

Inquiry based Learning in Computer Science teaching in Higher Education

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Abstract

This paper considers the role of inquiry based learning in connecting research with teaching in the Higher Education environment, in particular in the case of teaching Computer Science. The way in which technology can enhance and support inquiry based learning is briefly touched upon. Inquiry Based Learning is a topic which is identified with the so called “teaching research nexus”, an issue which has been identified internationally and in particular within the U.K. as of growing importance. Pressures on H.E. education have brought the matter of how research interfaces with undergraduate teaching into the spotlight. Indeed, in 2007 one of the key issues identified by the U.K. Higher Education Academy is the research-teaching nexus. This topic is relevant to the H.E. sector in general, but the focus of this paper is on how inquiry based learning is relevant to and can impact on the teaching of computer science, a subject which is often perceived as focussed on practical and applied knowledge.

Keywords

Inquiry Based Learning; Pedagogy in the teaching of Computer Science; Technology and teaching.

Introduction and context

The so called research-teaching nexus is a term with recognised usage, which encompasses the growing interest and focus on how higher education establishments provide an environment in which students can interface with

research. Inquiry based learning has been identified (Jenkins, 2005) as one way in which institutions can provide an explicit link between their research activity and student education.

This paper begins with a consideration of the similar but distinct approaches to learning, before a more in depth analysis of the role of inquiry based learning within H.E. computing courses. Some examples of practice are also described, along with the role of technology in supporting and delivering inquiry based learning.

Considering the political and economic context of the relation between research and teaching in H.E., there is a perception that the way to explicitly link these is through inquiry (sometimes enquiry) based learning (Jenkins, 2005). Since the U.K. Government white paper (Clarke, 2003) some commentators have characterised universities in the U.K. as being teaching-only universities or research universities. The distinction between them is blurred – as noted in (Nearey, 2007) with the idea of research-informed education which can be implemented in a variety of ways, such as that proposed by Boyer (Boyer, 1998). Whilst the notion of teaching only universities seems to have become prevalent following the white paper, the paper does not refer to them, but did develop the idea of institutions whose main focus was teaching. This has led to many focussing on how research within universities informs and engages with teaching, and how this can be promoted through inquiry based learning in particular. To consider this in detail, the first question is what is inquiry based learning? Inquiry based learning has been defined as (CILASS, 2007) “a process of self-directed inquiry or research”. With that definition, it is hard to think of any U.K. university or discipline which would not expect to use inquiry based learning as the driver for undergraduate learning.

The distinction between inquiry based learning and other approaches to learning - such as problem based learning or project based learning - is in

some respects quite fine. This paper will consider the overlap and distinctions between a number of teaching and learning approaches.

Approaches to learning

There are numerous approaches to learning, and many categories of them. Restricting the consideration to those that seem closest to inquiry based learning, the following summarises some of the typical learning approaches:

- Problem based learning (PBL): often perceived as a constructivist approach to learning (Savery and Duffy, 1995) where the focus is on students solving a problem. Here the learning is anchored around a specific problem and context, and students work from that in identifying what to learn and develop in order to solve the problem. Problem based learning tends to be based around group activity – where the community of learners provide a support during the learning process and can encourage the critical analysis and develop effective problem solving skills which are identified as appropriate learning outcomes.
- Project based learning: learning built around the concept of projects (Thomas, 2000) is another similar concept, where students again work in teams, to develop a project. This is similar to the problem-based approach – indeed in carrying out the project, the students are likely to identify and have to solve numerous problems; however, the focus is on completing the project itself.
- Inquiry (enquiry) based learning shares many of the same characteristics of the first two learning approaches, where students are typically presented with a task to do and have to discover for themselves – with tutor facilitation as appropriate – what knowledge gaps and deficiencies they may have, along with skills they may need to develop. Indeed, in a group context inquiry based learning may be considered as encompassing either of the previous two learning approaches.
- Discovery Learning: the critical notion here is that people learn something new in terms of their existing insight onto the world. The claim is that if they discover a concept for themselves they will have better understanding

of the thing being learnt rather than having third party model foisted upon them. Thus students (often children) develop/discover their own concepts and build upon existing ones that they already have. This has been extensively explored using the programming language LOGO (Papert, 1999). There has been debate about how open ended discovery learning can be and whether it is a good idea simply to abandon users to the fate. This has led to a proposal to have a mixed paradigm where the emphasis is still on discovery but there is now a coach or guide who oversees the learning process (Elsom-Cook, 1990) and ensures that the learning process stay on course.

The characteristics of inquiry based learning may be summarised as learning where

1. The task is based on an open problem – open in the sense that there are numerous approaches to solution;
2. Initially, the student(s) are presented with the problem, and must discover for themselves the nature of the problem, and in particular to identify what knowledge and skills they will need to investigate and develop in order to solve the problem;
3. Where students are required to demonstrate self analysis and critical thinking in order to choose between a number of possible solutions and approaches;
4. Where the teacher or lecturer acts as a facilitator in the process – but avoids simply providing solutions or being prescriptive in approaches.

In a later section some examples of activities which fall into this category will be described.

Inquiry based learning and research universities

There are implicit and explicit ways in which research and scholarship can be seen to influence and link with teaching. The more important of the implicit ways can be considered as the way that carrying out research and scholarship as activities require that the practitioner engage in their own

learning process and investigative processes. This can lead to empathy and understanding with the student perspective, as well as letting the lecturer act as an exemplar of how subject specialists work.

Examples of explicit links between research and teaching are usually where actual content is based on innovations and developments within the establishment's research community, and where students can access research facilities as part of their studies. In the culture of explicit learning objectives and assessment grids, many courses will explicitly detail how the research within a subject links with the teaching of that subject.

One of the drivers for the consideration of inquiry based learning is that it appears to offer ways to explicitly link the research that is generally considered fundamental to H.E. institutions, with the teaching that they provide. Depending on the nature of the tasks that the students are asked to perform – which may be part of a research project, or link with it in some way – there are opportunities for students to engage in activities which directly mirror or are actually part of the research processes that staff carry out.

One caveat is the perception of a growing gap between the education possible by the end of an undergraduate degree, and the knowledge and skills actually required to carry out research. As the knowledge and specialisations within disciplines are growing, many disciplines – in particular within the sciences – have identified this problem. One solution has been the increasingly popular route of integrated masters programmes, which allow students to be trained and developed to a level closer to that believed necessary for research. Examples of these courses include MPhys (Master of Physics), MMath (Master of Mathematics) and MEng (Master of Engineering) courses – the last one including a number of computing courses.

Another consideration is how well inquiry based learning, and other such approaches work in practice. Considered in their purest form, there are misgivings that unstructured learning can lead to no learning (Kirschner,

2006). The proposition of Kirshner et al (Kirschner, 2006) was developed and challenged in a number of subsequent articles - in particular the identification of Inquiry Based Learning with Problem Based Learning (Hmelo, 2007) and the question of what is taught rather than how it is taught (Kuhn, 2007). The reply to these (Kirshner, 2007) reinforces the argument that direct instruction is required to teach the type of information required in modern societies.

The opportunity for students to experience research environments, and the importance of teaching staff who are themselves research aware is something which is under consideration in a number of countries, where a tendency to accumulate research funds and expertise has led to pressures on this specific issue. As a way of characterising and classifying institutions, this becomes a political issue where the nature of university education itself is fundamentally questioned.

Inquiry based learning in a knowledge based and Internet aware environment – the role of technology in supporting learning.

One feature of education – in particular as children progress through the different stages of most education systems – is an apparent decline in the desire and willingness to ask questions. A common complaint within H.E. environments is that students refuse to engage with or enter a dialogue with their teachers, except within structured seminars. However, the rise of the Internet and the World Wide Web have altered the environment outside of the educational world, where children and adults alike carry out inquiry on a regular basis – as typified by the rise in search facilities and knowledge resources such as Google and Wikipedia.

However, this is more of a skill development: how to use technology, how to frame search terms etc. The higher level skills, something that would be expected to be developed within formal studies, and in particular in the context of a computing degree, are the analytical and critical skills to identify reliable sources of information from poor ones, and to provide appropriate

referencing and consideration of the validity and robustness of the information and its meaning.

Technology as a catalyst and platform with which to encourage learning is well acknowledged (Rubin, 1996). Indeed, few schools, colleges or universities would not provide some form of computer resource for students to use. Furthermore, within the IT and computing sciences this provision is essential and the skills to make effective use of this resource is a required skill.

As technologies have developed, students already make common use of social networking sites, online communities along with the information repositories and sources already referred to. As tools for inquiry based learning in particular, other resources can assist students in both identifying and developing knowledge and skills – such as the numerous computer based learning and (self) assessment facilities and other support mechanisms. Allowing students to essentially build their own learning packages in new and more flexible ways offers particular opportunities – both within the context of Inquiry Based Learning, and along other learning styles.

Inquiry based learning and computing

Whilst typical of Project and Problem based learning, focus on the students starting with a project or problem and working forward from that, and similarly with Inquiry Based Learning, in practice there is a much wider context within which the learner is working. This mirrors the reality of research workers, where again the context is usually defined through a prolonged period of education and research on the field of enquiry, to enable the researcher to have a good grounding and be informed on where to start as they investigate and research a topic or problem.

This leads in to the issue of how and when to introduce Inquiry Based Learning within a course. Inquiry based learning is not something unique to

research universities, nor to university education. Indeed, as an approach to teaching it has gained favour within schools and colleges and within many assessment regimes (Kantor D, 2006).

Considered in the context of the previous section, one area where computing courses can expect a majority of students to be prepared for inquiry type skills is with regards to investigation and some elements of research using the Internet. With this in mind, the authors' own experience is that first year computing students can usually start to explore answers to simple problems immediately, where the nature of the problems are mainly knowledge based – and includes finding, and understanding answers to what can appear quite simple questions. By providing a framework within which to investigate, reflect, judge and then have feedback students can begin to develop their critical analysis skills and to begin to consider where assumptions and lack of context can lead to possibly incorrect results. A simple example would be something like:

“What are the possible answers to $11+11$ ” where students may answer 22 (without any requirement for investigation.

Placing more context around the question “In what way could $11+11=100$ and what are other possible answers to $11+11$ ” then the students are required to demonstrate understanding of binary, and in producing an argument to investigate more general number systems. Explaining other possible answers are 22 (for number systems with bases higher than 2), or even 4 (if the symbols are interpreted as Roman numerals 1V).

Moreover, the nature of Computer Science education is such that it is common to include some form of problem or inquiry based learning i.e. present the students with a problem, and a set of tools (applications, code, etc) with which to solve it.

Within the framework of a degree programme, numerous opportunities to allow inquiry and problem type learning – both individual and group – are common, and the lack of identification of particular learning styles may be

more of a consequence of practitioners focus on what they deliver, rather than the pedagogy of that delivery.

Examples of inquiry styles of learning vary from modules with problem solving style coursework – within the context of a modules material, but where frequently students are required to identify and explore outside of the delivered materials. The extent to which they are expected to extend their research outside of the module may partly differentiate inquiry based learning from views of more traditional teaching, but this is a sliding scale and the overlap is extensive. Modules can include examples of project, problem and inquiry learning with all of the benefits that these learning approaches give.

Project based learning is common at level 6 (3rd year of a typical undergraduate course): indeed QAA and accreditation requirements typically expect such content to be included.

Where students are required or expected to carry out a complete research exercise, usually under the supervision of an academic who would be able to act as the mentor within the research and learning process. This exposure to research is something which does distinguish university education from training and other learning environments.

Subject based research provides an excellent opportunity for students to experience their subject beyond the standard techniques and knowledge, and to begin to become aware and familiar with the true subject philosophy, where the paradigms and concepts become more explicit and the critical, analytical and other skills particular to different subjects can be developed in context.

Whilst some view explicit involvement of inquiry into the pedagogy of a subject as outside the notion of inquiry based learning, this seems to limit the scope of such learning. Pedagogy within a discipline – such as computing – focuses on the way that practitioners develop that subject and thus is something that

some students at least should engage with, and which can provide a suitable subject based context within which to use inquiry based learning.

Conclusions

This paper has considered how Inquiry Based Learning compares with other – somewhat similar - learning approaches, and some of the context which has led to widespread interest in this particular learning model.

The paper has also dealt with some of the other contextual issues around this learning approach – in particular the impact of the Internet as a facilitator of inquiry style activities within general society, and in particular for education.

With regard to computing, some of the specific features that make Inquiry Based Learning both appealing and relevant have been identified and appraised.

Inquiry Based Learning seems a natural form of teaching within Higher Education. However, identifying to what extent students are being led – by learning context or explicit tuition – and so are really using this learning style as opposed to others is not an objective decision. Moreover, Inquiry Based Learning is not the only way in which research can – and should – feed into the learning environment for students.

References

Boyer (1998), Reinventing Undergraduate Education: a Blueprint for America's Research Universities, Boyer Commission on Educating Undergraduates in the Research University, Online
<http://naples.cc.sunysb.edu/Pres/boyer.nsf/> (October 2007)

CILASS 2007: Centre for Inquiry-based Learning in the Arts and Social Sciences, Inquiry-based learning (IBL), Online
<http://www.shef.ac.uk/cilass/ibl.html> (accessed October 2007)

Clarke, C (2003), White Paper on The future of higher education, HMSO, 2003

Elsom-Cook, M.(Ed), (1990), Guided Discovery Tutoring: A Framework for ICAI Research, Paul Chapman, London

Jenkins, A. and Healey, M. (2005), Institutional Strategies to Link Teaching and Research, Higher Education Academy, Online
<http://www.heacademy.ac.uk/resources.asp> (accessed October 2007)

Kanter, D, Schreck, (2006), Learning content using complex data in project-based science: An example from high school biology in urban classrooms, *New Directions for Teaching and Learning*, 108 (77)

Khan, P. and O'Rourke, K. (2005). 'Understanding Enquiry-based Learning', In: Barrett, T., Mac Labhrainn, I., Fallon, H. (eds), *Handbook of Enquiry and Problem Based Learning*. Galway, CELT. Online
<http://www.aishe.org/readings/2005-2/contents.html> (accessed October 2007)

Hmelo-Silver, C., Duncan, R., & Chinn, C. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006), *Educational Psychologist*, 42, pp 99-108

Kirschner, P, Sweller, J, Clark, R, (2007), Why minimally guided teaching techniques do not work: A reply to commentaries, *Educational Psychologist*, 42(2), pp 115-121

Kirschner, P, Sweller, J, Clark, R, (2006), Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist,

Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching, Educational Psychologist, 41 (2), pp 75-86.

Kuhn, D., (2007), Is direct instruction the answer to the right question?, Educational Psychologist, 42, pp 109-114

Nearey, M., 2007. Show young scholars a way in. The Times Higher Education Supplement, 14 Dec pp 20

Papert, S. (1999), Mindstorms: Children, Computers, and Powerful Ideas, Perseus Books.

Rubin, A (1996), Educational Technology: Support for Inquiry-Based Learning, In Technology Infusion and school Change, edited by K. Fulton, A. Feldman, et al, Technology Education Research Centre, Cambridge, MA, pp 34–71

Savery, J and Duffy, T (1995), Problem Based Learning: An Instructional Model and Its Constructivist Framework, Educational Technology, 35 (5), pp 31-38

Thomas, J (2000), A REVIEW OF RESEARCH ON PROJECT-BASED LEARNING, Online <http://www.bie.org/tmp/research/researchreviewPBL.pdf> (Accessed Oct 2007)