Students can experience flow from problem-based learning in Conservation Genetics

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Abstract

Learning in flow is the ultimate experience. Flow means being completely absorbed and focused in the moment. This study investigates the possibility of achieving flow from problem-based learning in students. Problem-based learning was used to teach Conservation Genetics to nineteen undergraduate students. Their perceptions of the learning experience were evaluated using a focus group interview. Four themes were generated: enjoyment of learning activity, cooperation, independent learning and appreciation of learning. Students were thoroughly engaged in the learning activity and simultaneously driven by curiosity and interest of the subject to remain challenged, focused and motivated at the task at hand. Problem-based learning applied in teaching Conservation Genetics influenced enjoyment, an aspect of flow during the learning activity. These findings suggest that the flow experience induced from problem-based learning enhances student learning and appreciation of the subject.

Keywords: problem-based learning, flow, focus groups, students, cognition, Conservation Genetics

1. Problem-based learning

Problem-based learning (PBL) is a teaching model where students learn by facilitated problem solving (Hendricus Gerard Schmidt, 1983; Henk G Schmidt, 1989). Using problem-based learning offers opportunities for students to collaborate with each other and develop critical thinking skills (Pennell & Miles, 2009) and problem-solving abilities (Henk G Schmidt, 1989; Tiwari, Lai, So, & Yuen, 2006). Other reported benefits from problem-based learning include improvement in communication skills, motivation and a wider appreciation of knowledge among students (Duch, 1996; Duch, Groh, & Allen, 2001). Throughout this paper, the abbreviation PBL will be used to refer to problem-based learning.

Depending on the pedagogical design and how teaching occurs, problem-based learning can carry different meanings and generate different educational objectives (Barrows, 1986). A subject area can be adapted to PBL with a little creativity (Duch et al., 2001). In PBL, the instructor takes on the role of an educational facilitator rather than that of an authoritarian role in transmitting knowledge and dispensing facts to students (Maudsley, 1999). Problems used in problem-based learning should not only reflect course learning objectives but also possess a level of complexity that will allow students to apply their knowledge from previous courses and relate solving the problem to real world examples. By solving the problems used in a PBL session, students should feel encouraged to gain deeper understanding and learning of concepts and be confident in the decisions they make in solving the problem (Duch et al., 2001; Kilroy, 2004).

At Monash University in Australia, problem-based learning was incorporated into several courses in the civil engineering degree (Mills & Treagust, 2003). The courses included Hydraulic Engineering, and Water and Wastewater Engineering. Problem-based learning was used to address teaching issues in Engineering such as the lack of design experiences, insufficient integration of technical courses related to industrial practice and the need to incorporate more opportunities to students to develop communication skills and teamwork experience (Williams & Williams, 1994). Results from a survey of second to fourth year students in the engineering degree showed that problem-based learning was well received by students. Students reported positive feedback on using real world applications and the development of technical and problem-solving skills (Hendy, P. L. & Hadgraft, R. G, 2002). Besides engineering, PBL has also been used in other academic areas such as architecture (Maitland, 1997), teacher education (Oberlander & Talbert-Johnson, 2004) and the health sciences (Poulton, Conradi, Kavia, Round, & Hilton, 2009; Savin-Baden et al., 2011).

Several studies have published on PBL in science subjects (Belt, Evans, McCreedy, Overton, & Summerfield, 2002; Dahlgren & Dahlgren, 2002; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Hsieh & Knight, 2008; Padmavathy & Mareesh, 2013; Ram, 1999). Current review of literature related to PBL in science is mostly in favour of this teaching model despite differing interpretations and approaches in research design and analysis (Walker & Leary, 2009). Despite several positive aspects of problem-based learning, it is not without shortcomings, for instance how accurately can instructors gauge students' comprehension of complex science data through problem-based learning, and whether faculty time for instructors to impart factual knowledge to students is at risk during a problem-based learning (Albanese & Mitchell, 1993). Lessons taught in PBL tend to cover less content in class time and may also deviate from the syllabus which is more reliably covered by traditional lectures (Woodward, 1996). Therefore PBL students do face a dilemma of meeting the expectations of covering both sufficient and relevant content (Dahlgren & Dahlgren, 2002). Yet, these students retain a greater proportion of their learning in comparison to their traditionally taught peers (Coulson, 1983; Eisenstaedt, Barry, & Glanz, 1990).

Most of the studies in problem-based learning have focused on pedagogy and the learning process. The relationship of the facilitation of flow in problem-based learning is still understudied. In fact, few studies have discussed student experience of problem-based learning through the concept of flow. While there is evidence in the literature concerning the contribution of both flow (Scherer, 2002) and PBL to students' learning (Kilroy, 2004), it would be interesting to add to the knowledge gap by investigating whether problem-based learning has the potential to induce flow amongst students during the learning process. As such, the aim of this study is to investigate the potential of problem-based learning in inducing flow during the learning process.

2. Flow theory

Flow is a state of optimal human experience where an individual is completely immersed in an activity which is intrinsically enjoyable with a simultaneous integration of concentration, challenge and management of skill at task (M. Csikszentmihalyi, 1990; M. Csikszentmihalyi & Csikszentmihalyi, 1988). Csikszentmihalyi describes flow in nine dimensions: autotelic experience (akin to enjoyment and self-rewarding feeling in the task), clear goals, feedback, balance between challenge and skills, sense of control, loss of self-consciousness and an altered sense of time (M. Csikszentmihalyi, 1990; M. Csikszentmihalyi & Csikszentmihalyi, 1988). Individuals in a state of flow perceive the activity to be almost effortless and in essence, reacts in harmony with the activity akin to being present in the moment where the experience becomes its own reward (Nakamura & Csikszentmihalyi, 2002). Maintaining a balance of challenge and skills is important for flow to occur because when this balance is disrupted, feelings of apathy, boredom or anxiety are likely to be experienced. Individuals in a state of flow seek to continue the activity that brings the experience to them, resulting in a development or improvement of their skills (M. Csikszentmihalyi, 1990; Mihaly Csikszentmihalyi, 1997; Nakamura & Csikszentmihalyi, 2002).

Flow theory is universal and inherently related to learning (Mihaly Csikszentmihalyi, 1997; Shernoff & Csikszentmihalyi, 2009). In the context of flow in education, most published studies agree that students experiencing flow are likely to become engaged in learning and motivated (Ellwood & Abrams, 2018; Raettig & Weger, 2018; Schworm & Holzer, 2018). Despite extensive research in flow, only one study has published on problem-based learning linked to flow experience (Barrett, 2010). Using a critical discourse analysis, Barrett (2010) proposes that the concept of the PBL process as finding and being in flow will encourage instructors' thinking and facilitating of practising PBL in new ways. For students, Barrett argues that the long-term benefits for those who experience flow during problem-based learning are the fostering of thinking and creativity in the learning process which may be extended across a wide range of situations, in higher education and in future employment.

Research in flow has involved both quantitative and qualitative methods. The Experience Sampling Method (ESM) has traditionally been used to gather insights into how people think and feel in their daily life activities (Bechtel & Churchman, 2003; Mihaly Csikszentmihalyi & Larson, 2014). Researchers can also use ESM to obtain empirical data to better understand how people's experiences are shaped (Mihaly Csikszentmihalyi & Larson, 2014). Many studies have researched the psychological states on flow by using the Flow State Scale (Jackson, 1996). Nevertheless, the evaluation of flow from a quantitative perspective differs from that of a qualitative perspective. Quantitative approaches tend to work with facts and values in contrast to the artistic understanding-seeking features of qualitative approaches (Smith, 1983). Thereby this study intends to evaluate the potential attainment of flow by combining inductive and deductive thematic analyses in order to better understand the emotional and cognitive aspects of students during the learning process.

3. Methodology

Participants were nineteen second year undergraduate students enrolled in the Bachelor of Science Zoology programme at the University of Cumbria. The taught module was Conservation Genetics. Following ethical guidelines, written informed consent was obtained from all participants.

The students were randomly divided into four groups. Each group was then randomly assigned a Conservation Genetics problem to identify, solve and share their solutions with their peers in class. The lecturer initiated the PBL session by talking around topics related to the problems and encouraging students to work together on further inquiry into the problem and how answers or solutions could be reached. Each group was encouraged to communicate their answers to the class by taking turns to speak, sharing written work or through visual representations such as PowerPoint slides. The learning process stages undertaken by the students were the following: to identify and select the learning issues in their assigned Conservation Genetics problems, work on the identified learning issues, peer-teach one another, and discuss and deliberate to complete the task given.

A focus group interview (Kitzinger, 1995) was held. The discussion lasted approximately twenty-five minutes and was audio-recorded and transcribed. Data collection was carried out adhering to BERA guidelines (BERA, 2011). Collected data were stored in compliance with the UK Data Protection Act 1998 (ICO, 2015). In this study, data are presented verbatim and should be viewed as illustrative rather than generalisable. The following issues were explored with the undergraduate students: their experience of problem-based learning, the influence of problem-based learning on their perception of Conservation Genetics, and their opinions about the inclusion problem-based learning into their Zoology curricula.

The data was analysed using a hybrid thematic approach of inductive and deductive coding and theme development (Fereday & Muir-Cochrane, 2006; Nowell, Norris, White, & Moules, 2017). Student responses from the focus group interview were transcribed verbatim and subsequently rechecked for possible errors to ensure veracity. Coding of the themes were identified by thorough examination of the transcript by the author and an independent researcher who was blinded to the study. The topic of problem-based learning on Conservation Genetics, data to be coded and rules of interpretation were discussed with the independent researcher. The emerging themes were compared to relevant literature against the backdrop of Csikszentmihalyi's (1990) Theory of Flow as a philosophical framework. There was unanimous agreement between the author and the independent researcher on the themes generated from the data.

4. Findings

All participants in the study perceived the problem-based learning session to be enjoyable and beneficial. Students also described differences between discussions during problem-based learning and the usual lecturer-student discussions held in class. Problem-based learning discussions involved identifying facts, student enquiry and generating ideas related to the problem assigned to them. Students felt that there was more work involved in problem-based learning but believed that learning this way could yield positive results if they put enough effort into it. Students reported an appreciation of Conservation Genetics and a renewed interest in Molecular Biology. Students welcomed the incorporation of problem-based learning into their curricula.

Four main themes were generated from the data:

- Enjoyment of learning activity
- Cooperation
- Independent learning
- Appreciation of learning.

The following themes are introduced using illustrative quotes from the focus group participants to help make the analysis transparent.

Enjoyment of learning activity

Majority of the students reported having enjoyed working together on the problems and learning from each other. Problem-based learning was perceived to be interesting, thought-provoking and engaging.

> *"This was great! Are we doing this again?"*
> *"I liked it, I thought it was good"*

One student mentioned that problem-based learning helped him to relate concepts of Conservation Genetics to pressing conservation issues such as environmental threats faced by endangered animals.

> *"This is better than usual lectures. I found myself thinking of DNA from ospreys and how it could actually be done, can we use feathers…"*

The spontaneous question of DNA from ospreys led to understanding feather keratin and enquiry into using feathers as a source of DNA because it is a non-invasive method of obtaining DNA from birds.

> *"We covered a wide range of topics and it was easier to grasp concepts."*

Students found themselves having to unpick problems when discussing molecular methods used in solving crimes in wildlife. The issue of sharks fin soup served in Asian restaurants came up which led to students discussing whether DNA could be isolated from cooked foods. The act of learning was deemed enjoyable by students in that asking questions about the origins of sharks sold in food markets led to enquiry about the integrity of DNA isolated from cooked or raw foods, whether cooking temperature had any effect on the quantity of DNA available, if a polymerase chain reaction could still take place with the DNA extracted and whether the size of a fragment to be amplified would affect the determination of species which could in turn, shed light on the origin of the food samples. The process of reaching answers through discovery and enquiry was presumably enjoyable to students. They were able to appreciate the many practical applications of DNA testing.

Cooperation

Students commented that it was easier to work on the problems together because they could delegate tasks and share the burden of studies. Cognitive collaboration through problem-based learning offered them opportunities for peer teaching and learning:

> *"It took us less time to put the answers together because someone else was doing something and then we just looked at we found."*

It was interesting to observe students taking charge of their learning. Students were seen explaining things to each other according to how they understood them. Whilst working together on the issues of genetic management of endangered species, they assigned tasks to each other looking at small inbred populations, fragmented populations, the management of gene flow involving translocation of pre-adapted individuals, and the genetic impact on reserve design. This showed students taking responsibility for their own learning and developing their own learning experiences which support independent learning.

One student also mentioned that she needed more time to take notes as some of their peers either spoke too quickly when presenting their solutions to the whole class. This suggested that students needed to improve on presenting within the given time limit.

> *"I couldn't take notes when everyone was talking, it was too quick to do so. It was only possible to take notes from the lecturer writing."*

This suggested that students would benefit from further cooperative and collaborative learning. This would not only involve them in active learning but also allow them to reflect and adjust their progress. For example, thinking about how much time they allowed each person to speak during their discussions, reflecting whether they covered their main learning goals and whether they questioned each other and waited for responses. Students could also individually reflect about their working habits as to whether they contributed sufficiently during group work, if they still needed to improve over the time spent working with their peers, and what else they would need to develop or work on to improve their progress. They recognised the value of cooperation in learning.

Independent learning

Students reported that they learned the subject matter more thoroughly through problem-based learning than the usual lecture- and discussion-based session. Problem-based learning had provided opportunities for students to revisit and reflect on their ideas and solutions.

> *"I learned more about the topic by looking into it."*

This indicated students' comprehension of learning and a willingness to structure their own learning by reflecting on how learning would take place for them. In other words, students controlling the pace and direction of their learning. This theme demonstrated a greater degree of student autonomy even though their lecturer had been involved in facilitating their problem-based learning session.

One student mentioned that problem-based learning helped him to critically think about Conservation Genetics concepts and organise the way in which he should study. Having experienced problem-based learning in class, he said that he felt more confident about the written examination.

> *"This will help in preparing for exams. I could try organising material like this at home when I'm studying."*

This observation was one of thought and reflection in a student that indicated intention of independent self-learning and adopting an alternative strategy of studying. Taking responsibility for their own learning charge of their learning may increase their engagement and enhance their appreciation of the subject.

Appreciation of learning

The problem-based learning session bridged the gap between theory and lab practicals. Some students found themselves discussing molecular methods away from the laboratory and how these methods related to conservation crimes and issues. The author's observations were that the PBL session had facilitated meaningful learning of Conservation Genetics for them, rather than Conservation Genetics being studied as merely scientific information.

> *"PCR [polymerase chain reaction] makes more sense now."*

One student described feeling more confident in studying Conservation Genetics.

> *"I will be able to answer if a question on lab techniques comes up in the exam."*

Another expressed an optimistic view of Molecular Biology. If given the opportunity, he felt that he would be able to learn and excel in the subject.

> *"Maybe I could do a molecular biology dissertation."*

During the PBL session, students were not tested but rather, allowed to generate their questions and develop creative solutions to their questions. Hence, conservation topics discussed became more meaningful to them and they perceived the application of Genetics to Conservation to be purposeful and significant. This optimistic perception of learning Conservation Genetics through PBL where students could conduct study at their own pace indicated that their expressions were appreciative of learning.

5. Discussion and conclusion

This study evaluated student experience of problem-based learning in Conservation Genetics. The first theme generated through the analysis is *Enjoyment of learning activity*. It is an important finding because enjoyment is one of the subjective conditions postulated in Csikszentmihalyi's concept of flow (M. Csikszentmihalyi, 1975; M. Csikszentmihalyi & Csikszentmihalyi, 1988; Mihaly Csikszentmihalyi, 1997). When one enjoys an activity whilst experiencing a balance in challenge and skill, he becomes completely immersed in the activity and is likely to continue engaging in the activity (M. Csikszentmihalyi, 1990). In this study, the students' enjoyment of learning encouraged their further exploration of DNA methods in Conservation Genetics. They wanted to find out more about the topic and their learning involved other issues or queries that came up from the topic in question. In education, flow experience has been examined in music (Bakker, 2005; Custodero, 2002; Fritz & Avsec, 2007), science (Ibáñez, Di Serio, Villarán, & Kloos, 2014), design (Reid & Solomonides, 2007) and physical education (González-Cutre, Sicilia, Moreno, & Fernández-Balboa, 2009). Collectively, these studies suggest the importance of enjoyment in setting a conducive attitude to learning amongst students. If students enjoy learning, their depth of understanding of concepts will increase (Blunsdon, Reed, McNeil, & McEachern, 2003; Prosser & Trigwell, 1999). Students will then be more willing to think critically (Inkelas and Weisman, 2003). The findings of the current study also agree with Blunsdon and colleagues' (2003) that enjoyment occurs prior to learning but can also be conceived as a parallel experience or as a result of learning.

The second theme is *cooperation*. Student interaction in class can either be competitive, individual or collaborative including taking on responsibility for each other's learning (Webb, 1982). Cooperation is a functional component from Johnson and Johnson's (1999) educational theory of cooperative learning which postulates that cooperative learning is achieved when students working together on a shared learning goal. In their study, Khine and colleagues (2017) found that cooperation correlated significantly with student cohesiveness, student involvement and task orientation. Task orientation refers to the extent in which students organise required actions and perform activities involved in solving the problem (Fraser, McRobbie, & Fisher, 1996). This implied that cooperation amongst students was influenced by how well students knew, communicated and connected with each other. Cooperation in turn, influenced how students negotiated problems in class (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Khine, Fraser, Afari, Oo, & Kyaw, 2018). Cooperation amongst students leads to team building (Hansen, 2006; Kagan, 1989) and encourages peer learning, teaching and problem solving (Qin, Johnson, & Johnson, 1995; Tannenbaum, Beard, & Salas, 1992; Topping, 2005). It has the potential to enhance critical thinking (Gokhale, 1995). *Cooperation* in the current study also highlighted issues in the development of presentation skills (J. R. Johnson & Szczupakiewicz, 1987) where students could benefit from learning to control the pace of their presentation to keep time and allow audience interest and responsiveness (MacIntyre, Thivierge and MacDonald, 1997). Previous studies have shown that students in cooperative conditions enjoy learning more than those involved in individualistic learning (D. W. Johnson & Johnson, 1999; R. T. Johnson & Johnson, 1986, 1991; Slavin, 1983). In their game-based civic learning study, Raphael and colleagues (2012) reported that students who experienced high quality cooperative learning also experienced higher levels of flow compared to those who had less cooperation amongst themselves. The relevance of *cooperation* to *enjoyment of learning activity* in this study suggests the compatibility of these themes in problem-based learning. While it may be that students in the current study experienced alternating states between *cooperation* and *enjoyment of learning activity*, the author's observations during the problem-based learning session were that students discussed their self-generated questions and answers, and collaboratively interacted with each other, suggesting simultaneous engagement in both *cooperation* and flow through *enjoyment of learning activity.*

The third theme is *independent learning*. Independent learning involves effective organisation of study material and preparation (Cottrell, 2013; Kember & Gow, 1994). It also paves the way for self-enquiry (Kimmons & Spruiell, 2005) and academic maturity in students (Berzonsky & Kuk, 2005). Students who take responsibility for their learning are likely to achieve better academic performance (van Den Hurk, 2006). Student responses in the current study accentuated the advantage of the PBL session over the usual discussions held in class which was indeed, the process involved in problem-based learning. While usual class discussions revolved around a topic that was being taught, the dynamics of learning during PBL involved students identifying facts, generating ideas and encountering learning issues related to the problem assigned to them (Hmelo-Silver, 2004). This led to students taking charge of their learning and generating self-explanations in solving and understanding the Conservation Genetics problems assigned to them (Chi *et al.*, 1989). In the context of flow, *independent learning* in the current study is synonymous to developing skills, talents or creativity which occurs in individuals who continue to follow their sense of enjoyment in the task they choose to do (M. Csikszentmihalyi, 1990). In the current study, students' experience of enjoyment may have encouraged independent learning by way of their further inquiry and expressed intention of self-studying the Conservation Genetics topics discussed in the problem-based learning session.

The fourth theme is *appreciation of learning*. *Appreciation of learning* has important implications particularly in overcoming barriers to understanding molecular biology concepts linked to conservation (Taylor, 2006). In the current study, students were able to relate Conservation Genetics principles to real life examples of issues and problems encountered in this area of study (Distlehorst, Dawson, Robbs, & Barrows, 2005). Appreciation of the Conservation Genetics module through problem-based learning may encourage self-directed learning traits and motivate students to excel in their studies (Abdullah & Abas, 2011; Albanese & Mitchell, 1993; Walton & Matthews, 1989). When students express appreciation of learning, they are likely to be more engaged in meaningful learning and progression of their studies (Abdullah & Abas, 2011; Brophy, 1999).

The findings of the study suggest that *enjoyment of learning activity, cooperation and independent learning* contribute to *appreciation of learning* (as illustrated in Figure 1). Flow experienced through *enjoyment of learning activity* during the PBL session encouraged students to appreciate, value and seek to learn more of Conservation Genetics. Mohammad-Davoudi and Parpouchi (2016) reported that enjoyment of learning activity correlated with team cooperation in their study of team-based learning environments amongst medical students in Tehran. They found that team cooperation, enjoyment and motivation significantly influenced learning results. Although the current study's analyses did not yield motivation as a theme or evaluate learning results, the findings broadly support Mohammad-Davoudi and Parpouchi's work in linking enjoyment and cooperation in learning. The current study also corroborates the ideas of Covington (1999) who suggested that students were more likely to appreciate learning if they were interested in their subject of study, when they could achieve their study goals and more likely when the reasons for learning were mostly task-oriented. The problem-based learning session was also task-oriented and students had worked together to reach possible answers to the problems posed to them. Brophy (2008) argues that students' appreciation of learning can be fostered with engaging and motivating learning activities and by shaping what they learn in ways that will help them to appreciate the value of their lessons. Instead, this study shows that appreciation of learning may be shaped by students' learning, reflecting, actions and reactions from problem-based learning. Once they show commitment and responsibility to their own learning, they tend to appreciate it more.

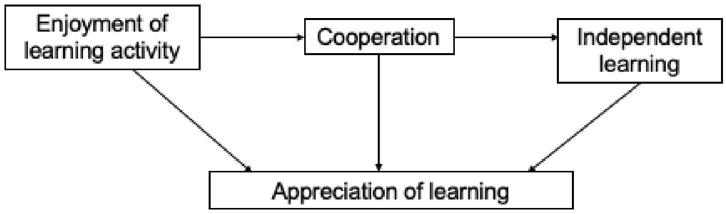

Figure 1. Themes derived from problem-based learning in Conservation Genetics

While the results of the current study are promising, they should be evaluated in light of the study's limitations. Students served as their own controls. Whilst this study focused on the perceptions of undergraduate Zoology students in the delivery of a Conservation Genetics session through problem-based learning, it did not include comparisons with student experience of traditional lecture- and discussion-based instruction. Future research under the same theme could examine the implications of longer term PBL instruction to enable the evaluation of student perceptions over time. Further work could also employ complementary analysis approach in mixed methods (Bazeley, 2017).

To summarise, problem-based learning in Conservation Genetics was well received by the undergraduate Zoology students. Students reported positive outcomes from their experience of problem-based learning. This results discussed in this review show that problem-based learning has the potential to induce flow amongst students during learning. The findings of the current study support the view that problem-based learning is an effective pedagogical approach in teaching and learning, and attainment of flow experience from problem-based learning.

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