Project-based learning

Literature review

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Talk to me… and I will forget
Show me…and I will remember
Involve me…and I will understand
Step back…and I will act

(Confucius quoted in de Graaf and Kolmos, 2009: 11)

1.0 Introduction

In the past decade, Project-Based Learning (PjBL) has increasingly been trialled and adopted across a diversity of educational institutions worldwide (Lehmann et al., 2008; Kolmos, 2009). In the Higher Education (HE) sector PjBL is notably widespread in engineering; for instance in Denmark, most engineering institutions incorporate PjBL to some extent (Lehmann et al, 2008). However a review of the literature confirms the use of the approach across a wide breadth of disciplines in differing national contexts, including Media and Business Studies, Geography, Environmental Science, Education, Information Technology and Sustainability. Defining PjBL is problematic; as Hanney and Savin-Baden explain, the term "is broad, far reaching and means different things in different countries and different disciplinary areas" (2013: 7). Furthermore it is closely related to, and sometimes used interchangeably with, Problem Based Learning (PBL) or included under other umbrella terminologies such as the Inquiry-based Approach (Edelson, Gordin, & Pea, 1999; Frank, Lavy & Elata, 2003) or the Trans-disciplinary Case Study (Stauffacher et al., 2006). Nonetheless it is clear from the literature that most of the key features of PjBL are included in the concept of an approach whereby "students pursue solutions to non-trivial problems by asking and refining questions, debating ideas, making predictions, designing plans/and or experiments, collecting and analysing data, drawing conclusions, communicating their ideas and findings to others, asking new questions and creating artifacts [sic]" (Blumenfeld et al., 1991: 371). As will be discussed below, other key features highlighted in the literature are the importance of collaboration between students; that the problem investigated should be authentic (relate to the real world), and that the inquiry covers more than one discipline (Blumenfeld et al., 1991). The stated advantages of PJBL are numerous and include the development of skills related to professional practice, some evidence of improved academic achievement, and the fostering of less tangible qualities such as motivation and self-discipline among students.

The following review is based on a literature search and analysis of fifty-nine articles sourced largely from subject-specific pedagogic journals. Also included is an unpublished white paper for MIT of PjBL in HE engineering (Graham, 2010) and a Guide to Curriculum Design for Enquiry-Based Learning (which includes PjBL) by experts at the University of Manchester. Online literature searches were conducted using the key word 'project-based' and relevant publications were also sourced from the reference lists of articles accessed. Roughly half were research articles in which the methodology was clearly described and results presented and discussed. Of these, the majority used mixed quantitative and qualitative methods or qualitative methods alone, only four studies used quantitative methods. A wide range of methods were used in various combinations, including observations of group work; interviews with staff and students; student surveys; analysis of student reports, reflective journals, online forums and meeting minutes; focus groups; course evaluation

forms, and videos of project de-brief meetings. However, many of the studies did not refer to a systematic methodology and were either purely descriptive of projects undertaken or discussed the philosophy and potential of the approach based on secondary sources and/or first-hand experience of PjBL in the classroom.

This review firstly outlines the main features of PjBL and its key differences from PBL. It then discusses the disciplinary spread of the approach before exploring the educational philosophy and other drivers influencing its adoption in HE. Some brief examples of the approach, particularly those related to the GEES subject area are then given, before the main advantages and challenges of the approach are outlined. Finally, a synthesis of possible solutions to these challenges and suggestions for good practice are provided.

2.0 Key features of the Project-based approach

2.1 Learning by doing

Central to the PjBL approach is the idea that learning is most effective when students put theory into practice - a philosophy derived from US educationalist John Dewey. In PjBL the student role changes from "learning by listening to learning by doing" (Stauffacher et al., 2006: 255), a key tenet identified by the majority of studies reviewed (Baron et al., 1998; Van Kotze & Cooper, 2000; Danford, 2006; Nation, 2006). As Blumenfeld et al. (1991: 372) explain: "the doing and the learning are inextricable" and the "artifact can be shared and critiqued leading to revision and further learning". The hands-on element of the PjBL approach may be particularly well-suited to some disciplines such as Business Studies which is 'practical-orientated' (Botha, 2010: 221) or to Geography with a tradition of fieldwork (Nation, 2006). However the use of the approach within a wide range of disciplines (see Table 1.1 below) suggests the 'doing' element may be successfully incorporated into a broad range of subjects. The central position of praxis within the approach links, as Lehmann et al. point out, to a further important characteristic: that of the doing being centred on real life problems which capture students' interest (2008: 287).

2.2 Real world problems

The 'real world' task is central to the practice of PjBL across the disciplines (de Graaf & Kolmos, 2009; Thomas, 2000; Bell, 2010; Hanney & Savin-Baden, 2010). This connection between academia and external social, political, and environmental realities is argued to engender and sustain student interest and motivation (Bell, 2010). PjBL learning centres on a real life problem requiring a solution and which, importantly, drives the research and the learning process (Blumenfeld et al., 1991; Stauffacher et al., 2006). A recent review of PjBL in UK HE engineering found "authentic content" was a key element (Graham, 2010). Furthermore the problem must usually be complex and open-ended in order to permit a range of possible solutions and responses (Kahn & O'Rourke, 2004). Examples from the literature range from technical questions, such as how to speed up motion recognition software (Otake et al., 2009), to those requiring a combination of scientific and social investigations such as a pre-feasibility study for a multi-purpose leisure trail on a disused railway (Nation, 2006), to social issues, such how to help adult learners returning to education (Green, 1998).

Who determines the problem (teacher, student or external partner) varies widely across the cases described in the literature. Danford (2006: 9) claims that a key feature of PjBL is that "students have some choice of topic as well as the nature and the extent of the content in the project" (although adding that the majority of projects are initially identified by the lead staff member and developed

further by students). Describing PjBL in schools, Bell (2010) also insists that the students' choice of a topic, based on "questions that have piqued their natural curiosity", is central to the approach as it fosters motivation (2010: 39). However several cases in the literature rely solely on teacher-defined questions. Within PjBL on sustainability, Brundiers and Wiek (2013) found project teams were rarely solely responsible for choosing and structuring projects and Spronken-Smith and Kingham (2009) provide an example of staff choice of research question for Geography students examining nitrogen oxide levels in the local environment. Alternatively, Moehr et al, describing the use of PjBL with students of health informatics, see ideal projects as "defined by professionals for their purposes rather than specifically for the students" (2004: 159), highlighting the importance of the external partner in some projects.

The differentiation between the extent of teacher versus student control of the project forms an essential part of Kolmos's (1996) categorization of project types which includes: (a) 'the assignment project' (significant input and control from teachers who choose problems and topics closely related to the academic subject) ; (b) the 'subject project' where students can choose their methods for investigating a their choice of a range of pre-selected problems; and (c) 'the problem project': where "the problem determines the choice of disciplines and methods" (Kolmos, 1996: 143). Kolmos explains that each is appropriate for different stages of study, providing different skills and learning outcomes. But for Blumenfeld et al. (1991) what matters is not who decides the question but that the outcomes must not be predetermined so that genuine ownership of the process and exploration may take place. There is also little consensus in the literature on whether the problem needs to be actual or may be simulated. For Morgan (1983: 66) it may be either, but the students must have some say over the design of their project. As suggested by Moehr (2004) above, some projects involve partnerships with external clients and deliver actual professional outputs which can be used by these external actors. Examples include international market research carried out by business students at Helia University in Finland for corporate partners (Danford, 2006) and feasibility studies for sustainable waste treatment facilities undertaken by students from Melbourne University for a new-build campus in Vietnam (Meehan & Thomas, 2006) and here, clearly, student choice may be limited.

2.3 Role of the tutor: 'a guide-on-the-side'

As a student-centred approach (Danford, 2006), there is a broad agreement within the literature that the role of teacher or lecturer in PjBL shifts from "sage-on-the stage" to "guide-on-the-side" (Nation, 2006: 109). This can create new challenges for the lecturer (see section 8.2.1), requiring additional training, support and resources (see section 9.6). A common description of the teachers' role in the PjBL literature is that of "facilitator" (Morgan, 1983; Green, 1998; Frank, Lavy & Elata, 2003; Frank & Barzilai, 2004; Stauffacher et al., 2006; Lehmann et al., 2008; Otake et al., 2009) or "mentor" (Frank & Barzilai, 2004). As Stauffacher et al. (2006: 255) explain: "The teacher's role changes from a distributor of knowledge to a process manager, helping students in their learning process by initiating reflection processes and supporting them, if necessary, on substantive matters". What is more, learning derives also from the knowledge, ideas and interactions between students in the group (Frank, Lavy & Elata, 2003). In Frank, Lavy & Elata's experience working with engineering student in Israel, "the instructor was essentially a supervisor and moderator" (2003: 275); while Meehan and Thomas (2006) acted as mentors to their environment students undertaking projects in Vietnam. The tutor's new role means that traditional hierarchies can be overturned, as described by

Botha (2010), who found that "students demonstrated to lecturers what entrepreneurship is all about".

With less tutor control, students are encouraged to take more responsibility for their own learning (Donnelly and Fitzmaurice, 2005: 89), often determining the direction and methods of the investigation and drawing on prior knowledge to identify their learning needs (Kahn & O'Rourke, 2004). Projects are largely 'student-driven' (Thomas, 2000); indeed Morgan identifies student autonomy and responsibility for their own learning as the key characteristic of PjBL (1983).

2.4 Interdisciplinarity

A further key feature of PjBL is an emphasis on interdisciplinarity (Danford, 2006; Lehmann, 2008; de Graaf & Kolmos, 2009; Otake et al., 2009; Hanney & Savin-Baden, 2013). Projects often either cross disciplines within the physical sciences (e.g. Kolodner et al., 2003) or combine the natural and social sciences (e.g. Nation, 2006; Lehmann, 2008). This stress on interdisciplinarity reflects a belief that the complexity of pressing contemporary social or environmental problems means HE must equip students with the adaptability and holistic thinking to tackle issues which defy disciplinary boundaries (see section 6.1.3 below).

2.5 Collaboration and group work

Also central to PjBL is the use of group work (Van Kotze & Cooper, 2000). As Hanney and Savin-Baden explain: "Student activity revolves around a complex series of interactions between team members over time and draws on a range of key transferable skills such as communication, planning and team working" (2013). Thus the process of team working, and the skills and qualities this engenders, form part of the learning outcomes (Danford, 2006). Collaboration can also include partners external to academia (Stauffacher et al., 2006; Cheung & Chow, 2011) such as community groups (Jarmon et al. 2008) or corporates (Danford, 2006), or even an overseas consulate (Korfhage Smith, 2010), leading to the development of further professional skills, behaviours and networks. However, while leading to valuable skills, group work is also identified as holding potential for conflict and student dissatisfaction as discussed in sections 8.1.1 and 9.4 below.

2.6 An end product

In the PjBL approach, significant emphasis is placed on the end-product of the project. For Danford (2006: 12) production of a "quality product" is a "distinguishing feature of PjBL" and one which "drives the project planning, production, and evaluation." The types of outputs described in the literature vary widely, usually depending on the discipline, but it is generally asserted that some form of end product or artefact is desirable. Donnelly and Fitzmaurice, for instance, describe PjBL as a prolonged activity "resulting in a product, presentation, or performance (2005: 88). Products vary from a standard academic dissertation or presentation (Spronken-Smith & Kingham, 2009), to a professional consultant report (Danford, 2006; Nation, 2006) to exhibitions such as fashion shows, reality TV shows, music videos and board games (Botha, 2010). As with the question of who defines the problem, the output may be chosen by the students (the South African business studies groups discussed by Botha (2010) were free to choose any final product which could form part of an exhibition), or the academic staff. Furthermore the product is usually shared, either among peers and academic staff or external audiences such as partners in the community or business sector (Danford, 2006: 14), although according to Bell it is important that the chosen target audience be "authentic and appropriate" (2010: 40).

3.0 Project v Problem based learning

While the main features of PjBL may be identified within the literature, differentiating the approach from similar pedagogies such as Problem Based Learning (PBL) is challenging as there is considerable overlap in terms of educational philosophy and practice; and different institutions may use the terms interchangeably (Kolmos 1996: Mills & Treagust; Thomas, 2000). A recent review of PjBL in UK engineering found that "Amongst UK engineering faculty there is clearly a wide variety of definitions of PjBL, and some confusion about the differences between PBL and PjBL." (Graham, 2010: 5). Similarities between the two approaches include a focus on problems (de Graaf & Kolmos, 2009), importantly those with relevance to the 'real world' (Donnelly & Fitzmaurice, 2005); and an emphasis on active, student-directed learning (Kolmos, 1996). Indeed, de Graaf and Kolmos (2009) incorporate both problem- and project-based learning under the heading PBL, arguing that they are based on the same principles, which may be mixed and adapted in different educational contexts. These similarities mean some authors do not always maintain a strict distinction between the two approaches. For example, Moehr et al (2004: 159) describe their approach as experiential 'problem-based' but then shift to discussion of 'the project'. Others use different terminology again to describe what appears to be a project-based approach, such as Stauffacher et al. (2006) whose Transdisciplinary Case Study (TCS) approach is based on 'functional socio-cultural constructivism' and project-based learning. Spronken-Smith and Kingham (2009) use the term 'Inquiry-based learning', which shares similarities with PjBL in terms of its constructivist, 'learning by doing', ethos and its investigation of a real world problem as its central activity. They describe Inquiry-based Learning as an umbrella term covering problem-based learning, smaller projects and workshops (Spronken-Smith and Kingham, 2009).

Nonetheless some key differences between PjBL and PBL are highlighted in the literature, the first being the preponderance of PBL within professional-orientated disciplines such as economics, law and medicine (Perrenet et al., 2000; Donnelly and Fitzmaurice, 2005), where it is often used in simulated work-based scenarios. Its origins are traced to McMaster University medical school in Canada (Perrenet et al., 2000), where the technique was used to encourage a holistic approach to diagnosis based on analysis of symptoms through the use of existing knowledge to formulate questions in a realistic professional setting (de Graaf and Kolmos, 2009). Project-based learning in HE, on the other hand, derives mainly from engineering, in which discipline the technique was pioneered at Aalborg and Roskilde Universities in the 1970s (de Graaf and Kolmos, 2007).

PBL is described as a learning cycle in which students initially encounter a problem (rather than first being given information); reasoning skills are then developed and learning needs identified with the staff support. This is followed by individual study and a cooperative phase in which the knowledge is applied to the problem (Perrenet et al., 2002). Here students identify and seek the information needed rather than drawing on existing knowledge with which to explore the problem. A further noted difference between these approaches is the emphasis within the project approach on the creation of an artefact or product (Donnelly and Fitzmaurice, 2005). Indeed Savin-Baden (2007) argues that the approaches are fundamentally different based on the task-orientation of PjBL and the tendency for parameters of the activity, if not the task itself, to be set by staff. Similarly, in the school context, Barron et al (1998) differentiate between PBL as producing a plan or strategy, whereas PjBL requires the execution of the plan, such as the creation of a blueprint for and the construction of an actual community centre playhouse, rather than a simulated activity. However,

Savin-Baden argues that although PjBL is differentiated by its emphasis on an outcome, this may in fact be in the form of a report (2007); and many of the examples of outputs given in the literature under the heading of PjBL are reports, designs or presentations rather than material artefacts such as devices or constructions. Indeed some authors clearly accept that in PjBL the problem can be theoretical or practical (Kolmos, 1996: 146).

Further differentiating features given by Savin-Baden include the use of supervision in PBL (rather than facilitation in PjBL) as well as greater emphasis on the provision of foundational knowledge by staff in PjBL, rather than student-directed learning in PBL; and the idea that PjBL may combine several subjects for a limited activity rather than representing a more holistic commitment to interdisciplinarity across the degree programme as in PBL, although this is contradicted by commitment to embedding project-based learning across the curriculum in universities such as Aalborg and Leuven (von Kotze & Cooper, 2000; Kolmos, 2007).

Problem-based learning is also often conceptualised as a sub-element of successful project-based learning (Barron et al., 1998; Blumenfeld et al., 1991; Hanney & Savin-Baden, 2013). Here, the problem sits within the project (Blumenfeld et al., 1991) and usually informs or drives the project (Kolmos, 1996; Thomas, 2000). Others approach the two as distinct but associated elements under one heading: 'Problem-Orientated and Project-Based Learning (POPBL)' where the project is carried out in response to and centred on a real-world problem (Lehmann et al, 2008: 284). Placing the problem at the centre of the project is argued to be a means of retaining the open-ended and creative nature of enquiry which may be stifled by rigid project management protocols focused on achieving an end product (Hanney and Savin-Baden, 2013).

4.0 Disciplinary spread of project-based learning

Much of the early work on PjBL derives from school level education, mostly in the US, and often focused on science. This includes work by Blumenfeld et al. (1991; 1994), many of the earlier studies reviewed by Thomas (2000), and more recent work by Bell (2010). However, PjBL in HE has also received increasing attention over the past decade and its implementation is described in a wide range of disciplines at this level. The approach is often associated with engineering, where the project is focused around the development of a tangible, material construction (Otake et al, 2009). While engineering is the discipline most frequently represented in the PjBL literature, a 2010 review of the practice within the UK concluded that its adoption was "not widespread"; it tended to be "very diverse and 'maverick' in its development, and implementation", and was often found to have finished or lapsed as staff moved on (Graham, 2010). The review presented here found evidence of PjBL having been used (at some stage) in a wide range of disciplines not only confined to science and technology but also embracing education, media, business, and social science (see Table 1.1 below).

Table 1.1 Discipline areas of literature reviewed on PjBL

Discipline	Number of studies
Engineering	13
Not discipline-specific	8
School-based studies (not HE)	7
Management learning (corporates, not HE)	4
Geography and Environmental Sciences	4
Education and Science/environment	3
Education	3
Business Studies	3
Sustainability	3
Information Technology	2
Health Information Science	1
Political and Social Sciences	1
Boat building	1
Conservation Biology	1
Planning	1
Adult education	1
Electrical engineering	1
Architecture and interdisciplinary communication	1
Chemistry	1
TOTAL	59

As mentioned above, PjBL is seen as providing the opportunity to bring interdisciplinary knowledge and practice to bear on complex problems which spill over traditional disciplinary boundaries. This has resulted in some unusual disciplinary combinations such as that adopted at Ohio State University where PjBL in a graduate course combined faculty and students from social work, geography and plant biology to explore issues around sustainability (Nation, 2006) or at the University of Texas where architecture and interdisciplinary communications graduate students collaborated on designing virtual social housing in Second Life software (Jarmon et al., 2008).

The term 'project-based learning' is also used within the discipline of management learning or organisational learning (Ayas and Zeniuk, 2001; DeFillippi, 2001; Garrick and Clegg, 2001; Keegan and Turner, 2001). However the focus of these studies is not on the development of individual learners but on how commercial companies generate and retain knowledge through projects undertaken as an integral part of their work. As such these will not be included in this review except where relevant knowledge transfer techniques are applicable to the HE classroom (see section 9.5).

5.0 Extent of project work within degree programme

The extent of the project work within the teaching programme also varies hugely, often depending on differing cultural and institutional contexts (Du, Su, & Liu, 2013), from cases where an entire university programme (Kolmos, 1996) or school curriculum (Bell, 2010: 39) is developed around PjBL, to the use of short projects embedded within modules. Morgan (1983: 66), for example, identifies a spectrum from "small 'project options' or exercises, to a 'project orientation' which forms the basis of the entire university education…". According to Thomas (2000) a key characteristic of the PjBL approach is that projects form the main learning approach and are central to the curriculum. This is

illustrated in a model developed by Aalborg University, Denmark, where all programmes are centred on problem-orientated work and project work constitutes two thirds of all programmes (Lehman et al., 2008). However, while a prolonged period of project activity is recommended (Donnelly and Fitzmaurice, 2005; Helle et al, 2006), Graham's (2010) survey of PjBL in UK HE engineering departments found the scope of PjBL varied widely from a first year induction week challenge to more comprehensive individual or group projects in the final year. Much of the literature describes projects embedded within one semester modules (Frank & Barzilai, 2004; Jarmon et al., 2008; Lehmann et al., 2008), while one IT project at the University of Tokyo was run in the university vacation over 52 days (Otake et al, 2009). The scope of projects thus varies widely across disciplines, institutions and stages of study.

6.0 Rationale and advantages of the Project-based approach

The following section discusses the main rationale and drivers for PjBL as presented in the literature. This is followed by an outline of the claimed advantages for students and staff of the PjBL approach.

6.1 Philosophies and drivers for project-based learning

Helle, Tynjälä, and Olkinuora (2006) highlight four main drivers for the adoption of PjBL in education: pedagogic; professional; democratic and humanitarian; and fostering critical thinking. While the first three categories align broadly with the drivers identified in the literature, the fourth, critical thinking was less evident, whereas the need for cross-disciplinary approaches to complex contemporary problems was emphasised. Each will be discussed in turn below:

6.1.1 Educational philosophical roots of PjBL

PjBL, according to Morgan (1983: 68), is not just a "technical' teaching method "but a curriculum design that can raise fundamental questions about the nature of higher education". He traces PjBL to the educational and psychological theories of influential US twentieth century thinkers including John Dewey (the importance of learning from experience); Jerome Bruner (learning as an active process in which the students' transformation of information engenders motivation, retention and personal development); and Carl Rogers (the importance of the perceived relevance of the topic for motivation) (Morgan, 2008). More recent influences cited are the experience of hands-on learning in Outward Bound classes, insights from 'problem-based learning', and insights from cognitive science regarding the importance of context to learning (Thomas, 2000); while de Graaf and Kolmos (2007) trace the origin of project learning to influential 20th century American teacher William Killpatrick who noted the correspondence between motivation and choice over subject of study. Closely aligned to these pedagogical theories is an adherence to social constructivism in which emphasis is placed on students' awareness, through active learning, of the role of social context in the creation of knowledge systems (Frank, Lavy & Elata, 2003; Frank & Barzilai, 2004; Lehamnn et al., 2009). PjBL is seen to offer a "construction site of learning" to which participants bring diverse voices, ideas and methods to co-create socially useful knowledge (von Kotze & Cooper, 2000). PjBL may therefore be seen as one response to developments in pedagogical thinking over the past fifty years which have advocated a shift away from a model where teachers impart knowledge to relatively passive students, to one in which learners became engaged and active participants in the co-construction of knowledge (Blumenfeld et al., 1994). As Donnelly and Fitzmaurice (2005) explain, the approach aims to foster active, motivated learners and to encourage initiative, and independence of thought.

6.1.2 Skills for the 21st Century

Adoption of PjBL in HE also takes place in response to a perceived need for university graduates to be equipped with skills relevant to future employers (Kolmos, 2009). These calls derive from government, industry and professional accreditation bodies as well as students facing highly competitive job markets (Lehmann et al, 2008). Traditional lecture-based teaching, particularly in subjects such as engineering, is widely believed to no longer provide the broad professional skills needed by contemporary graduates; whereas PjBL, with its hands-on experience, real world problems and group work is seen as providing these wider transferable skills (Mills and Treagust, 2003). Demands for graduates with skills relevant to the workplace sometimes derive from specific industries (de Graaf and Kolmos, 2007). For instance Dzan et al (2013) developed their HE level boat design and building project in response to a shortage of skilled boat builders in Taiwan; and the business studies projects described by Botha (2010) were created partly to help meet a need for more trained entrepreneurs in South Africa. Professional bodies such as the Accreditation of European Engineering Programmes and Graduates (Lehmann et al, 2008) may also drive the demand for changing or widened skill sets; while welfare reforms and intense competition for graduate jobs mean students need skills over and above traditional academic qualifications – including creative thinking, teamwork, and project-management, which are argued to be enhanced through PjBL (Green, 1998). Discussing PBL rather than PjBL, Pawson et al. (2006) argue that many Geography students will take-up jobs unrelated to the discipline, necessitating "the ability to learn as self-starters" rather than an emphasis on discipline-specific content; and that even in Geography-related employment, rapid technical change mean the ability to quickly acquire and apply new knowledge and skills is imperative. Several PjBL courses reported in the literature aim to give students a taste of future work through immersion in an actual professional context (Danford, 2006; Meehan and Thomas, 2006), enhancing their skills and employability.

A further incentive for the introduction of PjBL is its use in institutional rebranding (Kolmos & de Graaf, 2007) linked to increasing pressure and competition, due to government-led changes in HE funding, for student recruitment, and retention (Kolmos & de Graaf, 2007; Graham, 2010: 6). According to Graham this has led to an increased focus on promoting the first year of study and with "recruitment as a major motivator, a number of UK engineering schools have rebranded their education around project-based or active learning" (Graham, 2010: 6).

6.1.3 Increasing complexity of contemporary issues

As mentioned above, the need for critical thinking has been identified as an important driver for PjBL. The approach has been argued to highlight the process and power structures behind knowledge creation, engendering critical thinking and helping students consider alternative ways of thinking and acting (Von Kotze and Cooper, 2000). However a more commonly mentioned motivation is the ability of PjBL to provide the type of skills, behaviours and understanding needed to tackle challenges in a contemporary context of increasing complexity, where problems and projects transcend well-defined disciplines and sectors. For example Lehmann et al. (2008: 284) discuss PjBL in the context of the skillsets required "in a world where systems gradually become larger" and the "boundaries for engineering knowledge and skills are increasingly difficult to identify and define". These include not just technical skills but also "interdisciplinary skills of cooperation, communication, project management and lifelong learning abilities in diverse social, cultural and globalised settings" (Lehmann, 2008). The literature emphasises a new relationship between science and society wherein "science has become contextualized", requiring people-orientated skills and behaviours

such as communication and team work (Kolmos 2009: 263-264). This recognition of "increased complexity, connectedness, and speed of transformation in the research objects" is particularly pertinent in the study of the environment and sustainability, located at the interface of social, economic and natural systems (Stauffacher et al., 2006: 253; Du, Su & Liu, 2013). PJBL, with its interdisciplinary focus and embrace of open-ended questions and exploration, is seen as well suited to explore these interconnections and complexities (Stauffacher et al., 2006).

6.1.4 Democratic and humanitarian principles in PjBL

A further driver behind the adoption of PjBL is a commitment to what Helle, Tynjälä, & Olkinuora (2006) describe as democratic or humanitarian ideals. Kolmos (2009) locates the origins of PBL and PjBL in student protests and demands for greater democracy in HE in the 1960s and in the early adoption of the approach in universities in Germany, Netherlands, Sweden and Denmark. These principles and how they may be put into practice are described by von Kotze and Cooper who adopt a PjBL model developed at the Katholieke Universiteit of Leuven in Belgium (2000). Applying the model in adult education in Southern Africa, these authors emphasise the importance of working in and for the community for social democratic ends (2000). Students' prior knowledge and experience gained through community engagement and "nurtured in collective struggle" (Von Kotze & Cooper, 2000: 214) is valued and brought to bear upon the creation of socially-relevant new knowledge.

However, while several approaches discuss the importance of interactions with and contributions to the world outside academia (Nation, 2006; Botha, 2010; Cheung & Chow, 2011; Green, 1998) the Leuven Model discussed by Von Kotze and Cooper (2000) is exceptional in its explicit emphasis on social responsibility and the importance of learners and the researchers contributing to the communities in which they work, particularly to those members who are less privileged. Furthermore, De Graaf and Kolmos suggest that the project approach has not realised its aims for social change and that more emphasis is now placed on its ability to develop valuable professional skills (2007).

6.2 The advantages of PjBL

The main advantages of PjBL identified from the literature include: claims of improved academic results, the development of wider skills, increased student motivation and enjoyment, enhanced outreach and engagement beyond academia and advantages for lecturers. These will be discussed in turn below before attention is turned to the challenges of the approach.

6.2.1 Improved academic achievement

While there is some evidence in the academic literature of PjBL leading to enhanced academic achievement, very few studies measure this effect at the HE level, most seeking instead to either describe the process of projects or understand student perceptions of the approach. Nonetheless there are some claims of improved academic results. At the school level Baron et al. (1998) used pre- and post-testing to demonstrate that students at all levels involved in their playhouse design project showed improvement in their understanding and communication of basic maths and geometry. In the HE sector, Barak and Dory (2003) compared the results of two groups of undergraduate chemistry students at an HE institution in Israel, one using traditional methods, the other IT-based project-based learning to construct computer models of molecules. The authors found that in both qualitative and quantitative measures, the project-based students achieved better than the non PjBL group in their post-test assessment and final examinations. Frank, Lavy & Elata (2003) also found

their engineering projects particularly benefitted academically weaker students as the teaching assistant was able to identify and assist students needing extra help during project work. However, one study by Mills and Treagust (2003) found that while students were generally motivated and demonstrated better teamwork, communication skills and understanding of professional practice, "they may have a less rigorous understanding of engineering fundamentals", suggesting improvements in academic standards in PjBL cannot be assumed. The paucity of research which rigorously measures academic improvement at the HE level, using a control group and/or pre-project and post-project testing suggests further research in this area is needed.

6.2.2 Wider skills

There is widespread consensus, however, within the literature that PjBL helps students develop a wide set of skills beyond traditional academic subject knowledge. The frequency of skills as identified in the literature is outlined in table 1.2 below. Clearly these skills are not restricted to PJBL and may also be derived from other learning methods. Furthermore, while some of these skills were self-reported through student surveys or other methods of evaluation, at other times their presence was not supported by evidence. Nonetheless, the breadth of skills, reflecting the diversity of types of projects described in the literature, suggests the potential for the approach to help foster traditional academic skills, and professional and personal attributes.

Table 1.2 Skills and competencies identified in the PjBL literature

Skill or competency	Frequency of reference to skill
Team work/collaboration	18
Problem solving skills	13
Increased motivation	13
Communication skills (oral)	12
Communication skills (written)	10
Subject knowledge	9
Information finding/data collection	8
Professional knowledge and skills	7
Understanding of application of knowledge in practice	7
Data analysis	7
Creativity/innovative thinking	6
Critical thinking	6
Project management	6
Inter-personal skills and social relations	5
Increased self-esteem	4
Time management	4
Ability to learn from revision	3
Contextual analysis	3
Technical skills and understanding of technical procedures	3
Cross-disciplinary knowledge	3
Cross-disciplinary team work	3
Self-evaluation	3
Responsibility and self-accountability	3
Listening skills	2
Increased sense of belonging and identity with the faculty	2

Organisational skills	2
Improved relations between students and staff	2
Giving and receiving feedback	2
Deep understanding	2
Attendance	2
Self-discipline	2
Ability to reflect on performance	2
IT skills	1
Observation skills	1
Editing skills	1
Inquiry skills	1
Formulating goals, aims and objectives	1
Knowledge Management	1
Networking with professionals	1
Negotiation skills	1
Resourcefulness	1
Ability to deal with conflict	1
Ability to work independently	1
Grant writing skills	1
Ability to cope with complexity	1
Leadership skills	1
Decision-making	1
Cultural awareness	1

Group work skills are frequently claimed to be enhanced through project work, although it is arguable whether this is necessarily due to an intrinsic element of the project approach or might be found in other examples of group work. Similarly, problem-solving skills are frequently cited, as are communication skills, both of which may also be evident in other styles of learning. The literature also suggests that students, especially those in professional environments such as hospital health information departments (Moehr et al., 2004: 160) gain important work-based knowledge and skills; while student evaluations show learners value the opportunity to development professional skills as part of their academic studies (Joyce, 2013). Indeed where project work was optional, students volunteered to take part in order to increase their skills, contacts and experience (Otake et al., 2009). Moreover, the use of PjBL in engineering was found to give students a deeper appreciation of the wider social context and constraints faced by practicing engineers (Frank, Lavy & Elata, 2003). Frank and Barzilai (2004) reported that PjBL as part of a science and technology MSc, helped in-service teachers acquire inter-disciplinary subject knowledge which they felt in turn led to greater awareness of social contexts. Other benefits reported by the authors were the ability to give and receive feedback; improved relations between peers and between students and teacher; and improved self-esteem linked to formative assessment (Frank & Barzilai, 2004). Furthermore Wilkinson et al. (2002) reported that many students used their project experience as a vehicle for showcasing their skills in subsequent job interviews.

6.2.3 Motivation and enjoyment

The studies reported on in this review generally emphasised students' enjoyment of PjBL activities and linked this to motivation to learn. Some of these conclusions were not based on research but instead draw on practical experience and observation of the technique in schools or HE institutions

over a number of years (e.g. de Graaf & Kolmos, 2007; Bell 2010). Others used a wide range of research methods to evaluate students' perceptions of their learning experience. Frank, Levy & Elata, (2003), for instance, used observation and analysis of semi-structured interviews with students and student reports to establish that they enjoyed this type of learning and felt it increased their motivation to learn. Student completed evaluations of a sustainability course in Beijing showed 100% of respondents found the PJBL approach more "motivating and effective than a lecture-based pedagogy" (Du, Su & Liu, 2013: 87); while Botha's post-course student questionnaire found that 70% of respondents enjoyed the project and ninety percent rated their overall impression of the project as either average or positive (2010). Analysis of student feedback over three years confirmed that engineering students at Nottingham University enjoyed a hands-on approach to learning and gained satisfaction from completing a project (Joyce, 2013). Notably Botha also found that enjoyment of project work was positively correlated to students' acquisition of skills (2010: 228). In the school context Thomas (2000) reports on a study by Bartscher, Gould, & Nutter (1995) in which 82% of pupils indicated that projects helped motivate them, and 93% claimed increased interest in the topics involved.

Meehan and Thomas (2006) used analysis of the reflective element within student reports, videos of debriefing meetings and audiotaped informal interviews to establish that students were positive about the project work. Similarly Spronken-Smith and Kinghams'(2009) student course evaluations demonstrated that students enjoyed their project work and that the rating of the course quality improved following the introduction and subsequent adaptation of PjBL. At UCL, where PjBL is used in five-weekly cycles across the first two years of the engineering programme, dropout rates had fallen significantly and PjBL resulted in positive feedback from staff and students (Graham, 2010). Conversely, Stauffacher et al., found that "a sizeable number of students were always reserved or reluctant" and attributed this to their unfamiliarity and resistance towards a new learning style with non-traditional forms of assessment (2006: 266) (see further discussion in section 8.1.2).

The element of student choice enabled by project-based learning is argued to underpin increased levels of motivation (Blumenfeld et al., 1991; Kahn and O'Rourke, 2004), while the use of problems with relevance to the students' interests and experience is also seen as intrinsically motivational (Kahn & O'Rourke, 2004; Graaf & Kolmos, 2007). In-depth interviews with staff and students by Van den Bergh et al. (2006) showed that students made greater effort in their project-based learning than in other courses; while Baron et al. (1998: 278) argue that "if students know they will be completing real projects in the community, they will be motivated to learn". Engineering students interviewed by Frank, Levy and Elata (2003) reported the competition element between groups helped increase motivation; and feedback from engineering students at Nottingham University stressed appreciation of the "freedom for creativity and innovation" afforded by PjBL (Joyce et al, 2013: 70). Collaboration with industry partners and the chance to tackle real world problems was also believed by design and engineering students in Australia to increase their motivation (Lockrey & Bissett Johnson, 2013).

Other research is more equivocal regarding the motivational qualities of PjBL. Edelson, Gordon and Pea (1999) argue that because of the intensive and extended nature of project work, it may be harder to sustain students' motivation – an assertion supported by in-depth interviews with staff and students conducted as part of a study by Van den Berg et al., who found motivation was not as high as expected and waned over the course of the project (2006).

6.2.4 Diverse learners and PjBL

Beyond brief references to the importance of a balance of genders on supervisory teams and the appropriateness of PjBL in engaging learners with different educational needs and backgrounds, there is little reference in the literature to issues of gender, diversity, widening participation or to students with disabilities or different learning styles (see also Thomas, 2000). There is a brief mention within the literature of PjBL's ability to cater for learners with diverse needs and from diverse backgrounds (Blumenfeld et al, 1991), including those with special educational needs (Bell, 2010), although this is largely anecdotal rather than supported by scientific evidence. Gaps in student knowledge because of varied prior experiences may, it is argued, be more easily identified and filled within the context of project work (Kahn & O'Rourke, 2004) and the authors claim that project work means students are able to learn at their own pace in their own way - although as will be discussed below, tensions around group work were sometimes derived from perceived disparities in individual contributions (Mills & Treagust, 2003). Thomas reports that studies by Rosenfeld and Rosenfeld (1998) found that PBL catered better for students with learning styles unsuited to fact-based transmission; and that in research based on observational techniques (Horan, Lavaroni and Beldon, 1996), lower ability students showed the greatest gain in social participation and critical thinking behaviours (Thomas, 2000). However, authors have also noted difficulty with managing 'skills progression' where a modular undergraduate Geography degree meant some students had not taken relevant courses, particularly those providing quantitative skills relevant to the project (Spronken-Smith & Kingham, 2009). Attention to the experiences and needs of different learners within PjBL is clearly an area where further research is needed.

6.2.5 Enabling outreach

A further significant identified benefit of PjBL is its potential for fostering engagement beyond academia. The literature provides examples of projects developing partnerships with public bodies, industry, professionals and communities. One case is a project undertaken by Ohio University students for the Appalachian Regional Commission (ARC), a US federal body tasked with sustainable development and poverty reduction. The students undertook a pre-feasibility assessment of a disused railway, which included working with and reporting back to the local community and federal representatives (Nation, 2006). This type of collaboration can benefit non-academic partners in that they receive "cost-effective resources (students)" and access to academic staff expertise and international partnerships (Danford, 2006) as well as to students' findings (Lehmann et al., 2008). Similarly student surveys of turtle meat traders in China helped provide valuable data for researchers, NGOs and Governments working on conservation of endangered species (Cheung & Chow, 2011). Partnership also benefits the students as they make contact with professionals and future employers (Nation, 2006) and can, if successful, enhance the university's reputation (Danford, 2006). Moehr et al (2004), reporting on student audits of health information departments in Canada, argue that the professionals benefit from benchmarking their information strategies; may incorporate student findings into their operations; and that the projects help foster employment opportunities for students. Other initiatives encouraged students to draw on staff identified external organisations or actors as sources of information and expertise without the formality of a partnership (Du, Su & Liu, 2013).

6.2.6 Others benefits of PjBL

PjBL may also have benefits for academic staff. These include the possible provision of new results for research publications (Van den Bergh et al., 2006: Spronken-Smith & Kingham, 2009); better

cooperation and integration between students and staff (Van den Bergh et al., 2006); and the ability for staff to incorporate their research interests within their teaching. Project work may also highlight important research gaps (Spronken-Smith & Kingham, 2009). Khorfhage Smith (2010) found that staff members' team-teaching skills improved using PjBL, with faculty members learning from each other and from partnerships with students, business and government agencies.

A further reported advantage of PjBL is the opportunity for the students to learn by revision. School students in one study were keen to adapt and improve designs following feedback and reflection and drew on a variety of resources to make iterative improvements (Baron et al., 1998). UK engineering students welcomed the opportunities for revision; which, as one put it: "made u think – if it didn't work, made u rethink" (quoted in Joyce, 2013). A further advantage is that practical projects give students a more informed view of the profession they are training for and "a stronger sense of belonging and identification with the faculty" (Frank, Lavy & Elata, 2003). PjBL may also foster, an "inclusive knowledge which values non-traditionally academic discourses and approaches" such as oral histories and local knowledge on the environment (Botha, 2010). Other studies found that project involvement in sustainability/conservation projects engendered pro-environmental behaviours among students (Kılınç, 2010; Cheung & Chow, 2011).

7.0 Examples of projects

The academic literature describes a wide variety of projects under the label of PjBL. These can be categorised into three types based on the type of outputs produced: the research project (similar to small scale research projects which have traditionally formed the basis of third year undergraduate dissertations); the construction project and the professional work context project based on collaboration with external actors. Examples of each will be outlined below.

7.1 Research project

The first type of project results in a fairly traditional academic output such as a dissertation, literature review or research report. No other artefact is produced and no external partners are involved. An example is project work by Kılınç (2010) who developed projects for student teachers studying environmental science in Turkey where outputs included: a literature review on environmental pollution; preparation of a 2-hour lesson using problem-based learning; research on local news coverage of environmental issues; interviews with city officials regarding key environmental issues; and a survey of local schoolchildren's attitudes to nuclear power. A third year Geography unit, Earth Systems Interactions, at Monash University, Australia also involved fairly traditional fieldwork methods: 25 students from across arts, science, environmental and atmospheric science programmes investigated global environmental change and the urban heat island through temperature data collection (Beringer, 2007) resulting in a research report and seminar. Similarly a physical Geography project on a one semester Environmental Hazards and Management course in New Zealand focused on data collection and analysis (Spronken-Smith and Kingham (2009). Students investigated local nitrogen dioxide levels by wearing measuring devices over a two week period and keeping an associated activity diary, resulting in a scientific-style report.

7.2 The construction project

Because of the predominance of engineering within the literature on PjBL, many of the projects centre on the design and production of a technical product or artefact. Examples of products designed and constructed include a solar-powered car, a water desalination system, a remote

cardiologic testing system, an automated, watering system, a hot air balloon system, and an automated purification system for aquarium water (Frank & Barzilai, 2004). While this category is most commonly used by students in engineering and design, the end product may also be non-technical. For instance Botha (2010) describes projects in which first year entrepreneurship students at the University of Pretoria in South Africa devised creative exhibits of the business knowledge gained during the module. This included: reality TV shows, fashion shows, plays, board games, posters, dress-up characters, films and videos and cookery shows and classes. In other examples the end product was text based but non-academic, such as a handbook for adult returners to education produced by mature students preparing for their high school qualification in the US (Green, 1998).

7.3 The real-world project

At the other end of the spectrum is research for external partners such as international market research undertaken for commercial companies by students at Helia University of Business and Applied Sciences in Finland (Danford, 2006) and environmental consultancy projects by Melbourne University third year students on sustainable waste management solutions for a new-build university in Vietnam (Meehan and Thomas, 2006). Here the students' brief was presented to representatives of the Vietnamese University in Australia with the intention that it would be incorporated within the development (Meehan and Thomas, 2006). A Further example is collaboration between media students with a local youth charity to produce a music video for young people at risk of exclusion (Hanney and Savin-Baden, 2013). On a larger scale, graduate communications students at the University of Texas, Austin, worked with architecture students and staff members "to create a virtual presence for two green, sustainable, urban housing designs" (Jarmon, 2008: 162) to explore the use of Second Life as an educational tool. The course involved working with communities and architects and resulted in the construction of actual homes in Austin, Texas and an internet site where visitors could view the prototypes online and learn about the design process.

A further example of collaboration with extra-academic actors is that of Environmental Management MSc students at Aalborg University who often work with outside organisations. These include a University in Thailand which facilitated a project with a traditional paper manufacturer where students helped design processes for minimising the environmental impacts of the production process (Lehmann, 2008). Furthermore the social element of these projects is often stressed, linking to the democratic and humanitarian philosophies of PjBL. For instance Von Kotze and Cooper (2000) describe the use of the Leuven model where third or fourth year social pedagogy students collaborate with community and service organisations who bid for the projects based on relevance to their group or strategy, resulting in a final report of practical use to the partner organisation.

7.4 Staff input to projects

The literature provides scant concrete detail on staff input into PjBL and where examples are given they vary widely. For instance Nation (2006) describes class time as for giving students the tools they needed to learn, guest speakers and providing formative assessment on the final report (Nation, 2006). Conversely, others provide detailed break-downs such as Frank and Barzilai (2004) who researched an in-service teachers BSc course in science and technology which lasted across a 14 week semester and each week included: a one-hour lecture, two hours' microteaching and three hours' team project. For some, like the example above, there is a balance between formal lectures providing subject content and information on methods, and less formal mentoring of group work. In other cases lecturers have a less formal role and provide guidance on suitable literature, feedback

on drafts, and group mediation (Lehmann, 2008). In one case tutors did not meet students face-to-face except immediately prior to their presentations and instead communication was entirely via email and oversight of the students' online posts and progress reports (Otake et al, 2009). In other cases lecturers sometimes became involved in the projects, taking part as game show participants, fashion show members, etcetera (Botha, 2010) or helping students in China identify rare turtle species in local markets (Cheung & Chow, 2011).

Some institutions addressed the significant staff time needed for PjBL through the use of 'tutors' or 'facilitators', often Postdoctoral Research Assistants or PhD students (Graham, 2010), who provided the main point of contact for the student groups. At Manchester University, for instance, each group undertaking PjBL in engineering has a designated facilitator who attended and facilitated a de-brief session following all group meetings. These facilitators received intensive training on the PjBL approach, the project exercise and group facilitation (Graham, 2010). A slightly different technique was adopted at the Federal Institute of Technology in Zurich where: 'tutors' (doctoral students) divided responsibility for particular aspects of learning such as methods, content, and didactics (Stauffacher et al., 2006).

7.5 Examples of types of assessment

Similarly, the ways in which projects were assessed varied hugely across the literature. Many projects use multiple methods and stages of assessment in various combinations. For instance in the project-based course described above by Van den Bergh et al. (2006) the assessment is complex and multi-levelled and while individual grades are given, all written outputs are jointly produced. Instructors meet before the final presentation to discuss their supervisees and to jointly decide on a group mark. Next, the instructors allocate an individual mark to each student based on their performance over the year and the criteria for this are decided individually by each instructor. Finally the group report is assessed by panel of instructors; and the group presentation is assessed by instructors and students. Other courses use a combination of assessment of a group product or artefact, a presentation and a written report (Nation, 2006) which may be produced as a group or individually. For instance Lehmann et al (2008) describes how students are assessed at the end of the semester through a report and a group public presentation and viva. Often the meeting minutes of groups are included in the assessment to ensure the evaluation of project processes are taken into account (Wilkinson et al, 2002). Wilkinson, describing the assessment of engineering students' computerised 'mouse organ' projects, used a three-stage assessment: a group report, team meeting minutes and an individual report – to allow staff to evaluate both group and individual contributions. However in the Business entrepreneurship projects described by Botha (2010) no written assessment was done and instead lecturers used an assessment sheet to evaluate project outputs exhibited; and assessment for a turtle trade survey project relied solely on students' presentations to local schoolchildren and peer-assessment of videos of these presentations (Cheung & Chow, 2011).

Courses in other institutions involve the external client in the assessment process (Danford, 2006; Lockrey & Bissett Johnson, 2013). This then raises the question of the criteria used by external assessors, as Lockrey and Bissett Johnson describe how separate criteria are used by industry partners and academic staff to judge the same student project (2013).

One concern raised in the literature is the difficulty of assessing the input of an individual to group work (Van den Berg et al, 2006). To address this issue, Moehr et al (2004) describe how students are observed by their peers through a one-way mirror and videoed as they carry out distinct parts of the project. It is not clear whether this is used for formative or summative assessment but it allows the observing students to both critique and learn from other groups. Several studies also emphasise the importance of assessing the process as well as outputs. Thus Frank and Barzilai (2004) assessed not only the physical model, the presentation and the group report, but also the personal (reflective) report and participation in weekly group meetings, which each made up 10% of the overall grade.

A survey of students' favoured assessment types (Van den Berg et al., 2006) found students were wary of self-assessment and peer assessment as being too subjective but supported co-assessment (by peers and staff) as this provided an element of peer assessment with the perceived safety net of the instructor's input. The most favoured assessment type was the reflective journal, which they felt gave an insight into process and group dynamics, served to provide feedback to the instructor and enabled students justify their performance. Formative assessment of journals was preferred but students were also happy for part of this to be summative. However students felt it essential that the reflective journal should be confidential (other students should not see it) and entries not too frequent. In conclusion, Van den Bergh et al. found identifying suitable assessment for the projects problematic and a tension between students wanting clear guidelines and lecturers wanting their "academic freedom" (2006: 364). They suggest tailoring the assessment to the learning environment and using a diversity of types of assessment.

8.0 Challenges

This section outlines some of the predominant challenges of project-based learning raised in the literature. While these vary widely between discipline and approach, the two most significant identified challenges across the disciplines are that of group work, which is seen as a hugely important skill but holding the potential for conflict and free-riding by individuals, and difficulties experienced by staff and students in adapting to non-traditional teaching and learning roles. This section will first deal with some of the difficulties experienced by students undertaking project work before outlining staff concerns.

8.1 Challenges for students undertaking PjBL

8.1.1 Group work

Group work was frequently identified in the academic literature as the most significant challenge faced by learners undertaking PjBL. A study by Meehan and Thomas (2006), for example, found students undertaking environmental management projects in Vietnam reported team work as being the hardest element of their project work. Similarly Stauffacher et al., (2006) found the majority of challenges came from group work processes and Frank and Barzilai (2004) discovered from reading students' personal reflective reports that they were exposed to situations of conflict in their project-based work. Free-riding by a group member was often the most significant issue identified (Mills and Treagust, 2003). Furthermore, a lack of experience and a lack of understanding of the value of collaborative work, especially where learners had a background of high individual achievement in order to secure places in high ranking institutions (Pawson et al., 2006), were important factors impeding successful collaboration. Cultural factors may also influence team dynamics as implied by

authors reporting the use of PjBL in China where group members were reluctant to admit to lack of harmony among team members or to openly critique fellow students (Du, Su & Liu, 2013).

Difficulties with group work are attributed to lack of prior training (Frank, Lavy & Elata, 2003) and larger group sizes, which created problems in terms of communication and allocation of work (Joyce, 2013). A recent review of PjBL in teaching sustainability (Brundiers & Wiek, 2013) found that although class discussion covered teambuilding, and social events were provided, provision for developing group work skills remained insufficient. Student difficulties with group work also impact on staff and the literature notes concerns regarding the time intensive nature of this learning style and the challenges created by group dynamics (Stauffacher et al., 2006) particularly for staff in evaluating individual contributions in a group setting. However, while students often found group work challenging and difficult, it nonetheless can be a rewarding and positive learning experience which students recognised as important for their future professional work (Meehan and Thomas, 2006; Joyce et al, 2013).

8.1.2 Preference for traditional teaching styles

For students, a second significant challenge identified in the literature is that of adapting to an unfamiliar student-centred approach in which considerable responsibility for learning and work management shifts from staff to learner (Frank & Barzilai, 2004; Donnelly & Fitzmaurice, 2005; Danford, 2006; Kolmos & de Graaf, 2007); and where variable levels of uncertainty are intrinsic to the approach (Danford, 2006: 11). As Stauffacher et al. explain this type of learning "is a completely new environment with a spectrum of unknown challenges. There are pressures from many sides: peers, transdisciplinary partners, the project leaders, the tutor and the learning goals. The students perceive themselves as being in the middle of these pressures" (2006: 268).

The new burden of responsibility often starts right from the off as many students may find it problematic to have choice over topics or projects (see Morgan, 1983; Frank & Barzilai, 2004). Students also have to cope with new content in a relatively unstructured learning environment (Frank & Barzilai, 2004) and a review of PjBL for teaching sustainability in institutions in six countries found that degree programmes were rarely designed to prepare students for the demands of project work and seldom required prior relevant course completion (Brundiers & Wiek, 2013). Nation (2006) found students' adjustment to new types of learning and assessment as one of the most significant challenges of PjBL while Spronken-Smith and Kingham (2009) reported physical geography students in New Zealand needed considerable course scaffolding and staff support. Conversely, students participating in PjBL in other settings felt that felt there were too many over-long lectures in too traditional a format (Frank, Lavy & Elata, 2003), suggesting student experiences depend on the methods of implementation.

8.1.3 Evaluation

Less frequently reported in the literature are student concerns regarding evaluation. These focused mainly on one course where lecturers evaluating different groups each used their own criteria, giving rise to questions of transparency and equity (Van den Berg et al., 2006). Other studies found that students often undervalued what they had learned "particularly in the social and process domains" through lack of communication by staff regarding the aims and objectives of PjBL (Stauffacher et al., 2006: 269); and it is suggested that a lack of clarity around evaluation may be unsettling for students, particularly when they are used to a traditional system where grades

correspond to correct answers given (Blumenfeld et al., 1991). A study of industry-partnered PjBL undertaken with Australian engineering and design students noted that the use of ongoing reviews of student work mirrored professional feedback practices and allowed for timely reflection and revision but had the drawback of requiring that students perform consistently across the semester-long project (Lockrey & Bissett Johnson, 2013).

8.1.4 Weight of work

The adoption of PjBL has been linked with student and staff perceptions of demanding workloads for staff and students (Stauffacher et al., 2006). For instance, Van den Berg et al. noted that students perceived the workload as heavy, while instructors reported students found the workload "overwhelming" (2006: 354). Joyce et al (2013) also found that over the three-years in which a hands-on element of PjBL was introduced into an engineering module, students reported perceptions of rising workloads. Students' final reports on a practical-based computer engineering project also raised the issue of time constraints (Wilkinson, 2002). The need for extra time was not necessarily always negative however as some students appreciated having more time to work on their project (Joyce et al, 2013).

8.2 Challenges of PjBL for academic staff

The main challenges of PjBL for academic staff noted in the literature are similar to those faced by students and relate to problems adapting to new teaching methods and facilitation of group work.

8.2.1 New role of facilitator for the tutor

While lack of adequate content knowledge is identified by just two studies as a challenge for teachers implementing PjBL (Blumenfeld et al., 1991; Frank & Barzilai, 2004), most difficulties centred on anxiety and resistance towards their new role as facilitator in student-centred PjBL. As Green explains "For the instructor, the challenges lie, not so much in carrying out the actual project, but in being able to effectively assume the role of advisor and guide rather than a dispenser of information with all the answers" (1998: 15). Similarly Frank and Barzilai (2004) reported that lecturers struggled with the shift from being an imparter of knowledge to one of a mentor or facilitator and recommended the input of pedagogical trainers. Blumenfeld et al. (1994), who worked with US middle school science teachers over a three year period to collaborate on introducing PjBL, found that initially teachers understood PjBL as merely a change in style rather than a new approach and philosophy. By the end of the first year, however, teachers raised "dilemmas stemming from beliefs and personal preferences that conflicted with premises of project-based instruction" (1994: 543) and wanted clear guidelines on how to implement the new approach. They write: "Initial attempts to change instruction from a didactic or tightly structured, activity-based model, rendered the teachers novices once more" (1994: 544).

The literature also suggests that PjBL is challenging for staff in terms of determining the balance between need for input and allowing students the freedom to explore and innovate (Ladewski et al 1991, in Thomas, 2000; Joyce, 2013). Similarly teachers may be unsure about how much scaffolding to provide (Blumenfeld et al., 1991; Marx et al., 1997, in Thomas, 2000). Finally, one study reports on a lack of staff confidence regarding choice and implementation of appropriate methods of assessment (particularly formative assessment), which sometimes meant a focus on summative assessment and consequent heavy workloads for students and staff (Graham, 2010). Cultural factors

and social contexts may also play a part in teachers' beliefs about their role, with attitudes varying across national borders (Weenk, Govers & Vlas, 2004).

8.2.2 Time and resources needed for PjBL

The time and resource intensive nature of PjBL was also another significant challenge identified in the literature (Frank & Barzilai, 2004; Donnelly & Fitzmaurice, 2005; Van den Bergh et al., 2006; Stauffacher et al., 2006). Firstly, this related to the time taken to develop a PjBL module: Graham (2010) found one engineering faculty suggested 5-10 years was needed to develop and embed PjBL. Engineering staff at Newcastle University spent three years converting to a design and manufacture module incorporating PjBL (Joyce et al, 2013). Once introduced, PjBL can demand significant time from teachers in terms of project guidance and ongoing formative and sometimes complex combinations of assessment (Frank & Barzilai, 2004; Donnelly & Fitzmaurice, 2005). Identifying and developing appropriate problems and projects is also noted as time-intensive (Danford, 2006). In the school setting, Blumenfeld et al. (1994) found teachers worried about time management as projects or activities overran classes and deadlines. They expressed "conflicts about whether to cover curriculum or to allow students time to take ownership of their learning by designing investigations and thinking carefully about the science concepts involved" (Blumenfeld et al., 1994: 543). Time pressures on staff in HE may be particularly acute due the demands of the Research Excellence Framework (REF) or similar institutional pressures (Graham, 2010). Graham notes: "Many interviewees identified PjBL as an activity that demands significant amounts of time to both design and support, and reported difficulty in securing this from their own schedule and that of their colleagues" (2010: 7). Furthermore Graham identified a need for significant numbers of trained facilitators and a lack of available resources such as materials, equipment and teaching/project space (2010). Similarly Spronken-Smith and Kingham (2009) highlight the heavy input required from tutors and laboratory assistants and the need for materials and equipment. Time and resource pressures may also be exacerbated when working with or for outside organisations where there is the added pressure of delivering a quality product to a client (Danford, 2006).

8.2.3 Other challenges

At the institution or faculty level, challenges reported in the literature include that of getting a new course accredited (Graham, 2010) or accepted in time; as well as a wider cultural and institutional resistance to inter-disciplinarity (Nation, 2006). Developing courses and projects can also be an especially lengthy process where involvement from outside organisations is involved; and curriculum changes, or fluctuating student numbers, can cause the cancellation of projects, disappointing professional or external partners (Moehr et al., 2004). Another issue concerns the lack of status and value attached to the role of the tutor, a role identified as important for group supervision but which Stauffacher et al. (2006) argue is neither well recognised nor rewarded within academia. Furthermore, research by Edelson, Gordin and Pea (1999) highlighted problems including lack of adequate resources, timetabling issues and inappropriate technology while class sizes and constraints of the curriculum are also noted (Blumenfeld et al., 1994).

A further key challenge for teaching staff new to this technique is keeping the learning outcomes central and not promoting "doing for the sake of doing" Baron et al. (1998: 281). Spronken-Smith and Kingham (2009) found that focus groups following their project suggested students were not fully aware of the aims and objectives of the module. There are also concerns that some HE engineering courses in the UK are over-structured and over-scaffolded, limiting student-directed

learning and the potential for exploration (Graham, 2010). Similar concerns are echoed by Hanney and Savin-Baden (2013) regarding the overuse in the UK of predominantly 'techno-rationalist' models derived from professional project management such as the Prince II system used by the UK government. At Leuven University in Belgium, the impact of changing educational philosophies and the pressures of neo-liberalism meant the value placed on the end product had increased at the expense of process and reflection (von Kotze & Cooper, 2000). Von Kotze and Cooper argue:

> *Greater emphasis on elaborating expected outcomes and clearer guidelines seems to arise from the need to systematise, order and 'regulate' the messiness of PBL, which we would argue would seem to be one of its most important strengths. PBL is not a linear process of learning: it is an organic process which should allow learners to stray off the planned path and discover unknown treasures, develop unforeseen abilities, grow in unpredictable ways (2000: 223).*

A further potential pitfall identified by Graham's staff interviewees was that an emphasis on student recruitment and retention could lead to "a focus on 'wow factor' projects rather than the educational outcomes and long-term benefits to the students" (2010: 6). Graham's (2010) review of PjBL in UK engineering departments also found the following challenges, most of which are applicable to non-engineering contexts: firstly, the lack of rigorous evaluation of the approach and the associated barriers to its widespread adoption; secondly, issues of funding in the context of cuts to HE budgets and the closure of some Centres for Excellence in Teaching and Learning; thirdly, a lack of interaction between PjBL research communities and subject specialists; and fourthly a lack of academic staff with the relevant industry experience to support real world projects.

Further issues surround the adoption of PjBL in the context of distance learning. Moehr et al (2004) describe major challenges in adapting supervision in experiential project-based learning in Health Information Science to students undertaking projects a significant distance from the campus. Identifying, setting up and managing appropriate projects remote from the university were found to be time and resource intensive. Instead the use of a locally-based projects with remote learners using tele- or video conferences or online collaboration, was seen as offering the best solution to translating project-based work to distance learning.

9.0 Guidance on implementation of PjBL

The following section summarises the advice and suggestions gleaned from the academic literature regarding what works well in project-based learning. While some ideas are specific to particular disciplines or styles of implementation, many of the learning points are likely to be transferable. Furthermore, where the advice is of a more general nature, it serves to re-emphasises potential problem areas where particular consideration is needed for thinking through the implementation of PjBL in specific contexts.

9.1 Planning and preparation of PJBL

Institutional support for the adoption of PjBL, both at the senior management level and across the school or faculty, is identified as an important first step in effective implementation of the approach (Green, 2010; Du, Su & Liu, 2013). Also critical is advance identification of, contact with and negotiation between faculty and any external partners (Korfhage Smith, 2010). Next, careful piloting and testing of proposed projects is suggested before the course is timetabled for students, in order to ensure the tasks are feasible within the given timescale (Donnelly & Fitzmaurice, 2005). As

mentioned above, embedding a problem as the driving rationale of the project is recommended to help students and teachers clearly relate project activities to the specific conceptual learning points (Baron et al., 1998). Additionally, Nation (2006) suggests choosing projects which can be scaled up or down if student numbers fluctuate.

9.2 Student briefing and scaffolding

The importance of appropriate briefing regarding the nature, goals and timing of the project is emphasised in the literature. Kahn and O' Rourke (2004) underline the importance of an introduction for students to the PjBL approach and suggest strategies including: organising a 'have a go' trial for students and asking experienced students to model the process. This is also the stage at which to clearly communicate and discuss the learning objectives and goals, which can be further explored and emphasised throughout the project (Stauffacher et al., 2006: 263). Botha (2010) identified the introduction of the project at the beginning of the semester and frequent reminders up until its commencement, as a key success factor. Another effective strategy was to use edited videos from student project de-briefs in former years to help inform new cohorts of students about the project, and to provide "warnings and encouragement" (Thomas & Meehan, 2006: 132).

Strong scaffolding, particularly at the initial stages of the project and reducing as students gain the confidence to explore independently (Stauffacher et al., 2006; Bell, 2010), is highly recommended. This includes suitable resources to support the project, such as time-tabled sessions and provision of relevant reading or on-line materials (Kahn & O' Rourke, 2004) and adequate guidance for students who have choice over their topic, in order to limit overstretch on too ambitious projects (Donelly & Fitzmaurice, 2005). Donelly and Fitzmaurice (2005) also suggest the use of sample projects to help students understand what is expected in terms of scope and content; and the use of a written project guide. With school students, Baron et al. (1998) used video-based scenarios to introduce the problem within its context. This, they explained, serves to introduce some initial terms, concepts and tools, without providing solutions (Baron et al, 1998). Other scaffolding resources used by the team include: a 'SmartLab' of data collected, permitting collaboration, sharing, discussion and comparison among students; a 'Toolbox' of visual learning aids; student presentations to illustrate common errors and examples of good practice; and a resource providing written prompts for students to revise their work (Baron et al., 1998). Other authors highlight the importance of addressing students' resistance to new teaching methods and recognising and supporting those finding it hard to adapt (Stauffacher et al., 2006); as well as explaining at an early stage the new role of teacher as facilitator (Kahn & O' Rourke, 2004). An appropriate level of subject knowledge and methodological competence is also arguably required in order for students to carry out their projects. For instance, discussing high school students, Blumenfeld et al. (1991) argue that students without the relevant skills can face frustration and lose interest. Yet the authors also note that staff may need assistance in providing the types and levels of scaffolding appropriate for this sometimes unfamiliar approach (Blumenfeld et al., 1991).

9.3 Maintaining Motivation

In order to maintain student motivation throughout the project, several strategies are recommended. First is the use of projects which are authentic or have potential application in the real world (Blumenfeld et al., 1991). Stauffacher et al. also argue that choosing the right case/project is key to motivation: "Ownership is the key term when it comes to the motivation of students. The

most crucial aspect here is the choice of the case", which needs to have meaning for their lives or interests and are ill-defined so as to allow issues and solutions to emerge (2006: 265).

This connection to real world issues and contexts can be strengthened through collaboration with industry representatives (Botha, 2010), involvement in actual projects/constructions, and the chance for students to present or pitch outputs to professionals in the field (Graham, 2010). Baron et al. agree that presenting to external audiences can make "the work meaningful and they almost always offer new opportunities for learning" (1998: 285) and student interactions with their local community were also reported by students as rewarding (Nation, 2006). However despite an assumption that real-world problems sustain student interest, Blumenfeld et al. warn that there is little empirical evidence regarding the types of topics that will sustain student interest and motivation" (1991: 376) and students' interests are likely to vary widely across and within disciplines, different national contexts, levels of study and over time.

Other suggestions for maintaining motivation include the creation of a learning atmosphere where students feel safe and comfortable to discuss issues which have relevance to their own lives and where they can discuss their "beliefs and make mistakes without fear of criticism or judgement" (Green: 1998: 15) and the use of competition between groups or teams (Graham, 2010) with a prize incentive for the winning team (Botha, 2010; Graham, 2010).

9.4 Group Work

One of the most significant challenges identified in PjBL, group work, prompts a broad range of guidance in the literature. Most commonly suggested is the allocation of roles to group members. These may be management roles for some individuals (Meehan and Thomas, 2006) or more specific roles for each group member (Cheung & Chow, 2011). Stauffacher et al, (2006: 263) recommend assigning rotating roles to including: workflow coordinator (project management); logistics (looks after petty cash, equipment, transport, rooms); editors; content manager (for updating files and resources) and others. Another study recommends the use of the Belbin team role assessment system to identify and draw on group members' behaviours and ensure that these types are allocated evenly across the student groups (Danford, 2006). Recent research by Notari, Baumgartner and Herzog, (2014) found that effective group work was influenced more by the high and/or homogenous distribution of social skills within the group than by the levels of social skills held by individuals. The authors suggest an emphasis in prior training of students in group work on the ability to cooperate and compromise, prosocial behaviours and leadership skills and discuss the potential use of computer tools to help teachers form effective groups (2014).

There is relatively little detail in the literature, however, about how groups are chosen (for example see Du, Su & Liu (2013) merely state that groups 'formed' but gave no detail on choice or staff allocation, size or constitution). In most of the PjBL courses reviewed by Brundiers, and Wiek (2013: 1735) students chose their groups "based on topical interest, friendship, or previous collaboration". One study mentions that groups self-form as students with similar interests come together (Lehmann et al, 2008); another reports on the creation of teams made up of bachelors, masters and doctoral students from mixed disciplinary backgrounds within information science (Jarmon et al, 2008) but there is negligible discussion in the literature about the pros and cons of staff allocation over student choice of group membership or regarding the group size – a factor which varied across examples of projects given from pairs to larger groups of 10-20. The constitution of groups may also

depend on the skills and aptitudes needed for different types of projects. Students undertaking turtle trade surveys in China, for example, needed at least one member of each team to speak the Guangdong dialect used by traders (Cheung & Chow, 2011).

Provision of training for group work is also advocated by several authors. This can form part of the induction to the project (Donnelly and Fitzmaurice, 2005); or discrete sessions including training on different techniques for reaching decisions as a group such as consensus or the use of a chairperson (Frank & Barzilai, 2004). At Aalborg University in Denmark, where PjBL underpins the entire curriculum, students undertake, in preparation, a first year course in Cooperation Learning and Project Management (Lehmann et al, 2008). It is also suggested that students need training in group work during and after the project (Frank, Lavy & Elata, 2003).

Stauffacher et al. (2006: 263) use the following methods to support group work: team building tests; synthesis moderation, techniques for facilitation of group discussions; computer assisted group work; visualisation techniques; feedback and meta-discussions and activity journals, although how these work in practice is not detailed. The authors also use Tuckman and Jensen's (1977) framework which outlines typical stages of group work such as 'storming' and 'norming' to suggest the appropriate tutor activities at each stage of the process (Stauffacher, et al., 2006). Another technique for promoting collaboration and students' support of each other is described by (Baron et al., 1998: 285) where the whole group is not permitted to move on to the next project stage until every student has attained a designated milestone.

Other authors stress the importance of staff involved in project work receiving training in facilitation and mentoring (Frank, Lavy & Elata, 2003). The balance between providing advice and encouraging exploration and risk taking can be tricky and suggestions for effective facilitation include "asking open-ended questions; supporting students and valuing their contributions; encouraging students to reflect on their experiences; monitoring progress; challenging student thinking; and "developing an atmosphere of trust" (Kahn and O' Rourke, 2004: 5). Interestingly, Danford suggests that rules regarding performance and participation are set out at the beginning of the project and that one principal rule is that students who do not fully participate e.g. by missing meetings or not delivering results, are asked to leave the project (2006).

Research has established that group work can increase student motivation but also lowers students' personal responsibility and as such Blumenfeld et al. (1991) argue that the make-up of groups and how students are held individually accountable need careful consideration. At Helia University in Finland, where students are already chosen for their motivation and resourcefulness, further qualifications for project work are considered necessary, such as the prior attendance of certain courses (Danford, 2006). Lou and MacGregor (2004) found that online mentoring by effective student groups of less effective groups helped improve the quality of their group work and a similar project review by strong groups of weaker groups' work, led to increased skills among the less effective group.

9.5 Assessment

Assessment has been identified as problematic in PjBL but the advice from the literature is of a fairly general nature. Key is the idea that the assessment should be in keeping with the enquiry and the abilities being developed (Kahn & O'Rourke, 2004). A range of assessment is recommended, including those that evaluate indicators of process, such as meeting notes, presumably to capture

the different learning outcomes and to cater for different learning types (Kahn and O'Rourke, 2004). In a questionnaire of students using PjBL, Frank and Barzalai (2004) found the majority appreciated having the assessment criteria clearly stated at the beginning of the course and supported ongoing assessment throughout the course as it helped students evaluate their own progress and work on problem areas. Formative assessment at stages throughout the project is argued to allow for revision and learning. For example Baron et al. (1998) use three cycles of general and non-directive feedback and revision, allowing students to learn through doing and re-doing. This type of assessment may also help staff and students reflect on the integral role and value of mistakes in the learning process (Blumenfeld et al., 1991). Another suggestion promoting reflection and revision is the use of SWOT analysis throughout the project to encourage critical thinking and self-evaluation (Hanney & Savin-Baden, 2013). Although discussing learning within the context of companies where project work occurs as part of the production process, Ayas and Zeniuk (2001) and Keegan and Turner (2001) note the importance of reflection for learning and the use of learning tools based on collective reflection such as 'after action reviews, project and team audits, lessons learned databases and reviews at specific project milestones.

Botha (2010) used no form of written assessment, only lecturer observation of student exhibits and noted the time saving this represented for students and lecturers. While alternative assessment methods may be suitable for PjBL, training may also be needed to help staff master new techniques such as evaluation of student journals, assessment of portfolios, the use of the viva or the analysis of student discourse (Blumenfeld et al., 1991).

9.6 Tutors

The importance of having module leaders and tutors who understand, support and are trained in the PjBL approach is underlined in the academic literature. According to Graham (2010), successful examples of PjBL in the UK HE engineering sector have in common module leaders who are "personally committed to excellence in education, benefit from a high level of autonomy in the design and operation of their modules and often draw from significant levels of experience in engineering industry" (Graham, 2010: 6). Stauffacher et al (2006) found the choice of tutors to be crucial, with success dependent on choosing those with a background in transdisciplinary research and who had undertaken the project-based module in previous years. Due to the centrality and challenges of group work, teachers are sometimes chosen specifically for their group work skills (Stauffacher et al, 2006).

A great deal of emphasis in the academic literature is placed on the importance of training tutors in the PjBL approach, particularly in appropriate methods of assessment (Mills & Treagust, 2003). Tutors often receive intense training before the projects start and during the semester as well as built-in opportunities to exchange experiences and receive coaching from more experienced colleagues (Stauffacher et al, 2006). At the University of Twente in the Netherlands, where PjBL in engineering dates from 1994, short courses for lecturers on PjBL are run frequently and PjBL is also part of compulsory two year training for all new lecturers (Weenk, Govers & Vlas, 2004). These training courses are themselves run using the project-based model so that teachers can experience the student perspective.

Various strategies are suggested in the literature to support teachers and lecturers facilitating PjBL. One is the use of 'tutors' who are usually trained postdoctoral or postgraduate students (Meehan &

Thomas, 2006; Stauffacher et al., 2006). Also important is the time for teachers to become accustomed to the new techniques through iterative cycles of collaboration with PjBL researchers, practice, evaluation and reflection (Blumenfeld et al., 1994). Moreover institutional recognition of the extra demands on tutors, particularly in terms of assessment, is noted as essential (Donelly & Fitzmaurice, 2005). Web-based support for staff includes the provision of online resources such as a the hypermedia Project Support Environment developed by Blumenfeld et al. for school teachers (1994) which contained information and case studies (including videos of classes using PjBL), a project planning tool helping teachers to develop driving questions, a communication forum for teachers to share ideas and issues, and a personal journal to aid reflection.

9.7 Technologies and resources

The use of online technology is central to many of the projects detailed in the literature. This includes university-wide software such as Blackboard but also dedicated password protected websites where students can store and share minutes from meetings and other project data (Danford, 2006). Aalborg University researchers, Tolsby, Nyvang and Dirckinck-Holmfeld (2002), assessed different virtual learning technologies for supporting PjBL and isolated three key needs for online learning in PjBL: a space for negotiation of meaning between the students, for coordination of the project work and for the organisation of resources. They assessed three virtual learning systems: Virtual-U 2.5, Lotus Learningspace, and Lotus Quickplace 2.08 (moodle was not included) and concluded that each of their systems partially fulfilled the criteria, providing a conference space for discussion, a calendar for work coordination, and tools for hosting, organising and sharing resources. However, without adequate support and training staff can struggle with the use of new technology (Blumenfeld et al, 1991).

9.8 Resources for Lecturers

Graham (2010) found that within engineering HE the Engineering Subject Centre and the UK Branch of the CDIO initiative (an international innovative educational framework engineer training) was useful in supporting PjBL and innovative teaching practice. The Centre for Excellence in Enquiry based Learning at the University of Manchester holds a wide range of resources. A resource pack (Hutchings, 2006) on the centre website gives examples of the standard introduction of Problem-based learning used to brief students; and ideas for project outputs such as scripts for a Radio 4 programme or introductory pamphlets for an Open University course, which could be adapted to various disciplines.

Table 1.3 Summary of identified challenges and solutions

Identified challenge	Potential solution
Group work	Allocating fixed or rotating group roles to individuals (possibly based on members' behavioural strengths or skill sets).
	The provision of formal training in group work for students prior to and/or during the project
	Providing time and support for the groups to gel and feel comfortable together
	Staff chosen on the basis of their experience and skills in group work
	Provision of staff training in group work and facilitation
	Between-group mentoring and review
	Clear guidelines and rules on the expectations regarding individual contribution to group work and how this will be assessed
Planning and preparation	Piloting the project
	Using a real world problem as a driving question for the project
	Choosing projects which can be scaled up or down depending on student numbers
	Advance identification of and negotiation with external partners
Scaffolding and student support	Providing a thorough briefing for students about the aims, methods and content of the project
	Use of past student experiences to help brief new students
	Use of sample projects or written project guides
	Appropriate levels of scaffolding, often providing greater lecturer input in the early stages and reducing as the project continues.
	Appropriate materials and resources provided
Maintaining motivation	Choice of projects which interest students and have real world significance
	Use of competitions between teams and prizes
	Showcasing or performances to external or professional audiences
Assessment	Assessment should be appropriate to the task and the learning outcomes targeted
	Inclusion of several types of assessment (summative and formative; peer and staff; group and individual)
	Formative assessment through cycles of feedback and revision
	Training for staff in alternative forms of assessment
	The inclusion of time and space for students to reflect on their learning throughout the project
Staffing	The choice of staff who understand and have experience in PJBL or transdisciplinary work
	Training for staff in PjBL approaches
	The use of trained postdoctoral or PhD tutors for group work
	Time for staff to trial, evaluate and reflect on PjBL supported by pedagogical experts
	Access to materials and resources for lecturers regarding PjBL
	Institutional or management recognition of the extra staff time and resources needed for PjBL

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