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Optimising inter-disciplinary problem-based learning in postgraduate environmental and science education: Recommendations from a case study

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As the value of multi-disciplinary working in the business and research worlds is becoming more recognised, the number of inter-disciplinary postgraduate environmental and health sciences courses is also increasing. Equally, the popularity of problem-based learning (PBL) is expected to grow and influence instructional approaches in many disciplines. However, very limited research has been conducted to explore the perception of students of PBL in inter- or multi-disciplinary environments; particularly wide-ranging multi-disciplinary courses which cross the natural-social science barrier. The findings from this case study evidence the difficulties and benefits students derive from group PBL, many of which stem from working in multi-disciplinary and multi-skilled groups on a part-time basis. Acknowledging, accepting and overcoming conflicts based upon prior experience that influences epistemological and ontological beliefs may be key to the development of effective PBL in inter-disciplinary and multi-disciplinary programmes. Recommendations for good pedagogic practice to maximise learning in postgraduate environmental and science education are made.

Introduction

Problem-based learning (PBL) has been used in medical education for decades (Armstrong, 1997; Camp, 1996; Wood, 2003). As a teaching approach PBL aims to instil a culture of learning and intrinsic motivation by providing a knowledge and skills basis for problem solving, collaborative skills, and a context in which acquired knowledge can be applied to realistic situations (Hmelo-Silver, 2004; O'Shea, 2003; Schmidt, 1983). This is achieved by utilising a scenario approach, with group work and self-directed learning in which learners define the parameters of the problem(s) and their own learning objectives, while teaching takes on a role of facilitation (Neville, 1999; Savery, 2006). Well designed and implemented PBL can align to constructive, self-directed, collaborative and contextual learning principles (Dolmans, De Grave, Wolfhagen, & Van Der Vleuten, 2005) which enforce deeper learning by incorporating reflective components; thus mapping onto Kolb and Fry's model of experiential-learning derived from psychologically-based learning theory (Fry, Ketteridge, & Marshall, 2008; Kolb, 1984; Lewin, 1946).

It has been suggested that PBL is a powerful way of developing 'learning for capability' rather than learning for the sake of acquiring knowledge (Engel, 1991). In this way, argues Engels, students developing self-directed learning skills through PBL will be well placed to adapt to future economic, political, scientific and technological changes. Dahlgren and Öberg (2001) suggest that PBL may be especially well suited to environmental science education. They showed that as students became more skilled and confident in working with PBL, they tended to generate fewer 'encyclopaedic' questions that imply there is a simple and unambiguous answer and more complex questions exploring the relationships between constructs, meaning and values. PBL also creates opportunities to bring together heterogeneous groups of students with different professional backgrounds and prior life experience. In this way, PBL can create a context for inter-disciplinary and multi-disciplinary learning. Since these terms have frequently been used interchangeably (Phoenix et al, 2013), it is helpful to define how they are applied in the present study. Table 1 depicts a typology for distinguishing between trans-disciplinary, multi-disciplinary and inter-disciplinary learning that can be applied to PBL.

Table 1. Characteristics of Trans-disciplinary, Multi-disciplinary and Inter-disciplinary Problem Based Learning, after Phoenix et al, 2013)

Trans-disciplinary Learning	Multi-disciplinary Learning	Inter-disciplinary learning
Collaboration in which exchanging information, altering discipline-specific approaches, sharing resources and integrating disciplines achieves a common learning goal.	Learners from a variety of disciplines work together at some point during a project, but have separate questions, separate conclusions, and disseminate in different contexts.	Learners interact with the goal of transfer of knowledge from one discipline to another. Allows learners to inform each other's work and compare individual perspectives.

There has been considerable debate about the positives and negatives of homogeneous vs. heterogeneous student grouping in inter-disciplinary PBL (Papanikolaou & Gouli, 2013). For example, there is evidence that group heterogeneity reduces the productivity of research groups (Cummings, Kiesler, Bosagh Zadeh, & Balakrishnan, 2013), since differences among members can weaken group identification and therefore requires increased attention to motivating members and coordinating tasks. This may be especially true for inter-disciplinary PBL groups in which there may be a perceived status hierarchy based on age and/or prior experience (Thistlethwaite, 2012).

Despite the concerns of some educators that this resource intensive approach does not provide the benefits it claims in terms of knowledge, performance and skills development (Colliver, 2000; Norman & Schmidt, 1992), the use of PBL continues to grow. The aim of this case study is to explore student perceptions of the challenges associated with PBL as a learning tool for an inter-disciplinary postgraduate course in environment and human health, and to make recommendations for adjustment to pedagogic practice to maximise learning. More specifically this case study explores the positive and negative perceptions of learning and the content, the process, obstacles and benefits of inter-disciplinary PBL in a group of learners.

Methods

Setting The Scene: Course, Student Cohort and Learning Activity

To investigate the aims outlined above, a part-time (1 day per fortnight) inter-disciplinary MSc programme at a UK research and education institution was chosen for investigation. The student cohort invited to interview was the first cohort to undertake this newly designed course and consisted of 16 mature students (ages approximately 20 – 50), the majority of whom also work full-time.

PBL formed the major component of the first module in year 1. Students were allocated to four working groups, each consisting of four individuals and each group assigned to one of two PBL scenarios (harmful algal blooms or osteosarcoma scenarios). As an example, for the first scenario students were provided with limited written introductory information on harmful algal blooms as a potential environmental hazard to human health and a simplistic scenario in which a costal algal bloom was occurring (see Figure 1 for a summary of the scenario). The groups were allocated six weeks to work on the learning activity and had the opportunity to meet an expert in the subject, before a final formative assessment consisting of a press conference presentation to an invited audience of interested stakeholders and postgraduate broadcast journalism students (who were also undergoing assessment for which they were producing a news bulletin). Subsequently an essay on a related topic emerging from the PBL activity was summatively assessed.

<u>PBL Task: Marine Harmful Algal Blooms (HABs)</u>

<u>Introduction</u>

In this scenario, a potentially harmful algal bloom has developed off the coast. Local press reports of a previous outbreak earlier in 2011 suggested that there was no danger to health, based on an analysis of a previous bloom in 2009 by the Marine Lab. However, it is now not clear whether the current outbreak is potentially harmful, following media reports of the death of animals in recent outbreaks of algal blooms in Brittany and The Lake District.

Local residents, farmers and representatives of the local shellfish industry have asked us to address their concerns and present an overview of the relevant environmental and human health issues.

Figure 1. Harmful Algal Bloom Scenario

Interviews and Participants

Following local research ethics committee approval, students were invited to voluntarily participate in this pedagogic research. Six students (covering three of the allocated PBL groups) underwent a 30-40 minute individual audio-recorded interview with a semi-structured format that was used to guide discussion towards areas of interest. An active listening approach (Wolcott, 1995) was used with open questions, such as “Tell me about your PBL project”, to allow a variety of themes and issues to be brought up. In addition, questions designed to guide the student to discuss areas of interest not covered in open discussion, such as process; content; the learning experience; benefits and downsides, were posed, e.g. “How did your group manage the work?” and “What did you think of the subject?” Once all areas of interest were addressed, participants were given the opportunity to express any further thoughts in relation to the PBL exercise.

Data Processing and Analysis

Interview audio-recordings were subject to verbatim transcription, followed by a round of cleaning to remove language stumbles and maintain confidentiality, prior to coding. A final round of cleaning was used to prepare the transcripts for analysis in Wordle™ (word cloud software) by replacing and grouping words, using hyphenation and deletion of uninformative words, as a supplementary research tool to aid in initial stages of coding (McNaught & Lam, 2010).

Thematic analysis with an inductive content analysis approach was conducted via traditional coding approaches upon manifest content consisting of rounds of data familiarisation, open coding, theme construction, abstraction and interpretation (Elo & Kyngäs, 2008; Taylo-Powell & Renner, 2003). This allowed similarities in data to be identified, discovery of themes and the development of thematic patterns in the relationships between themes (Braun & Clarke, 2006; Smith & Sparkes, 2005). Three main themes were selected for further elaboration and interpretation: "prior experience / maturity" (referred to henceforth as "student background"), "scenario" and "facilitation".

Results and Discussion

Student Background

The challenges associated with inter-disciplinary work featured as subcomponents of many of the themes emerging in this research. This is illustrated by a student who explained that she felt lucky with the allocation of her group members because they all had a similar background. When the interviewer followed up on this asking "So, you actually felt it was beneficial that you had a similar background, as opposed to a multi-disciplinary team?", the student replied:

> *"It's just nice to work with people that have a certain common language and understanding ... I think that could be a challenge and just people wanting to take things in different directions, and certainly, yeah there would have been certain directions that people would have wanted to take ours in that I couldn't have contributed to, and that would have been frustrating"* (Participant L).

It is both apparent and not surprising that this student felt a desire to stay within their own discipline. However an inter- / multi-disciplinary course should seek to challenge these attitudes and guide students towards collaborative working and where necessary highlight the benefits of a multi-disciplinary team on an individual team level. The advantages of inter-disciplinary working are further highlighted by Spiro, Feltovich, Jacobson, and Coulson (1992) in discussion of oversimplification (including intellectual investigation from only one perspective) as the cause of failure in most advanced learning situations. One means by which to emphasise the benefits of inter-/multi-disciplinary approaches is to purposefully assign students to groups which are both inter-disciplinary and multi-skilled; by designing groups consisting of students with different backgrounds and experience and explaining why the groups have been allocated in this way.

Working as part of such as diverse group poses additional challenges itself, and a number of interesting and surprising sub-themes emerged due to the wide age range (and therefore experience) of group members. Older members generally felt that they had established skills sets that were not developed by this PBL activity:

> *"some of the benefits of PBL perhaps aren't so relevant to that group. So, for example giving presentations: I would say a lot of people would already have those skills because of their work experience or, you know, just working as part of a group and, I don't know, listening, how you communicate to each other, you know,*

respecting peoples' views, all that sort of stuff. I think a lot of people would already have those skills, so again, I can see for someone who's 18 and coming in as a first year undergrad some of that might be more relevant, than it perhaps is to our course" (Participant L)

" there's one person, ... who's kinda 20-something, but most people have been around the block a few times in various jobs. ... If that was one of the learning objectives, about presentation skills, ... then I think that was wasted on us really" (Participant R).

Whereas younger students gained more in terms of skills development from working with their more experienced peers:

"that's what happens in everyday life; you have your specialist skills and you have your skills that you know a little bit of everything, but not a lot of anything, type of approach. But I think you have to have specialist skills as well. And that was important I think, within our group". (Participant M)

"I think it's a brilliant task, in ways of equipping you with your skills, you know, communication and team work and research… Brilliant task, as group work… through the task you really learn a lot of like skills in terms of communication, how to get on with people ... And also I suppose you try to utilise each other's skill and strength" (Participant Q)

However in some situations the younger students purposefully left the organisation and leadership to the more experienced students or students they deemed had more relevant backgrounds, or even felt intimidated by those with more experience:

"Yeah, I mean they were, they were, public health, so they had that sort of knowledge and experience and being older as well ... I was coming from the science background when we originally got together so of course I was thinking we were going to need a lot more scientific stuff but they came from it from that and go "no, you just need this, this and this"; bang, bang, bang; which helped steer us in the right direction." (Participant M)

"But I think that's because ... of their jobs. Like [peer's] job – they're very much ypublic facing and they are always doing that sort of thing, so, and because they're older – it is quite intimidating. It's like a ... Oh, I don't know… a younger person who's got less experience to butt in and go "well actually I think"." (Participant O).

Overcoming issues of different levels of skill within group work is difficult, but before we as educators try to addresses this problem it is necessary to have a really firm idea of the skills that are both present and lacking. Interestingly despite many of the older students believing they did not need skills development many admitted to lacking certain academic skills, such as knowledge on how to search and reference literature. Therefore when setting up and explaining group composition attention should also be drawn to the skills of younger members (who may have more recent experience of formal education), which would also help some of the younger students overcome confidence issues.

From the outset it would appear that adults would be suitable candidate students for PBL due to their tendency towards self-directed learning as described by Knowles (1990) model of adult learning. However these adults will also have "developed habitual ways of thinking and acting, preconceptions about reality, prejudices, and defensiveness about former ways of thinking and doing" due to their prior experience (David & Patel, 1995, p. 358); further exacerbating the difficulty of encouraging such adult learners to engage on an inter-disciplinary level. However careful consideration of the individuals who constitute each PBL group has the potential to supress some of these habits and provide appropriate situations for the enhancement of learning, from the skills and knowledge base to a conducive, non-intimidating, but challenging, learning environment. Maskell (1999) identified the problems with multi-disciplinary working and used a group design approach, as suggested, to enable "the group as a whole to take advantage of the different strengths of the individual members by drawing upon a wider range of experiences" (p. 239).

Scenario

Another method by which all group members can appreciate their own value is to use a much more detailed scenario, which requires engagement in multiple disciplines. This would also help address feelings of a lack of direction. Many participants aired their frustrations with the scenario, despite their logical approach to the working process. All participants interviewed explained that their group had split the work load into sub-sections for individuals or pairs to research:

> *"we looked at the scenario and identified there was like 4 elements, which we then divided up into 2 halves. We thought about taking an element each, but then thought that might be difficult because we might cross-over. So I think we split it into 2 halves, with again 2 people doing a half each. And that way if I thought of something and [my partner] thought of something else, you've got that sort of safety-net of what if I find something and somebody else finds something different"* (Participant I).

Problems with "deciding what areas to pursue, given a multitude of possibilities; and figuring out how to extract relevant information from the available mass" (Chin & Chia, 2005, p. 44) and insecurity over the expected breadth and depth of knowledge (Solomon & Finch, 1998) are reported in studies of ill-structured PBL and were also observed here. Scenarios presented were very broad in scope due to the nature of the multi-disciplinary subject and many students struggled with this, finding that they were not sure where to focus their efforts, or feeling that they had not gone into enough detail for MSc level work as they'd had to cover such a large topic.

> *"I'd have preferred the scenario to have said it's a harmful bloom. You haven't got to say which species it is, but you can just say it's been identified as one of the harmful blooms. It would lend itself for you to go into your presentation … And the scenario was so vague, that we kind of just had to run with it."* (Participant I)

> *"it was a scenario that none of us particularly were okay with, it's something that your straightaway thinking "Oh God this could be quite challenging""* (Participant O)

> *"I mean, in a sense there was clarity because we were given this scenario and we had to present something to an audience. So, there was clarity in that sense, but I wasn't clear about what the qualitative aspects of the exercise were."* (Participant R)

> *"I've acquired some knowledge, but in terms of MSc level of skills and knowledge I don't feel I've acquired a huge amount."* (Participant L)

Giving further explanation at the inception of the exercise that within PBL it is the learners' responsibility to establish their own parameters and define their own end goals would have allowed more detailed learning and overcome frustrations with the lack of direction felt by learners. However, this would not necessarily overcome issues around conflict within groups regarding the direction of the research, nor prevent narrow discipline- or background-specific approaches to the exercise, which limit opportunities for inter-disciplinary learning:

> *"Having that direction from one of the girls who said "no, I think we shouldn't go into this direction and not to delve deep, just go into this direction" so yeah, having a little bit of a steer. But, all agreeing that was the direction we should go into and not try and go onto that scientific-based stuff."* (Participant M)

To combat issues around the scenario a much more detailed scenario which is designed with the principles of constructive alignment at its heart (Biggs & Tang, 2007), while taking account of recommendations on effective scenario design by educators such as Wood (2003) and Dolmans, Snellen-Balendong, Wolfhagen, and van der Vleuten (1997), is required. Generalised recommendations on scenario design should however be used only under consideration. Dahlgren and Öberg (2001) question the applicability of Dolmans, Snellen-Balendong, Wolfhagen, and van der Vleuten (1997) seven principles of scenario design for the inter-disciplinary subject of environmental science, because "different players have different disciplinary perspectives that lead to different definitions of the problems" and that the overall objective of environmental science education is "that students should develop an ability to discern different perspectives and critically appraise them" (p. 265). This again highlights that for inter- / multi-disciplinary courses the paradigmatic assumptions and hence disciplinary perspectives of both educators and students must be considered in depth prior to the development of any instructional approaches to ensure that a balanced educational programme can be provided.

Modification of an authentic situation as a scenario could help overcome some of the student feelings that the scenario was not relevant; as observed in other studies of student perceptions of PBL (Sockalingam & Schmidt, 2011). As a point of interest during the weeks following formative submission a genuine harmful algal bloom occurred in the locality and researchers at the educational institution were contacted for advice. It is proposed that this real event could be transformed into a suitable PBL scenario. The scenario presented would detail the species of algal found, and a treatment process which was used prior to filling public bathing pools with this water. The formative submission would again consist of a press conference. Careful design of a scenario such as this ensures students engage on a multi-disciplinary level (Jonassen & Hung, 2008); as biology is needed to understand species present, chemistry is needed to understand water treatment, toxicology is required to interpret impacts upon human health and knowledge of public health, responsibility of government organisations and legislation is required to produce a press release. Use of such a scenario would overcome the issues discussed, but does not limit the final conclusion of the exercise, as key information that determines risk to human health is excluded, therefore still allowing the students to set their own parameters in response to the scenario.

Facilitation

For inter-disciplinary PBL with mixed background groups, facilitation takes on another role beyond the subject matter. Facilitation must also account for the broad subject area and should act as means to facilitate multi-disciplinary working by illustrating how to draw together disparate disciplines and how to utilise peer skills and knowledge in terms of the scenario given and the group make-up:

> *"I think at the beginning A) someone explaining what PBL is properly, which didn't really happen and just how it is going to work, and how it should work, ... But specifically looking at this project to say, given our variety of backgrounds, just here are some things you might want to look at. ... This is a way to approach this problem, here is where you'll find information ... when you're doing this sort of study these are the things you need to consider."* (Participant L)

Students valued the face-to-face contact time they had with the project expert, but wanted more of this facilitation throughout the duration of the exercise with a range of specialist experts, along with more peer-to-peer contact time; mainly to aid in shaping the direction of the projects but also to share knowledge gained and deepen understanding:

> *"just a little bit of support and guidance, even it was tutorial, optional ... it's there and the support's there for some extra learning if you require it. It's a good discussion, it's a debate, ... it gets your thoughts then going." "masters is a different level ... Having that self-learning, I think that's new to a lot of people. ... and that's where maybe those tutorials would have helped" (Participant M)*

> *"there's nothing like sitting together, so you can all air your views at the same time, rather than email which is one person at a time ... I just found it very disjointed and very messy way of doing it. And frustrating."* (Participant I)

These comments illustrate how isolated many of these students felt during the exercise despite working as a group and how facilitation in a tutorial format with a range of experts/ resources would have supported these students, in part by helping them overcome trepidation associated with self-directed learning and by providing a range of disciplinary perspectives (Dahlgren & Öberg, 2001; Hmelo-Silver & Barrows, 2006; Hoffmann & Ritchie, 1997). Use of a tutorial format would also provide an environment which stimulates "students to elaborate on their knowledge" (Schmidt, 1983, p. 12) by asking questions which challenge the learners' thinking and support their intellectual development through scaffolding and extending their zone of proximal development (Savery & Duffy, 1996; Vygotsky, 1978).

It should however be noted the students requirement for facilitation may change as the cohort becomes more accustomed to PBL; "Novice students, with little experience of PBL or prior knowledge, probably benefit from directive and knowledge expert tutors to provide the necessary structure or foundation upon which to build their learning" (Neville, 1999, p. 400). Mpofu, Das, Stewart, Dunn, and Schmidt (1998) illustrated that students inexperienced in PBL placed an importance upon understanding PBL goals/objectives, interaction with a coherent group approach and the facilitator. Once these students were more experienced in PBL the emphasis turns towards understanding PBL goals/objectives and away from facilitation. Perrenet, Bouhuijs, and Smits (2000) also acknowledge the benefits of PBL, especially around motivation and cognitive development, in the early stages. However in a technical subject such as engineering which require complex problem solving and hierarchical knowledge, particularly at later stages, extra support in the form of "separate direct instruction and supervised practice are needed" (p. 356). Fortunately as an instructional approach PBL is highly flexible in terms of guidance levels, which Schmidt, Loyens, Van Gog, and Paas (2007) argue ensures the underlying principles of PBL are compatible with cognitive structures of students.

Provision of more peer contact time, specifically within the middle of the working day, would benefit learning and knowledge transfer as many students did not take the opportunities they had, or were not able arrange further meetings due to scheduling, external pressures and geography:

> *"Because we didn't really have much time in our taught sessions and often because the time would be set aside as 3 o'clock and people would just say well either go home or we stay at the site another hour, so everyone would just be like "oh, I wanna go home"."* (Participant O)

> *"Our group … went from [city to city]. So, you can't meet up, or you don't want to meet up, you haven't got time to. We've all got family commitments, you know, and study time is quite precious."* (Participant I).

Conclusions and Recommendations

The issues aired by many of these students reflect the tensions of studying in an inter-disciplinary, part-time environment, but also suggest generic group work-, as opposed to PBL-specific issues. Specific inter-disciplinary issues emerging include the challenge of heterogenous grouping, especially in the context of perceived status hierarchy based on age and previous experience, as predicted for this case study. The results suggest that many of these issues could be overcome, or ameliorated with more considered group design in terms of participant backgrounds, more detailed scenarios, further explanation of student responsibilities within PBL (e.g. defining parameters), with greater facilitation and consideration of logistics. Table 2 summarises recommended 'good practice' approaches to maximise learning during PBL (and group work) in postgraduate inter-disciplinary science education derived from the current study.

There is very little evidence in the literature of pedagogic studies investigating PBL in inter-disciplinary contexts, especially in complex interactive disciplines such as 'environment and human health' which go beyond established science, technology, engineering and mathematics (STEM) programmes. Recommendations for the effective implementation of PBL in group working environments with individuals from a range of backgrounds, to maximise learning; as generated from this study. The incorporation of natural sciences alongside social sciences necessitates understanding and application of knowledge in complex environmental, social and cultural contexts. However the literature does provide evidence of further benefits of inter-disciplinary PBL within the context of inter-professional learning, and demonstrates additional benefits of PBL around "perceptions of teamwork, collaboration, and positive professional identity" thus supporting professional development (Cusack, O'Donoghue, Butler, Blake, & O'Sullivan, 2012, p. 31).

Nevertheless, the value of inter-disciplinary approaches in tackling complex issues within the multi-disciplinary fields of health and environmental science is widely acknowledged (Gohlke & Portier, 2007; Hrynkow, 2008; Schwartz, 2005) and it has been suggested that they should "become the standard rather than the exception" (Aboelela et al., 2007, p. 343). Inter-disciplinary learning is undoubtedly challenging, even for the most experienced educator, due to conflicts between disciplines in terms of their differing and often opposing epistemologies and ontologies (Kessel et al., 2009), which can result in different vocabularies, attitudes, techniques and even views of reality (Bracken & Oughton, 2006; Jacobs & Frickel, 2009).

Table 2. Checklist for implementing PBL in inter-disciplinary postgraduate science education

The Problem	Implement	Benefit to Teaching and Learning
• Multi-disciplinary working not evident. • Students struggle with scope of project. • Limited knowledge transfer between students	Explain benefits of multi-disciplinary working.	• Allows students to value alternative approaches and place themselves within a multi-disciplinary context.
	Design groups to be multi-disciplinary in terms of student experience (prior education and employment history; knowledge audit specific to PBL exercise), and explain group composition in these terms i.e. what each member brings to the group.	• Creates an appropriate environment to encourage multi-disciplinary working, and provides a diverse knowledge and skills base for the whole group to utilise. • Should increase confidence of each individual by highlighting their unique value to the activity and increase peer learning.
	Design groups to be multi-skilled (skills audit specific to PBL exercise; range of ages), and explain group composition in these terms i.e. what each member brings to the group.	• Allows students to approach the project from a range of disciplinary perspectives and come to a consensus on parameters. • Encourages development and use of multi-disciplinary communication.
	Challenge students to engage in multi-disciplinary working by using a specific PBL scenario. And enforce by using principles of constructive alignment to ensure assessment criteria include multi-disciplinary components.	• Gives students more structure which will help to overcome feelings of needing steering, or not understanding the purpose of the activity. May prevent an individual dominating project direction/parameters. • Ensures multi-disciplinary working.
	Support multi-disciplinary working by providing facilitation with tutors from a diverse backgrounds / disciplines.	• Provides students with an insight to the different disciplinary perspectives, methodologies and data sources which are needed for multi-disciplinary study. • Supports working by providing forums where all disciplinary perspectives can be addressed and consolidated.
	Evaluate level of multi-disciplinary working by requiring students to present out of their own comfort zones e.g. scientists to present social science component.	• Safeguards better transfer of knowledge between students, peer learning and multi-disciplinary understanding.
	Explain PBL as a T&L approach, inclusive of student responsibility in establishing parameters of activity.	• Students understand that they are allowed to focus their project towards perspectives of interest, thereby increasing motivation and ownership of project.
	Increase contact time and place within the working day for group work.	• Increases peer-to-peer engagement, enabling knowledge transfer and supporting multi-disciplinary working.
	Schedule peer meeting sessions before events (e.g. press conference, meeting with project expert).	• Acts as a motivator for students to make continual progress on the project, rather than last-minute working.
	Where possible, group students by geographical location.	• Increases opportunities for further meetings / group work, thereby enhancing peer learning.

As educators on such programmes we should therefore seek to enlighten our students as to the value of inter-disciplinary approaches that embrace and celebrate these different scientific paradigms, ensuring we do not indoctrinate them within a singular paradigm, but allow them to become genuinely inter-disciplinary scientists, regardless of our own backgrounds and doctrines (Phoenix et al., 2013).

Thus, for successful PBL to be established with inter-disciplinary environmental and science education programmes we as educators must first challenge our own prejudices and preconceptions and recognise how we have been indoctrinated into specific disciplines. As inter-disciplinary courses that cross the natural-social science barrier are still emerging we do not yet have educators who have been trained in this way of thinking in a formal educational environment. This suggests that the future development of truly effective trans-disciplinary PBL relies on us as educators broadening our own horizons:

> *"I think that more experiences of this type (i.e. working in inter-disciplinary groups and interacting with the media) are very valuable – I only wish I had had this sort of experience and training during my professional training!"* (Project Expert)

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