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3 authors:

Sarah Naomi Gretton
University of Leicester

Derek Raine
University of Leicester

Craig Bartle
Coventry University

SCAFFOLDING PROBLEM BASED LEARNING WITH MODULE LENGTH PROBLEMS

Sarah Gretton[1], Derek Raine[1] and Craig Bartle[2]
[1]Centre for Interdisciplinary Science, University of Leicester, Leicester, UK
[2]GENIE Centre, Department of Genetics, University of Leicester, Leicester, UK

Abstract:

At the Centre for Interdisciplinary Science (University of Leicester, UK) we have developed an undergraduate programme in Natural Sciences in which the core sciences (biological sciences, chemistry, physics and earth sciences) are taught entirely by Problem Based Learning (PBL) through modules that address inherently interdisciplinary problems. We have found that the extended nature of the research tasks presented by the problems presents various challenges including surface learning, lack of pre-session preparation and an inappropriate division of learning within groups. To address these issues we introduced a number of interventions to scaffold the student activities including less frequent but longer facilitation sessions, pre-session tasks (recommended reading, questions for discussion and detailed learning objectives) and assigned weekly questions. We also introduced facilitation by dedicated trained, subject specific teaching fellows, rather than employing ad hoc graduate teaching assistants, to provide continuity over the programme. We report on the implementation of these interventions and provide quantitative indicating resulted in a statically significant increase in the average module grade. Qualitative data from focus groups with the students indicated that the most significant change was the use of teaching fellows in PBL facilitation.

Keywords: Problem-based learning, scaffolding; natural sciences, interdisciplinarity

INTRODUCTION

The Natural Sciences programme offered by the Centre for Interdisciplinary Science at the University of Leicester is an undergraduate degree in interdisciplinary science. The programme began in 2004 (under the title of Interdisciplinary Science) encompassing content from biology, chemistry, physics and earth sciences. It is innovative in at least two particular respects: the core modules are interdisciplinary in nature (e.g. astrobiology, forensic science, biophysics) and are taught by problem-based learning (PBL).

The core modules in each of the three years of the BSc programme are studied sequentially, each over 5 weeks, through facilitated sessions and informal lectures. Assessment is via coursework (65%, group work and individual) and examination (35%). There are additional support modules (skills, mathematics and computing) and a laboratory programme in all four disciplines.

The PBL pedagogy is *'a student-centred method of teaching in which students learn by investigating real-world problems and, working in groups, seek out the tools necessary to solve them'*. (Raine and Symons, 2012, quoting from the Delaware Institute for the transformation of undergraduate education, ITUE)

The approach has met with varying success in different contexts, although most meta-analyses of the research data conclude that it has positive benefits in terms of long-term retention of learning and transferable skills (Strobel and van Barneveld, 2009). Our experience suggests that the variability may arise from the detailed way in which the PBL methodology is implemented.

BACKGROUND AND FRAMEWORK

Issues in the delivery of the programme

Despite the enthusiasm of its proponents, PBL can present a challenge for some students (Wiznia et al. 2012). The challenges we have found in developing the PBL pedagogy are:

Surface learning and lack of engagement

Unlike in training courses for the professions (medicine, architecture, law etc), it is difficult to find open-ended problems in pure science which define the depth and level of the response. Thus, for example, in a medical degree one might set a problem involving the diagnosis of a particular cancer and a recommendation from the standard approved treatments. In pure science, one might want to look at the cause of cancer, but at what level of detail? In a traditional approach, this would probably be defined in the lecture notes. In undertaking their own research some students disengage fairly close to their "comfort zone".

Satisfaction with first "googled" search term

One consequence is that weaker students are satisfied with the first "googled" search that yields a paragraph which they can understand. This is acceptable within the context of a class facilitation session where the facilitator can probe more deeply, but it can lead to a lot of wasted time between sessions. Increasing the frequency of facilitation sessions to one per day (O'Grady et al., 2012) is not only expensive, but can have the opposite effect in signalling to the stronger students that in depth thought is not required.

Lack of research between classes

Even where students have identified their own learning issues and agreed these with a facilitator, the research between facilitation sessions can result in little acquisition of knowledge, either through excessive "cutting and pasting" or a failure to probe a lack of understanding. Related to this is the "cliff edge" effect whereby extending a student a small extent beyond their comfort zone can produce a very large diminution in performance.

Inappropriate division of learning within groups

Students may divide tasks inappropriately. In order for the sharing of expertise by a group to work effectively in problem-solving, there has to be a shared basis of knowledge which members bring to the group discussions. Unfortunately, while the hierarchy of knowledge may be clear to the facilitator, it may not be so clear to the students. For example, to an expert it is obviously inappropriate to share the task of mastering Newton's three laws one each between three members of the group, but to the group it may seem no different to sharing the analysis of three causes of the first world war. Only the expert knows when parts are connected or independent.

Lack of detailed subject knowledge

Related to all of the above is attention to appropriate detail. This is most clearly found in analytical work where students google answers and not methods, so calculations are something to be looked up rather than executed (or, if really necessary, to be adapted at best by substitution of different numerical values into a formula).

Scaffolding

These issues can were tackled by a number of interventions at the start of the 2010-2011 academic year. Scaffolding provides a structured approach that avoids cognitive overload. It can take various forms but its principal feature is to ensure that the task space is in the student's zone of proximal development. In the classical description of PBL this is provided by the facilitator, in class, through questioning that allows students to identify their learning issues. Unfortunately, in reality, the identification of a learning issue in pure science is a complex task that rarely boils down to a simple label. In practice the complexity is often circumscribed by limiting the place where the issue is being dealt with. What is required is an extended dialogue that leads students step by step to the relevant learning outcome. That extended dialogue however cannot in practice always be supplied by face-to-face contact, or supplied at the right moment. Instead, our approach was to provide guidance to pre-session preparation by specifying recommended textbooks and reading topics. Reading to no identified purpose can be ineffective: students need help in identifying the key content, which should ideally be the content that is directed to the solution of the PBL problem. In pure PBL this would be provided through an exegesis of the learning issues with the help of the facilitator. To support this process we provided suggested questions to guide preparation for the discussion at the facilitated workshop sessions. For each module an extensive list of learning objectives was compiled for students to refer to if they wished.

Finally, we consider the well-explored question of expert or non-expert facilitator (Schmidt and Moust, 1995). Initially, in setting up the programme, we either used staff as facilitators who were knowledgeable about the PBL process but did not generally in the discipline subject matter or available and (mostly) willing postgraduates with relevant discipline knowledge who usually had little experience of PBL beyond a basic training. Neither of these approaches turned out to be satisfactory. Students master the PBL process quite rapidly but need expert guidance in the discipline knowledge. Facilitators need to get to know their students and build a rapport with them in order to provide help with subject knowledge in a useful way, supporting the students' research without doing all the work for them. We therefore moved to a system of dedicated team of teaching fellows, each of which had either completed or undertook a PG Cert in Academic Practise in Higher Education (UK qualification for teaching in higher education). We settled on two facilitation sessions per week, one of two hours and one lasting one hour, using the floating facilitator model (Duch et al., 2001) in which the facilitator rotates between groups during the sessions.

METHOD

Each module is assessed by four individual submissions of answers to set exercises, one or more pieces of group work and an examination (which counts for 35% of the total module mark). The effect of scaffolding was examined by comparing pre and post- scaffolding module marks.

We analysed the module results by comparing the change in grades for those students who experience the change in teaching between years one and two (the 2009-2010 cohort, number of students $N = 13$) in comparison with a group for whom years 1 and 2 were taught in the same way. Because the classes are small, we used for the comparison group both the 2008-2009 cohort ($N = 9$) and the 2010-2011 cohort ($N = 16$), both of which experienced no change in teaching between years 1 and 2.

Student focus groups were conducted to provide qualitative data.

RESULTS

Analysis of the changes in module grades between years one and two for students who had experienced the introduction of scaffolding between years 1 and 2 (the 2009-2010 cohort,) compared to those who experienced no which experienced no change in teaching between years 1 and 2 (2008-2009 and 2010-2011 cohorts) were calculated. The cumulative distributions for the difference between the year averages of the students on their core modules are shown in figure 1. The distinction between the probability functions is apparent and indeed the Kolmogorov-Smirnov test is marginally significant ($P = 0.087$), which is probably as much as we could expect with such small data sets. The conclusion is that the interventions were effective in raising the performance of the students. Although the small numbers make definitive conclusions difficult, there is no significant difference in the *gains* between years 1 and 2 for the 2008-2009 and 2010-2011 cohorts. The higher average marks for the latter cohort (57.4% and 58.0% in years 1 and 2 versus 52.1% and 51.0%) could result from the positive effect of scaffolding or could be a cohort effect.

External evaluations of the programme have provided us with a range of qualitative data to assess the changes, although one must caution that all of our data is based on small numbers of students.

> *[Action on feedback] has included changes to the facilitation arrangements, specifically the change from a broad group to a more limited set of continuing facilitators, partly at least in response to concerns about the variability of facilitation styles. The view [amongst students] was that the new approach will lead to … a stronger sense of how to support [students] in the PBL process* (Unpublished Report by the Centre for Recording Achievement, 29/07/2010)

Both quantitative data and the external qualitative data suggests that the interventions had a positive effect, but they do not tell us which aspects of the changes were the most important. To try to determine this we held several focus groups with the 2009-2010 cohort.

On the introduction of pre-session preparation, we found that students sourced their own reading materials, based on similar titles, rather than relying solely on the specific texts in the reading lists. They also found the suggested discussion questions useful for focussing their reading. Students also made use of the 'Intended Learning Outcomes' as a revision checklist.

On the introduction of feedback sessions for weekly question sets, students liked the sessions but would like all questions covered not just the major difficulties.

However, our conclusion from the focus groups was that the major impact was the use of teaching fellows. Students had more confidence in the teaching fellows' knowledge base and ability to effectively run the sessions:

> *"There's been a change since the first year where the PhD students that were there were just there to make sure we'd do the work rather than assisting and facilitating, whereas now they'll prompt you towards an answer if you're not quite getting it."*

> *"I think facilitation sessions are great... They are a very good way of 'Here's the sort of knowledge you have so discuss it as a group' and we have a facilitator who can help you steer the conversation in the right direction…"*

Interestingly this aligns with the finding of Gibbs (2011) on the effect of extensive use of graduate students and ancillary casual teachers on student engagement in the US.

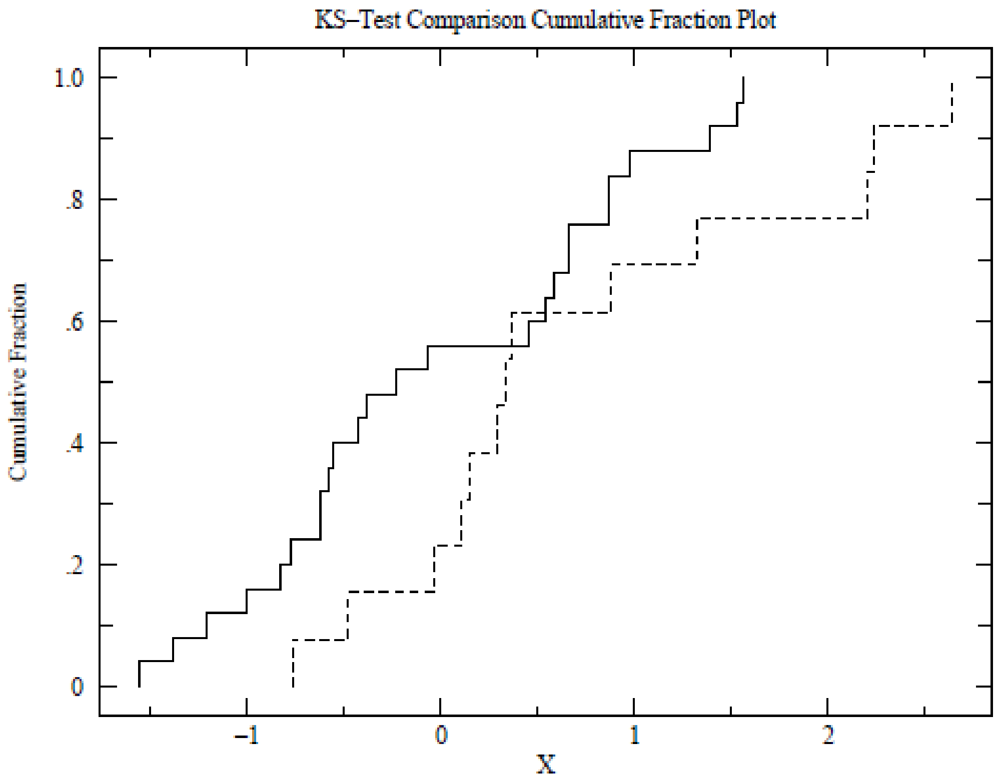

*Figure 1.*Cumulative distributions for average gains between years 1 and 2 for core modules for the 2008-2009 and 2010-2011 cohorts (solid line) and the 2009-2010 cohort (dashed line). The differences are significant at $P = 0.087$.

CONCLUSIONS

The PBL approach does not work for every student: not all students engage, in particular students who maximise their social activities during term and their studies during vacation (Edmonds, 2008). We use an interview to select students for the programme in order to discourage students who feel unwilling to commit to the PBL approach.

Our students are generally positive about the changes in scaffolding. These may seem to some to violate the principles of pure PBL, but we have found them appropriate to an interdisciplinary programme in pure science. Students report that they particularly like the class feedback sessions on submitted work and the use of dedicated teaching fellows in the delivery of the programme.

While it does not distinguish between the effect of employing highly qualified teaching staff and the guidance provided by the detailed documentation (provided by such teachers), our quantitative data suggests that the changes in scaffolding were effective.

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