision to pursue a career in research.
Physics	Abell (2005)	Research project to determine how teacher and students perceive IBL in a second year undergraduate physics course for elementary education majors
	Volkman and Zgagacz (2004)	Examines the experiences of a teaching assistant involved in teaching a first year IBL course in physics.
Meteorology	Yarger et al. (2000)	Describes and evaluates an IBL forecasting activity in an introductory course on meteorology.
Chemistry	Ball et al. (2004)	Describes the use of undergraduates in faculty research
	Barak and Dori (2005)	Describes and evaluates the incorporation of IBL projects using technology into three undergraduate chemistry courses.
	Zoller (1999)	Describes and evaluates IBL in organic chemistry for first year (small class) and second year (large class) students.
Science	Rangachari (2006)	Describes and evaluates a second year IBL course on the ‘Social Life of Scientific Knowledge.’
Forestry	Yin (2006)	Describes and evaluates an undergraduate research project on natural resources and environmental policy in China

Evaluation of IBL

As Justice et al. (2007b) note, innovations in higher education tend largely to be under-evaluated. Certainly in the IBL literature some studies are purely descriptive with little effort to fully evaluate the impact of the IBL activities on students' learning and teachers' teaching and research. Many studies give patchy anecdotal evidence for improved learning while some triangulate evidence using a range of quantitative and qualitative sources, and a few studies involve careful comparative analyses to demonstrate in a statistical sense, how learning in an IBL framework differs from traditional teaching. Many evaluative studies have occurred for IBL use in a school curriculum and there is also a wealth of evaluative studies for PBL in the medical literature.

Prince and Felder (2006) provide a good overview of four studies evaluating IBL (Haury, 1993; Rubin, 1996; Shymansky, 1990; Smith, 1996; all cited in Prince & Felder, 2006). The research concludes that IBL is generally more effective than traditional teaching for achieving a variety of student learning outcomes such as academic achievement, student perceptions, process skills, analytic abilities, critical thinking and creativity.

Some studies compare the learning outcomes of students taking an IBL version with those of students taking a more traditional course. Berg et al. (2003) compared the learning outcomes of an open-inquiry and an expository version of a first year chemistry laboratory experiment. Data on student experiences of the two approaches were gained from interviews, questions during the experiment and students' self-evaluations. The key findings of this study were that students taking the open-inquiry experiment version had more positive outcomes including a deeper understanding, higher degree of reflection, the achievement of higher order learning and more motivation. Justice et al. (2007b) used five years of data to examine whether taking a first year IBL course made a difference in students' learning and performance. In a comparative study between students taking an IBL course and those who did not, and, taking into consideration factors such as age, gender, high-school grade point averages etc., they found that students who took the inquiry course had statistically significant positive gains in passing grades, achieving Honours and remaining in the university.

Other studies opt to compare how the IBL experience has changed perceptions about the topic or student abilities. For example, Houlden et al. (2004) examined medical students' perceptions of an undergraduate research elective. They found that the IBL elective resulted in students being more confident in their ability to pursue a research career as well as more interested in such an option.

There are a host of other suggested benefits both for students and teachers including the mutual enjoyment of the approach by both students and teachers, even if there may be some adjustment and initial anxiety about learning or teaching in this manner. Students can become more engaged by the approach and enthusiastic for more inquiry courses (e.g. Kennedy & Navey-Davis, 2004). Some studies also discuss how the IBL approach results in students acting as apprentice researchers in the field (e.g. Slatta, 2004).

There are a few reported negative aspects associated with IBL. Justice et al. (2003) found that students perceived an increased workload in IBL courses, while Luke (2006) and Plowright and Watkins (2004) suggest that anxiety occurs over the need to become self-directed learners. Plowright and Watkins (2004) also noted student difficulties in coping with group dynamics.

Spronken-Smith et al. (2008) provide a review of the potential benefits for teaching staff who use an IBL approach. They cite a strengthening of teaching-research links, the rewarding aspect of seeing students being so engaged and gaining improved understanding and skills. Another benefit for teachers is the increased interaction with students and the induction into a wider community or practice of IBL practitioners (Slatta, 2004). Like students, teachers can have difficulties adjusting to the approach and IBL can be challenging and involve emotional turmoil (Spronken-Smith et al., 2008).

Conclusions

This review set out to explore the contested landscapes of IBL in order to determine the key attributes of the approach and the extent of use in higher education. IBL is a pedagogy which best enables students to experience the processes of knowledge creation. The key attributes include learning stimulated by inquiry, a student- or learning-centred approach in which the role of the teacher is to act as a facilitator, a move to self-directed learning, and an active approach to learning. Students should develop research skills and be prepared for life-long learning. They should achieve outcomes that include critical thinking, the ability for independent inquiry, responsibility for own learning and intellectual growth and maturity. Strong support for an IBL approach comes from constructivism, cognitive research on motivating learners, intellectual development, approaches to learning and learning cycle-based teaching. Furthermore, there has been a recent movement towards strengthening teaching and research links and IBL is an enticing and convincing pedagogy that offers a way for teaching and research to be strongly integrated to the benefit of all stakeholders (students, teachers and institutions). However, the research on learning styles gives rise to caution, as many students may be uncomfortable with inquiry approaches and thus need adequate support to make the transition.

A range of examples of IBL were presented showing that the approach is applicable in all disciplines and at all stages of higher education. Inquiry-based learning can range from more structured and guided activities, particularly at lower levels, through to independent research at advanced levels. Furthermore, IBL can occur at a range of scales within the curriculum from a discrete activity through to the design principle for the whole degree. However, there is a need for further studies to describe and evaluate how inquiry skills can be progressively developed throughout a degree programme.

While there is a growing literature that evaluates PBL, there is a lack of such studies for IBL activities. A handful of studies were related that all concur in terms of IBL producing improved student learning in terms of student engagement, academic achievement and higher order learning outcomes. Students may have difficulty adjusting to the approach and in coping with group dynamics when collaborative learning is employed. Also there is a perceived higher workload associated with IBL. Teachers, too, can reap benefits from using IBL through the integration of teaching and research, increased enjoyment and interaction with students, their induction into a wider community of practice of innovative teachers and the rewards gained from improved student engagement and academic achievement. However, teachers can also struggle with adjusting to the approach. Most of the literature on teachers' experiences of IBL focuses on issues surrounding teaching, and fails to report how the inquiry approach has influenced the individual teacher's research. Given that IBL is advocated as a way to integrate teaching and research, evaluation of IBL should probe both students and

teachers about how they perceive the teaching-research nexus and whether there is the development of a community of inquirers.

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