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# Supporting practitioners in designing and delivering Enquiry-Based Learning activities: A reflective account

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## Abstract

Enquiry-Based Learning (EBL) is a broad term given to learning activities, which require participants to seek and apply knowledge in order to engage with an open-ended task. EBL could find multiple applications in Higher Education and may particularly aid the development of both content knowledge and process skills for those studying Science, Technology, Engineering and Mathematics (STEM) subjects. EBL principles are already embedded in the standards for these subjects in US schools, where a number of initiatives exist to support teachers in designing and delivering EBL activities. Participation in one such programme and subsequent reflection highlighted some issues, which could have implications for Higher Education. The differing approaches adopted by school teachers depending on their interpretation of EBL indicate that a clear definition should be the starting point of any attempt to implement EBL.

**Keywords:** enquiry-based learning, science education, teacher education

## Introduction

It has been suggested that incorporation of Enquiry-Based Learning (EBL) in undergraduate teaching could benefit both students and staff (Kahn and O'Rourke, 2004) and the University of Glasgow has made the adoption of EBL a central theme of its new Learning & Teaching Strategy (Nolan, 2006). Here, reflection on my recent involvement in a project aiming to support US school teachers in development of EBL

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activities for teaching STEM (Science, Technology, Engineering and Mathematics) subjects is drawn upon to explore some of the issues raised by practitioners involved in the design and delivery of EBL.

### *Enquiry-Based Learning*

Kahn and O'Rourke (2004) define EBL as 'learning that is driven by a process of enquiry'. This definition is deliberately broad and encompasses a wide range of activities, which can be applied across any discipline. The key characteristic is that students direct their own investigation of an open-ended task and that the shaping of the enquiry, the finding and processing of relevant information, and the analysis and presentation of the results are all part of the learning experience. These aspects of EBL mean that it has potential to counter many of the perceived problems within our mass Higher Education system by offering meaningful learning experiences to students despite a wide range of knowledge and abilities. The competencies desired by academics and graduate recruiters alike such as team-working, communication skills, initiative and organisation can also be developed by well-designed EBL activities. From a staff point of view, there are opportunities to incorporate topics or skills relevant to individual research interests.

### *Issues in STEM Teaching*

It is often said that STEM teaching lends itself to enquiry-driven approaches particularly well because the scientific method is based upon the principles of enquiry (Uno, 1990). Many would agree that investigating, analysing and explaining are essential scientific tools; however, past educational initiatives based upon the assumption that these skills can be taught without accompanying content and are universally applicable have proved controversial (Hodson, 1996). Equally though, our present system is criticised for overloading students with facts to regurgitate and promoting content knowledge at the expense of independent research skills. Indeed, a study of over 200 academics teaching STEM subjects in Scottish Higher Education institutions concluded that university teachers would welcome a reduction of specific content knowledge in the school science curriculum 'so long as pupils can gain the skills and techniques of science combined with a knowledge of the fundamental underlying principles.' (Coggins, Finlayson and Roach, 2005).

This “content versus process” debate has continued in STEM education for many years (Haefner and Zembal-Saul, 2004) and it seems that a balance must be found in which both vital scientific content and the nature of scientific investigation can be conveyed. Currently, it is expected that the practical component of STEM courses will engender development of process skills as well as reinforcing content knowledge but research has indicated that the closed nature of most practical instruction leads students to focus on completion of the task with little learning taking place (Gunstone *et al*., 1999). EBL alternatives requiring students to seek and apply knowledge in an investigative framework may therefore be of particular value in STEM courses.

### *The role of enquiry in the US school system*

A 1996 report by the National Research Council (NRC) aimed to address similar concerns about STEM standards in US schools and a lack of scientific literacy in the wider public. This placed EBL (often called Inquiry-Based or Inquiry-Led learning in the US) at the centre of STEM teaching and learning and emphasised that enquiry had a role in the development of both process skills and specific content. However as Smith and Anderson report (1999), the teaching of these standards falls to teachers who may well have no experience of EBL and many prospective school teachers feel under-prepared in both the content knowledge and practices associated with STEM subjects.

## The EBL project

The need to support teachers in US schools in developing this STEM knowledge has led to a number of projects, which seek to engage teachers in “hands-on” science (Smith and Anderson, 1999, Haefner and Zembal-Saul, 2004). These courses are based on the principle of “learning by doing” and contend that by engaging in scientific enquiry as students, teachers will build the understanding and confidence to explore similar approaches with their students. I recently had the chance to observe this approach as a workshop leader on a similar initiative in South Carolina.

### *Overview*

A voluntary three-day course was delivered to four groups of approximately fifty elementary and middle school teachers, who were paid a stipend for attendance. The programme was structured so that teachers experienced model lessons for two days in themed workshops before co-teaching some of the same activities to a group of summer school students on the third day. A final activity then gave the teachers the opportunity to supervise a group of students while they completed a group task.

### *Course design and delivery*

The course aimed to fulfil three interrelated purposes. Firstly, to deliver STEM content to increase the teachers' knowledge base, secondly to give them experience of performing science *as* enquiry and an appreciation of the underlying principles, and finally to encourage them to teach these concepts *by* enquiry. The five challenges identified by Edelson, Gordin and Pea, (1999) as requiring to be addressed before students can successfully engage with EBL approaches were taken into account in the course design. These are motivation, accessibility, background knowledge, management and practical considerations. Given that the "students" who would be completing the activities included both teachers with varying levels of experience and students ranging in age from six to sixteen some of these factors were particularly significant. Students and teachers would have to find the topics interesting and have some background knowledge, which they could apply as well as the ability to perform the tasks required by the investigation.

Teachers were asked to suggest the STEM topics they would like to see explored to give them a sense of ownership. Workshops were then designed around these areas to take account of local knowledge and interests, for example using weather phenomena to teach physical science principals in an area beset by extreme weather. Topics were selected which both teachers and students could expect to encounter in the news and find up-to-date resources on easily.

Practical considerations included the time available for the course and the equipment required. All activities were designed to require materials, which could be obtained easily, and cheaply to meet teachers' concerns regarding costs and lack of experience with scientific equipment. The time constraints meant that asking participants to search for background information was impossible, and instead selected resources were provided by the workshop leaders. This 'hybrid' approach (Kahn and O'Rourke, 2004) may not conform to all models of EBL but offers a greater degree of flexibility when circumstances are less than ideal.

In the workshops, a topic such as renewable energy was introduced with a demonstration by the workshop leader and open-ended questioning was used to initiate discussion. In small groups, teachers were then asked to perform an open task, for example making a model wind turbine. Initial time was given to identifying variables, deciding on a design and selecting materials. Selected reading material was provided and workshop leaders were available to provide further information if requested. The results were then used to generate discussion about underlying principles. Opportunities were also provided for teachers to suggest adaptations of the activities to suit their students and fit into their existing teaching, with reference to the NRC standards.

On the third day, teachers were asked to lead small groups of students through the activities, mirroring the workshop leaders' approach. In the morning, teachers and workshop leaders co-presented some of the activities from previous days. These sessions acted as 'staging activities' (Edelson, Gordin and Pea, 1999) in that a relatively structured environment was used to introduce the enquiry-based approach and provide some content knowledge that could be used in a final open-ended activity. For that activity, the workshop leaders provided only introductory instruction and teachers were given responsibility for directing their groups.

The final task required teams to design and build a boat capable of floating and propelling itself along a lane of water. A competitive element was introduced to provide motivation, with the team whose boat travelled furthest winning a prize. Teams were provided with a kit containing basic household materials and a number of propulsion options. Pictures and models of different types of boats and other information relating to the task such as the dimensions of the water lane were placed around the room for consultation throughout the enquiry. Each group was also allowed two opportunities to test the boat's performance and make modifications. This required teams to make and justify design decisions, carry them out and then analyse the results to inform repeats of the process, which is the fundamental basis of design and promotes creative and analytical approaches (Hiley and Johnson, 2003). The need to allocate time for planning, building, testing and modifying also gave teams some insight into the importance of managing the task.

***Observations***

At the start of the course, teachers typically fell into one of two groups similar to the ‘knowers’ and ‘wonderers’ identified by Smith and Anderson (1999). Those who considered themselves to be competent and confident STEM teachers attended because of an enthusiasm for the subject and expected that the course would provide them with new resources and ideas. Less confident teachers tended to view scientific knowledge as a body of information, which they did not understand and expressed views that the course would provide them with knowledge in the form of “correct answers” which they could then teach.

In initial sessions, the more confident teachers were dominant and tended to provide what they thought to be definitive answers. Open-ended questioning was required to direct these groups away from limiting assumptions. Meanwhile the less confident groups believed that other teachers had an advantage over them and would automatically arrive at the “right” solution. These teachers expressed disbelief that they could offer equally valid solutions, and genuine surprise and delight when they were successful. Here the workshop leaders directed the teachers to articulate the reasons for this success, then explore ways in which it could be improved upon. By the final day, it was noted that some of these teachers were challenging the assertions made by the more dominant group.

The differing approaches adopted by teachers when facilitating groups of students were striking. Many used open-ended questions to direct their group and encourage them to revise incorrect assumptions. However some adopted an entirely hands-off approach, believing this to be the way to “get the kids to do it for themselves”. Others gave didactic introductions based on past knowledge and were very resistant to alternative suggestions, particularly during the activities that they had already practised. There was no clear distinction between the teachers who had previously identified themselves as keen on science and those who were not.

During the final task, the open-ended nature of the activity also created some tensions. The decision to include multiple options for propelling the boat had been taken to encourage creative thinking and engage participants in justifying their solution. However some students and teachers were uncomfortable with this degree of flexibility, feeling there to be a “correct” solution, which they were not aware of. The competitive element may have exacerbated this issue, with some teams viewing winning as paramount and feeling threatened by any deviation from what they considered to be the correct interpretation of the rules, for example when teams used the plastic bag their kit had been provided in to make a sail.

Despite these difficulties, all teams successfully completed the challenge. It was clear that both teachers and students enjoyed participating in the activities and were extremely motivated. Groups of teachers and students were seen carrying on discussions over lunch and many wanted to stay longer at the end of the day to continue improving their designs. Teachers who had been previously daunted commented that they “couldn’t wait” to try the activities out with their classes while some of those who had initially doubted that student-led activity could produce meaningful results admitted to being “blown away” by the quality of work produced.

**Issues raised**

These observations suggest that the project was successful in delivering many of its aims, but that future improvement is required to deal with some of the issues raised. Much was achieved in terms of raising teacher confidence and enthusiasm for teaching STEM subjects, with positive feedback received from almost all participants. This also represents a missed opportunity: there was no in-depth study of how attending this course shaped the attitudes and abilities of the teachers. Although there are plans to rectify this in future years, this emphasises the need to build in capacity for robust evaluation from the start.

It was apparent that although participants had been teaching the 1996 NRC standards for some time, few of them had been applying an enquiry-led approach to their teaching. Whether they characterised themselves as keen science teachers or not, almost all instinctively viewed STEM activities as having one correct solution. Many had interpreted EBL as discovery learning (see Hodson, 1996) where students are expected to learn through exploration without any kind of guiding framework. Others were aware of EBL principles but returned to using didactic methods when faced with a familiar teaching situation. Therefore it is not enough to assume that describing EBL standards or even allowing practitioners to briefly experience them as students will equip them to use EBL in teaching.

Perhaps the failure to address all these issues results from the problem of trying to do too much in a short space of time. The workshops were intended to deliver STEM content knowledge in addition to introducing the EBL format, but for workshop leaders it proved difficult to encourage the teachers to arrive at their own conclusions while being viewed as an expert with access to specific knowledge. Trying to adhere to these dual aims probably benefited neither, and instead an explicit decision to sacrifice some content in order to focus on developing enquiry skills should have been made. In future years the scientific content could be reduced to a few key principles, which are reinforced, by a number of activities, rather than each workshop session covering a different topic. This would allow more time to be dedicated to directed reflection and discussion between teachers, which seemed to have the greatest impact on their attitudes and should therefore be viewed as the main focus of each activity. If the purpose of these workshops is clarified in this way, this will also need to be clearly communicated to the teachers in advance and reiterated throughout the programme to ensure there is no mismatch in expectations.

However even if these changes are adopted, it seems unlikely that attendance on one course will be enough to change the practices and views of all teachers. Studies of teachers participating in longer courses have also concluded that although some changes in attitude were observed, these would require further reinforcement (Smith and Anderson, 1999, Haefner and Zembal-Saul, 2004) and while this programme may have been a useful introduction for teachers who would have been put off by a longer course, it should not be viewed as a stand-alone solution. Participating teachers suggested they would value regular opportunities to experience hands-on STEM activities and share good practice as part of their continuing professional development. In the longer term, consideration may need to be given to explicitly developing both STEM content knowledge and enquiry skills in the training of future teachers. This will require STEM practitioners and educators to work together to agree on exactly what these key principles and skills should be.

## Implications for Higher Education

At first glance, activities designed for school-children may have few parallels with university teaching, but producing a course which aims to teach skills as well as content to a group of mixed ability and motivation in a limited time is exactly the situation teachers in Higher Education face. Based on this experience, EBL can offer much to address some of these issues. The learning experience was enjoyable for both teachers and students and allowed a diverse range of topics to be examined on multiple levels. Connections were made between observations and existing knowledge, and investigative skills were reinforced and their importance placed in context.

However this depended on the level of engagement and approach to EBL displayed by those teaching, which was strongly affected by their differing interpretations of the term. Therefore it is important for any institution seeking to encourage adoption of EBL to make explicit their meaning of the term. A broad definition encompassing hybrid approaches could have potential as long as the desired learning outcomes are carefully considered, and it may be the case that choices must be made regarding how much content can be sacrificed in order to facilitate development of more general skills. Finally, although this would provide a useful starting point, this experience has also indicated that a definition alone is not enough, and consideration must be given to providing ongoing opportunities for practitioners to engage in and reflect on the design, delivery and evaluation of EBL approaches.

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