

Constructive scaffolding for accessible PBL

Situated meta-critique in the classroom

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Abstract—We reflect on the success of embedding legal, social, ethical and professional issues (LSEPI) into computing courses while at the same time encouraging a "growth mindset" in our students. We review the only compulsory course for our first year computing undergraduates, with a broad range of technical ability, impairment and educational background. We chose problem-based learning (PBL) as a natural fit with contextual demands but also paid special attention to the scaffolding required to make PBL effective with novice learners. Our main PBL element is a final "capstone" activity, in which small multidisciplinary teams of students who have not worked together before, design and deliver a Web-based game inside a week, using techniques and technologies seen during the preceding 12 weeks. This paper describes the approaches taken to practical and tutorial learning events and evaluates the results of the PBL phase. The main contributions of this paper are a) the identification of PBL as a vehicle for delivering generic graduate attributes (GGA), b) the use of PBL with novice learners, and c) the use of situated meta-critique as a constructivist trigger for developing self-reflection.

Keywords Problem-based learning, HCI, growth mindset, first year computing undergraduates, situated meta-critique

I. INTRODUCTION

Building on previous work [1] we reflect on the success of embedding legal, social, ethical and professional issues (LSEPI) into technical courses within our School of Computing, while at the same time encouraging a "growth mindset" [2] in our students. In the UK, state funding of universities is contingent on meeting such needs and this is currently referred to as the "Graduate Attributes" agenda [3] and is one of a number of external drivers for curriculum design. Some of these are **mandated** by the UK government through its Quality Assurance Agency and described as Enhancement Themes¹. These are essentially what a university must conform to. Others are **promoted** by professional bodies such as BCS, The Chartered Institute for IT, who accredit degrees towards achieved Chartered Professional status, or trade bodies such as ScotlandIS, IntellectUK or TIGA, who represent the views of employers, and to whom we must react effectively. Lastly there are areas where individual academics, based on their reflective practice and pedagogical research

¹ www.enhancementthemes.ac.uk contains many publications on this topic

interests, can operate ahead of the previous two sets of stakeholders, and the encouragement of a "growth mindset" among students is an example of this proactive approach.

We reflect here on the first three deliveries of a first semester, first year undergraduate course (one sixth of a full year's academic credits). We argue in favor of using PBL to deliver on contextual and discipline-specific demands. We then explore our success in achieving the desired growth mindset, and the extent to which this learning is achieved and retained, reflecting on the notion of "deep learning". First, however, we present some contextual information about the students and the course, before reviewing the literature on problem-based learning, scaffolding to support PBL, and the notion of mindset. We follow this with a description of how we ran the module before reviewing the outcomes and identifying priorities for further development.

II. CONTEXT

A. Learners

"Introduction to Human Computer Interaction", is the only compulsory course for all (typically 200) first year students in the school. These students are diverse - a broad age-range, multiple first languages and nationalities, 10-15% with impairments such as dyslexia or Asperger's syndrome. While most students in a School of Computing anticipate and desire to learn technical subjects, far fewer approach the human aspects of technology with as much enthusiasm. In this module, however, we lay the basis for later work in effective requirements gathering, design, and legal, social, ethical and professional issues (LSEPI). Three years ago, in designing this course, our challenges were to encourage a stronger sense of self-efficacy, to embed basic understanding of LSEPI and to lay the groundwork for achieving the required graduate attributes. At the same time we had to ensure the achievement of the required subject matter learning outcomes. Additionally we had to reverse what was then an unacceptable failure and drop-out rate amongst first year students which stemmed at least partially from a predictable drift in attendance starting around mid-trimester. Our institutional policy of avoiding end-of-trimester examinations for first year undergraduates presented an opportunity to engage in some innovative activities in the final two weeks of the trimester. At that time, the students would be free of any other academic obligations,

and access to dedicated resources would be much easier with all formal classes having come to an end.

III. LITERATURE REVIEW

A. Delivering “graduateness”

In 1964, Justice Potter Stewart ruling in a pornography case in the United States Supreme Court concluded that “I know it when I see it, and the motion picture involved in this case is not [pornography]” ([12]). Since then the phrase has been debated in legal circles and appropriated in many other contexts. It could equally well be applied to the problem of defining what it means to be a university graduate, a debate that has grown increasing more intense over the last few decades.

Australian academics, in particular, have been influential, and Simon Barrie’s considered approach [13] provides an excellent snapshot of academic opinion at the time. Barrie demonstrated a diversity of opinion among Higher Education (HE) teachers as to what constituted generic graduate attributes (GGA). His framework, summarized in Table 1, divided that opinion into four categories, two of which were further labeled “additive” and the other two “transformative”. The additive view of GGA is that they are transferable soft skills which are essentially distinct from any discipline-specific skills that the student might learn during a course of study at university. The transformative view, in contrast, holds that GGA are integrally connected to discipline-specific skills and allow the student to apply those skills more effectively in context.

Table 1: Generic Graduate Attributes [4]

Group	Category	Conception of GGA
Additive	Precursor	Generic skills acquired prior to university entry and therefore in advance of discipline-related skills
	Complement	Distinct and can be acquired independently of discipline-related skills
Transformative	Translate	Facilitate the application of discipline-related skills in the world and acquired in parallel with discipline-related skills
	Enable	Are inextricably linked with discipline-related skills and are acquired at the same time

The diversity of opinion exposed by Barrie, and the challenge in reconciling discipline-specific needs, puts into stark relief the difficulties of attempting to pin down a single list of GGA that all academics would be willing to endorse. Indeed, since the articulation of a classification of perspectives, opinion appears to have diverged rather than converged [14]. Building a consensus around the definition of candidate skills, such as “critical thinking” throws up challenges when cross-disciplinary requirements come into play. Nevertheless, Green et al. [14] provide a strong argument for preferring the transformative view of GGA, which they develop as **specifist** (integrally related to discipline-specific knowledge and skills) and **relativist** (necessarily different from one discipline to another).

Despite the seemingly intractable problem of achieving academic consensus over the definition of GGA, universities are nevertheless under pressure to articulate their approach to

delivering employable graduates. Nowhere is this more clearly exemplified than in Scotland where the Quality Assurance Agency for Higher Education, Scotland (QAAS) maintains a rolling program of work whose aim is the enhancement of the student learning experience in Scotland. Through a series of “enhancement themes” Scottish universities contribute to reflective and developmental projects, the most recent of which, entitled “Graduates for the 21st Century” (G21C) ran between 2008 and 2011. A concluding summary of the G21C theme makes specific reference to need to allow HE institutions and subject disciplines to fine-tune the outputs and approaches [3], and the set of GGA identified during the theme – shown in Figure 1 – is therefore necessarily couched in general terms. The final framework based as it is on current existing practice demonstrates a balance between the managerial need for articulation of goals and the complex nature of the area.



Figure 1: Scottish GGAs [3]

B. Psychological mobility

Several of the attributes identified in [3] are concerned with the graduate’s responsibility for on-going personal development, typified by “lifelong learning”. This growth-oriented perspective, however, is not one that can be assumed to exist in all students and often needs to be actively cultivated during a higher education program.

Indeed, encouraging students to take a “deep” approach to learning rather than a “surface” approach has been a recognized problem for higher education for around 30 years [15]. According to a study at an Australian university [16] school leavers demonstrated a tendency towards a surface approach compared to mature students, and the authors suggest that school leavers may be more syllabus-bound and rely more on rote learning because of their recent secondary school experience. This observation accords well with Perry’s (1970, cited by [17]) finding regarding the development of a student’s conception of knowledge over time. According to Perry, the conception of knowledge shifts through a series of recognizable stages from the dualistic right-or-wrong perspective at one extreme to a commitment within relativism at the other.

In this context, the role of the tutor is to manage the student's transition from a simplistic understanding of the subject through to the more sophisticated understanding expected of the university graduate. However, attempts to modify the learning environment to promote the deep approach have met with mixed results [18]. One explanation for this may lie in the development of the deep/surface distinction articulated by Dweck [19]- that a psychological disposition towards an entity or incremental self-theory can be identified in children as young as 10, and this disposition can be reinforced according to the learning goals they are set during their school years, and the feedback they receive. Those with an entity self-theory, or "fixed mindset", hold the belief that intelligence is fixed, and that learning consists of the accumulation of essentially independent facts, while those espousing the incremental self-theory, or "growth mindset", believe that intelligence is malleable and that learning consists of mastering the subject. Mindset can thus be interpreted as a precursor to a particular approach to learning, and the university tutor may have considerable work to do to instill a growth mindset before a deep approach can be expected to emerge.

Dweck's view is that learners' beliefs about learning, knowledge and their own abilities directly impact their selection of approach to learning, and by extension on the quality of that learning. A similar relationship between beliefs and behavior was articulated by Bandura, in his work on self-efficacy [20]. He hypothesized that a strong sense of self-efficacy – a belief in one's own capabilities to carry out the behavior required to deliver a particular outcome – predicts a greater expenditure of effort to achieve an outcome and the sustaining of that effort over a longer period. Both of these behaviors could be used to characterize a deep approach to learning in a student making sense of subject material. A low sense of self-efficacy in contrast would predict a greater tendency to give up on a difficult task. Dweck [19] calls this the "helpless response" exhibited by students with a fixed mindset compared to the perseverance or "mastery-oriented response" of those with a growth mindset. In his original work, Bandura suggested that self-efficacy could be enhanced by persisting in activities which appeared initially threatening, but which eventually proved to be safe. Studies of self-efficacy among university students have borne out this prediction, indicating that it is not only possible to influence self-efficacy through intervention, but also that the most effective way to do so was through "enactive mastery experiences" [21]. These are experiences in which the student is exposed to apparently difficult tasks in which they can test their own capabilities and experience authentic success.

C. Solution opportunities

Originally pioneered with highly motivated medical students in the 1960s [4], PBL has been adopted more recently by teachers in a range of university-level courses [5] as well as in some high school settings (eg. [6]). As an inherently constructivist approach it promises to encourage high levels of self-efficacy among learners [7]. Although proponents (eg. [8]) claim PBL provides a more engaging alternative to traditional university instruction, the poorly-structured nature of realistic problems leads some (eg. [9] [10]) to suggest that PBL may be less appropriate for learners who have not yet developed a high

degree of self-direction. On the other hand, various forms of scaffolding have been suggested to compensate for the lack of structure (eg. [11]; [6]), and adequate attention to appropriate scaffolding was clearly essential in our application of PBL to novice learners. We saw PBL as a natural fit with disciplinary demands on the one hand and contextual demands on the other. Computing professionals are continually presented with novel, poorly-structured problems in a constantly changing technical environment while externally the generic graduate attributes agenda requires students to develop a reflective, self-directed approach to their own skills development. Other authors have drawn similar conclusions in other disciplines such as engineering for example [22].

The constructivist position casts the tutor's role as that of facilitator while the learner constructs personal knowledge of a subject through experience [22]. Despite debates about the nature of constructivism (e.g. [23]) and a persistent mismatch between teachers' beliefs about constructivism and their actions in the classroom (e.g. [24]), it remains a leading model of academic learning. Much of the debate surrounding constructivism arises from the fact that a theory of learning is not the same thing as a theory of instruction [25]. Unguided discovery learning in which the learner sets the learning goals, pace, process, etc. might be considered the most extreme form of constructivist learning. In this model, a learner typically selects a problem on which to work which then subsequently determines the content of the learning programme. However, this form of problem based learning (PBL) has been shown to be less effective than those which are structured by a tutor (See [25] for references). Proponents of PBL on the other hand argue that scaffolding provided by a tutor is required for successful PBL [26] and that effective pedagogical design centers on the choice and application of appropriate scaffolding for the subject domain. This disagreement suggests the need for a more nuanced approach to PBL such as that offered by Barrows (1986 cited by [27]) which is shown in Fig. 2. For models other than "Pure PBL" which corresponds to Kirschner's undirected learning, scaffolding is provided by the tutor. It should be pointed out that the model in Fig. 2 in which PBL is the broad category which is then subdivided is not the only way of conceptualizing the field. Prince and Felder [28] for example prefer the term *inductive teaching and learning*, in which PBL, as a technique, is contrasted with project-based learning and a number of other approaches. Their arguments correspond closely with those presented here, and in addition they review a number of empirical studies which demonstrate the medium- to long-term benefits of problem- and project-based learning, compared to more traditional ones in the field of engineering.

The term "scaffolding" was originally introduced [28] to describe support activities for children between 3 and 5 trying to solve a puzzle with wooden blocks. The concept is equally applicable to older students working in the zone of proximal development [22] to describe the support provided to enable them to perform tasks they would be unable to do independently. The term is specifically chosen to emphasize the temporary nature of such support so that when the learner has achieved competence, the scaffolding can be removed. Hmelo-Silver et al. [26] discuss a wide range of support that

could be considered scaffolding for PBL which includes traditional lectures as well as other more subjective interactions between learner and tutor.

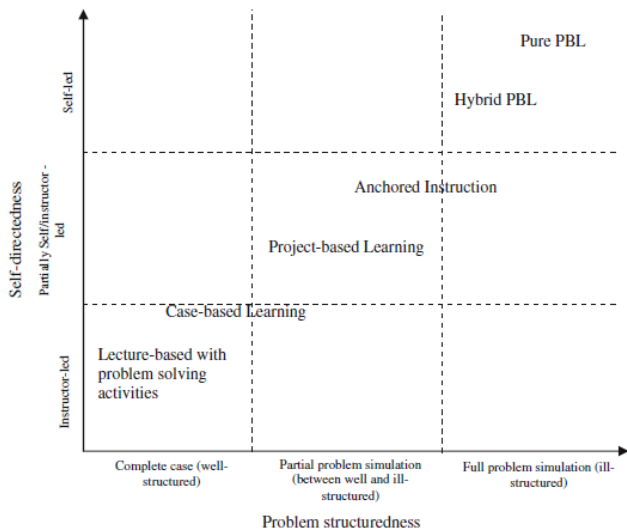


Figure 2. Six representative PBL models in Barrows' PBL taxonomy [27].

In seeking to make sense of the array of scaffolding available, others [29] distinguish between hard scaffolds which are prepared in advance, and soft scaffolds which are situational and ad-hoc. In this classification, lectures are clearly hard scaffolds, and question-and-answer techniques to guide the learner's thinking are soft. However, the distinction does not capture the possibility that some scaffolds may be both planned and situational, such as a problem-specific critique session. A further useful distinction not found in the literature therefore is between preparatory scaffolds and others which are concurrent with the problem-based activity. This leads to a 2x2 matrix shown in Table 2.

Table 2: Scaffolding approaches

	Hard	Soft
Preparatory	Traditional lectures, tutorials, etc	Feedback during tutorials, modelling during practical exercise, etc.
Concurrent	Scheduled group events during the PBL exercise	General ad-hoc support

It should be noted that a particular scaffolding activity (eg. expert modeling of a technical strategy) may feature in more than one quadrant. Thus the model represents a tool for planning PBL activity rather than a static taxonomy of activities.

IV. IMPLEMENTATION

A. Module Design

The approach we took best corresponds to Barrows' *Project Based Learning* in that the main problem-based element was an independent group project which followed a relatively traditional series of learning events. The final project requires

that students work in small multidisciplinary teams of to design and deliver a Web-based game using techniques and technologies seen during the preceding 12 weeks. The problem is of realistic complexity and only loosely structured, thus fulfilling the requirements for a PBL subject. To further add to the realism it is time-limited, and concurrent scaffolding measures are provided as the work progresses.

The first four weeks involve the students learning and applying Benyon's [30] PACT techniques (People carry out Activities in a Context, using Technology), gradually learning about the people-technology system. The middle four weeks involve learning how to give and take criticism of requirements and designs, and to formulate and apply criteria for evaluation. The last four weeks combine learning the formalities of group-work, with some case studies and research technology designed to develop imagination. In parallel students' technical skills are leveled up.

B. Preparatory elements

Of the three main components of the module, only lectures were delivered in an entirely traditional way while a more inductive approach was used in practical sessions and tutorials. The practicals were focused on establishing a minimum skill level with basic Web technologies which could then be relied upon during the project itself. Self-study materials were provided at the beginning of the module, and later a series of staged practical problems and reference material was introduced. Students were instructed to make use of the scheduled practical session to consult with the module tutor, but also to continue working on the practical tasks during private study time. The intention was to instill in students a sense of responsibility for their own skill development, and to encourage the development of personal strategies for information discovery when faced with a novel problem. As expected, some students took this in their stride, while others expressed their frustration in the final module evaluation at the lack of direct step-by-step instruction in the practical stream. This divergence can easily be interpreted as a difference in mindset and self-efficacy.

A hands-on workshop approach was adopted for the tutorials associated with the module. The tutorial classes were large - typically 40-50 - split up into tables of 5-7. Each table tended to have the same groups as the students were in for weekly meetings with their Personal Development Tutor (PDT), and thus were usually all classmates from the same degree course, and with identical timetables. These students tended to know each other well after the first few weeks - a specific goal of our PDT system. In the tutorials, students were asked to put techniques into practice, such as storyboarding, design critique and system specification. The usual format was an introductory stage, which included expert modeling of the technique in question, followed by a staged exercise in which students worked in groups to apply the technique. Each tutorial concluded with a sharing of final results in which each group could see the work of others and could raise issues. Stationery items such as flip chart pads, marker pens and post-it notes were provided to encourage active participation, discussion and the development of final artefacts.

An underlying theme from lectures was the need to be conscious about ways in which documentation communicates ideas and choices to other stakeholders. This is exemplified by a particular tutorial exercise in which groups created and reviewed a system specification. To demonstrate the importance of accuracy and attention to detail, one group prepared the specification for a simple computer-based game using a simple template and a second group provided feedback on the content from the perspective of a development team who would have to implement the application. Finally, the first group had the opportunity to correct and complete their initial specification by responding to the feedback from the second group, before presenting their specification to the rest of the class. In other classes we used a third group to critique both quality of the second group's critique, and the adequacy of the first group's response. Because the exercise allows for several layers of evaluation of one group's input by another in the context of a goal-oriented activity, we refer to this process as "situated meta-critique". As preparation for the final project, the purpose of this type of activity was to emphasize the need for accurate and complete communications when working in a team. The group presentations at the end of the module demonstrated that the majority of project teams had taken this on board and had put considerable effort into their design documentation.

For the final project, teams of five students were constructed according to their specialist subject areas. A typical team would therefore include at least one software engineer, digital media designer and business computing specialist, and some also had computer networking students. Coming from different courses, team members were unlikely to know each other well, and therefore have only the common experience of the HCI module on which to build their working relationship. The approach to team construction actively encourages students to adopt roles within their teams that are appropriate to their own specialisms and therefore imposes a certain degree of reflection on the type of skills that they are supposed to be developing. The project task is to design and implement one of four simple Web-based games for one of four specific target audiences with rich contextual issues to consider (such as off duty soldiers in a war zone, rally car drivers between races, people with limited memory capacity, children in a kindergarten), and is designed to occupy the students on a full-time basis for an entire week (35 hours) in a week when the students have no other classes or assessments due.

The week begins with a workshop session on teamwork during which the students discover with whom they will have to work. The kick-off session and the final presentation of results, at the beginning of the following week, are the only compulsory events related to the project. However, several opt-in sessions are offered to the teams to guide their work. At the start of the project week, a software design workshop specific to each of the games is held during which the software developers from different teams can contribute to the development of a viable application design. These are lively affairs in which there is a good level of active participation from the students. Often though, the first workshop takes the students by surprise and has to be repeated. However, this helps to underline the need to be aware of what is going on.

In the middle of the project week, a series of design critique sessions are run, this time organized around the intended target audience rather than the game itself. This allows the team designers to discuss different ways in which the interface can be adapted to suit a particular group of users. As with the code design sessions, participation is lively.

In addition to these hard concurrent activities, soft concurrent scaffolding is provided in the form of student demonstrators and ad-hoc access to tutors. Teams draw on these resources heavily during the week, and there are always interesting problems to deal with. The ratio of students to tutors during the project is very high (approximately 100:1), and the effect is that teams are forced to focus their questions very specifically. This leads to a demand-led model of support in which students are obliged to take responsibility for identifying, describing and resolving problems.

V. RESULTS

The student attendance stayed reasonably strong throughout the term with at least 75% attending at least one class each week, an improvement on previous years. The pass rates were comparable with other modules as can be seen in Table 3, demonstrating that the PBL approach had no adverse effect on student attainment despite the inexperience of the cohort.

Table 3: Module pass rates

Module	Numbers and pass rate			
	all	pass	fail	pass rate
Introduction to Human Computer Interaction	197	174	21	88%
Being Digital	47	40	7	85%
Digital Imaging	70	59	11	84%
Information Systems in Organisations	150	143	7	95%
Software Development 1	142	133	7	94%

Given the aim of improving student engagement with the material, and the development of self-directed learning skills, comments provided by the students themselves in the end-of-module questionnaire gives a better measure of the success of the module as a whole. Feedback was collected using a standard pro-forma which asks students to rate the module on a five point scale from very poor to very good. In addition, free text comments are invited on the least and most rewarding aspects of the module. Out of a total of 102 questionnaires received, 34 chose to mention the final project in their comments, and of those 29 were positive and only 5 were negative. These results, shown in Table 4, indicate that the approach taken was successful in providing an engaging experience for the majority of students. The following exemplify positive comments about the project:

"Having a physical item (...) to show at the end of the course.

It felt like I had something to show for my effort."

"The intensity of the [project] process felt meaningful and productive. Good professional atmosphere during this time.

Not taken on a task like that before."

The negative comments tended to be less detailed, but two of the more informative focused on the fact that the students already had experience of group work, and therefore learned

nothing new during the project. This perspective could be interpreted as indicating a fixed mindset showing that some work still needs to be done on communicating the rationale to the students. We also plan further support in web-authoring for the practical classes.

Table 4: Student ratings and feedback

	Very good	Good	Neutral	Poor	Very poor
Rating	22	56	22	2	0
Project		29		5	
Practicals		13		26	

VI. CONCLUSION

The available evidence suggests that the course design is generally successful; however, there are specific issues that remain to be dealt with, the students who did not understand the purpose of the final project being one example. Another is the dissatisfaction with the practical element of the module as shown in Table 4. Informed by reflection on the experience so far, the priorities for further development are:

- More scaffolding for practical skill development
- Preparation for tutorial session in the form of expert modeling during lectures
- Further refinement of the general format for tutorial sessions including wider use of situated meta-critique

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