Assessment for learning in engineering design within a project-based framework

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Abstract: *Engineering design courses require students to develop industry relevant design skills. This mandates using technologies and design tools that represent industry trends. Rapid advances in technologies and tools, for example in microelectronics and computer engineering, mean that students must develop independent and lifelong learning skills. This can be a challenge in the context of increasing cultural, language and academic diversity among student cohorts. To address these issues a structured project-based learning methodology has been used in two advanced design courses at the University of South Australia with marked improvement in student satisfaction. A central element of this PBL methodology is student engagement in the summative and formative assessment tasks. These tasks are aimed at providing feedback through active student engagement, whereby students develop a sense of ownership of the feedback generated and the learning that eventuates. This paper first examines some of the issues surrounding assessment strategies in engineering design courses and then describes the assessment strategies used in conjunction with the structured PBL methodology in two courses. The paper also analyses student responses, both formal and informal, as well as their performance.*

Keywords: *Assessment for learning, assessment of projects, student diversity, project-based learning*

Introduction

Assessment is an integral part of learning. Considering assessment tasks merely as mechanisms to evaluate student learning and to award grades violates the principle that the assessment tasks should be aligned with the course objectives (Biggs, 1999). This appears to be a very straightforward statement. However, if the relationships among the course objectives, learning activities and assessment tasks are not well understood then this principle is bound to be overlooked and the value of learning is bound to be diminished. One of the most important issues in the design of learning activities and assessment tasks is the context in which the course is delivered, particularly the academic and cultural diversity of the student cohort. A 'one size fits all approach' to learning and assessment design is surely a recipe for disaster. Good assessment design is responsive to the diverse needs of the student cohorts based on their backgrounds and must clearly lay the interrelationships between the learning activities and assessment tasks. Above all, good assessment design motivates and engages students to learn and reinforces learning (Biggs, 1999).

By and large all engineering design courses have some learning objectives in common. In the author's opinion the most important of them are the development of design skills that are relevant to industry practice and the development of independent learning skills to enable graduates to adapt to rapidly changing technologies and design practices. Being able to think critically and approach new design problems independently are essential elements of becoming an independent learner. In the case of microelectronic circuit and computer design, the development of technologies and design practices is so rapid that without the ability to learn independently and renew design skills continually graduates run the risk of becoming professionally irrelevant. Having said this, the academic diversity of students can be a real challenge for developing independent learning and problem solving abilities unless the learning activities and assessment tasks are designed to actively engage students from diverse backgrounds. This paper presents the author's experience of using assessment strategies in two engineering design courses, namely Computer Hardware Design (CHD) and VLSI (Very Large Scale Integrated circuit) Design with a view to maximise student motivation and engagement. First, the Project-Based Learning (PBL) strategies used are briefly introduced to assist readers in obtaining an appreciation of the context and the issues arising.

Project-based learning

There is perhaps some difference of opinion among educational researchers about what constitutes Problem (or Project)-Based Learning (PBL), with some advocating the use of open ended problems/projects right from the beginning (Hadgraft, 2005) while others advocating a more structured approach initially (Surgenor et al, 2005; Duque et al, 2004). It is important to consider that a 'one approach fits all' strategy may not lead to the desired learning outcomes for diverse cohorts of students. Highly motivated and bright individuals with relevant academic background and generic skills may be capable of pursuing independent investigations into a new (or unfamiliar) problem and approach a complex design project with reasonable degree of confidence. However, while applying the philosophy of 'open-ended projects' to culturally diverse student cohorts with widely varying levels of academic abilities and background knowledge, the author observed many demoralised students struggling with the projects. Some of them did not have adequate background technical knowledge and design skills to pursue the complex projects, while others were not used to conducting independent investigation and problem-solving in a complex (design) project (Aziz et al, 2009). The diverse student cohorts included TAFE graduates, mature age entry and international students. The consequence was a serious lack of motivation, disengagement and dissatisfaction leading to either withdrawal from course or failure. As the author pondered over the need to use challenging and real design projects through which students could develop industry relevant design and problem solving skills, he could see that the lack of preparedness to undertake complex projects meant that many students could not cope with the tasks. Over the last eight years the author has developed and used a structured project-based approach in the CHD and VLSI course to assist the diverse groups of students to develop industry relevant design and independent learning skills. The philosophy is illustrated in Figure 1.

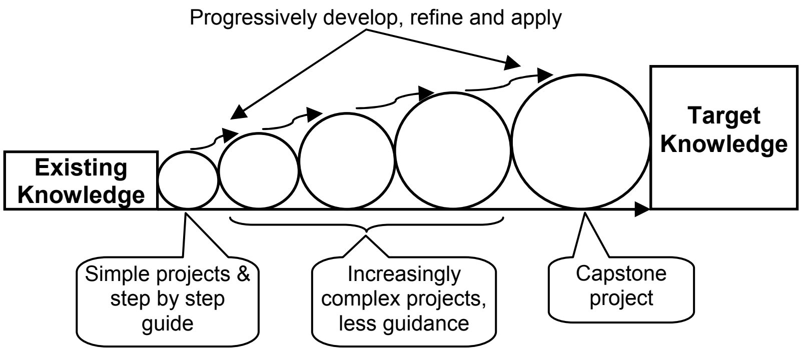

Figure 1: Developing independence through self learning projects

It supports students to build on their existing knowledge by undertaking simple early projects in a self learning manner using well structured guides. As projects get more and more complex, less instructions are provided on how to do them, leading up to the capstone project. High achieving students are encouraged to achieve higher goals at accelerated pace. The important thing to note is that starting at the capstone project may lead to frustration for students who do not have the knowledge, skills and independence that are required, and are developed by doing the earlier projects. An important aspect of this PBL strategy is that students are required to reflect on the knowledge and skills developed through the projects, link them to theory, and refine and apply them in subsequent projects. Thus experiential learning (Kolb, 1984; Boud et al, 1985)) is facilitated by scaffolding the projects, from simple to complex, and stimulating critical thinking, refinement and application of knowledge/skills. The PBL strategy has led to marked improvement in student engagement and satisfaction. In one student's opinion:

- *"The project-based learning was very good, the first project had in depth instructions and it gradually backed off giving us time to adapt to the software and applying the theory"* (Student, VLSI course 2006).

Assessments

Table 1 summarises the learning activities in the two courses and the assessment weights for the summative tasks associated with some of these activities. Whilst the lectures introduce key theoretical concepts, and the tutorials and projects reinforce these concepts, all the activities are aimed at developing knowledge of contemporary design technologies and industry relevant design skills. Therefore, significant weight is placed on the assessment of the projects. Student engagement with the projects and with the assessment tasks therein is emphasised through active learning exercises in the lectures and tutorials. These learning activities provide ample opportunities for self and peer assessment and feedback, and are briefly presented next, before presenting the specific strategies used to engage students with the project assessment tasks.

Table 1: Learning activities and assessments in two design courses

Activity	Summative weight	
	Computer Hardware Design (CHD)	VLSI Design
Projects	45%	40%
Lectures	0%	0%
Tutorials	0%	-
Class test	15%	10%
Final exam	40%	50%

Formative assessments in lectures and tutorials

In both the CHD and the VLSI course the practical projects students do builds on the concepts, design principles and technologies introduced in the lectures/tutorials. The lectures and tutorials also engage students in some of the problem solving tasks required to undertake and successfully complete the design projects. The specific strategies the author has found useful to engage students in the lectures include:

- Summarising key concepts on each topic by asking questions and discussions
- Begin lectures with a summary of the previous lecture, once again by asking questions and discussions
- Short quizzes during lectures (Harwood, 1996)

All of the above strategies are aimed at providing opportunities for thinking, reflection and participating in discussions, thereby facilitating self and peer assessment and feedback. Many students can still remain passive unless prompted by the lecturer in a way that encourages participation. Students need to feel comfortable in responding and participating without the fear of being humiliated. Otherwise they are not going to participate. The author has found that a few encouraging words and a friendly atmosphere is very useful for breaking the ice. It is an atmosphere where students do not feel embarrassed if they get an answer wrong. They should be able to think of the lecturer and fellow students as partners embarked on a common learning journey. This may seem to be a pretty obvious strategy to use, however in reality this type of 'teaching practice' often remain unexplored in the midst of the rush to cover the content. Albeit content is important, however if students aren't engaging with the content then what's the benefit? In the author's opinion when students are responsive and engage effectively with the lectures their learning is enhanced. They are better able to assess their learning. Active student participation enables the teacher to better assess the students' learning, and adjust the contents, activities and pace on an ongoing basis. These strategies have enabled the author to use lectures for ongoing (formative) assessment of student learning and make adjustments as and when necessary. In the last three years students have consistently stated that the above strategies have motivated and engaged them in learning.

- *"(There was a) a friendly atmosphere where the students would enthusiastically participate in the discussions. This was an example of student engagement and collaborative learning at its best",* (Student, CHD and VLSI course, 2007).

Whilst the VLSI course does not have any tutorial activity, the CHD course has weekly tutorials. Low student attendance in the formative tutorial sessions was a concern. The main reason students cited was that they did not find the tutorial sessions interesting because the activities did not engage them deeply with the issues they were facing in their design projects. Starting in 2005 tutorial activities were redesigned as follows:

1. Tutorial handouts with problem solving tasks directly related to the design projects
2. Group problem solving and presentation based tutorial sessions

Detailed design and analysis oriented exercises were developed for some tutorials to provide students with the problem solving, design and analysis skills they need to do the projects. This link between the tutorial exercises and design projects has made some difference in student motivation to engage with the tutorials. Students work in groups on the tutorial exercises before the scheduled weekly sessions. Each group presents their work during the tutorial session. The class participates in discussions following each presentation. The tutor acts as a facilitator, prompting further discussions on critical aspects, emphasising links to the design projects. Students benefit from the presentations and discussions, obtain feedback from the tutor as well as their peers. This strategy has worked quite well for the last four years as is evident from the very positive student responses in the official course evaluations. These strategies have been useful for increasing *student participation* and in fostering *student ownership of learning* as is evident from the following representative comment:

- *"During the tutorial sessions …… we felt that the feedback generated and the learning that occurred was our own creation"* (Student, CHD and VLSI course 2007).

Continuous assessment of projects

UniSA emphasises the use of assessment schemes to enhance student learning, and in particular to assist students in developing *graduate qualities*: namely problem solving, critical thinking, lifelong learning, ethical action and international perspective. The assessment schemes in the CHD and VLSI courses aim to facilitate the development of these qualities. In particular, the PBL approach aims to develop independence, an important skill for students to become lifelong learners and effective problem solvers. In the CHD and VLSI course, while students work in group projects and develop team work skills, every student is expected to demonstrate his/her individual attainment of knowledge, problem solving and design skills. It is critically important to know what the students' think about their learning attainments and whether they perceived the assessment techniques to be helpful for achieving their learning goals. Majority of the students in the above courses expressed the view that the assessment of projects based primarily on written reports would not allow them to demonstrate their attainment of the above skills in a meaningful and engaging manner. Many said that assessment schemes focusing on *face to face demonstration* of the projects and the skills they had developed were most helpful. Indeed, their views were in tune with the author's observation over the years that *face to face assessment* facilitated useful interaction and feedback provision leading to enhanced student learning. In particular, face to face demonstration of group projects enabled the author to ask individual group members to demonstrate parts of the projects and ask questions individually. This enabled the author to differentiate among individual members in terms of their contribution to group work and learning attainment. Therefore, to align the assessment strategies with the objectives of developing the *graduate qualities*, student learning in the projects have been assessed *on a continuing basis* throughout the semester leading to the assessment of the capstone project.

The face to face assessment strategy enabled the author to provide immediate feedback on students' designs and on their progress. This was evidenced in numerous student comments that the direct feedback on their designs and discussions on alternative design styles had helped them to further their understanding.

- *"I found the face to face assessment of projects to be very useful for enhancing my learning as you provided immediate feedback on my designs and answered my questions"* (Student, CHD and VLSI course 2007).

Student evaluation

Both courses have been regularly evaluated anonymously using UniSA's course evaluation instrument (CEI). Table 2 lists four of the ten core evaluation items (questions) in the CEI. Figure 2 shows the percentage of respondents agreeing with these statements for the two courses during 2005-2007. Note that the CHD course wasn't offered in 2006. Clearly both courses ranked very highly in all the evaluation items. In the evaluation of the CHD course, on average 89% of the respondents said that *the assessment tasks were related to the qualities of a UniSA graduate*. In the evaluation of the VLSI course, this figure was 95% in the three year period compared to an average of 64% in the previous two years (2003-2004). Majority of the respondents were satisfied with the feedback they had received. This was largely due to the various interactive formative assessment strategies used during lectures, tutorials and project sessions. The PBL strategies along with the continuing formative and summative assessments in all course activities contributed to the high overall satisfaction with the quality of the courses for consecutive years.

Concluding remarks

The assessment strategies adopted in two courses on integrated circuit design and computer hardware design have been presented in this paper. Both courses use a Project-Based Learning approach where the projects gradually increase in complexity. Early projects are supported by well structured guides to assist students in completing the projects in a self-learning manner. This encourages independent learning for diverse groups of students with widely varying levels of academic backgrounds. As students progress through increasingly complex projects they are required to engage in complex problem solving, design and optimisation tasks using the knowledge and experience gained in the earlier projects. Students are supported in the design projects by a face to face continuous assessment strategy allowing assessment of group and individual attainment, as well as provision for direct feedback on the designs. These are regarded by students as very useful way to enhance their learning within the Project-Based approach. Student engagement and success with the design projects are closely related to the continuing formative assessment activities in lectures and tutorial sessions. Interactive lectures, group activity, presentation and discussion based tutorials were found to be very helpful for engaging students in the Project-Based Learning framework. An important aspect of the approach is the close interrelationships among the various learning activities. Careful design of the tutorial exercises to develop knowledge and skills applicable to the design projects were found to be most helpful.

Table 2: Selected questions from course evaluation

Serial #	Question
Q1	The course enabled me to develop and/or strengthen a number of the qualities of a University of South Australia graduate.
Q2	I have received feedback that is constructive and helpful.
Q3	The assessment tasks were related to the qualities of a University of South Australia graduate.
Q4	Overall I was satisfied with the quality of this course.

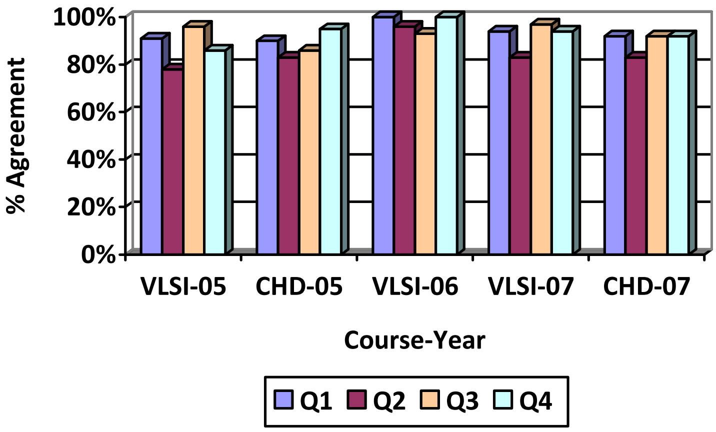

Figure 2: Percentage agreement with the course evaluation statements of Table 2

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