Introducing undergraduate electrical engineering students to reflective practice

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Abstract*: A major feature of engineering courses at Victoria University (VU), Melbourne is a problem-based and work-related approach to student learning aimed at equipping students with both technical competencies and generic employability skills. Engineering courses at VU are accredited by the professional association, Engineers Australia (EA) and thus subscribe to developing in students the competency standards required of graduate engineers.*

This paper reports on student responses in a reflective practice assessment task newly introduced in a unit of study in the Bachelor of Engineering (Electrical and Electronic). The assessment task was comprised of two elements, a self- audit on EA competencies and a guided self reflection on the students' strengths, skills gaps, and improvement strategies. An assessment in reflective practice was instituted because of the considerable literature attesting to the benefit it has for student learning. As Hinett (2002) states, reflective practice enables students to: 1) understand what they already know; 2) identify what they need to know in order to advance understanding of the subject; 3) make sense of new information and feedback in the context of their own experience and 4) guide choices for further learning. Reflective practice is not common in engineering courses and it was believed that this exercise would heighten students' awareness of EA competencies, how they were tracking on attaining them and what they needed to do to improve. This paper reports the preliminary findings of how students responded in their assessments in the first unit of study. Although this is primarily presented as a case study, the responses have been quantitatively and qualitatively analysed. The early findings demonstrate how student perceptions on their proficiencies changed between the start and end of semester; the skills that they felt were most lacking; and the difference in value and accuracy of self-audits compared to guided reflections.

Introduction

A recent review on engineering education has challenged Australian Universities to improve the quality of their engineering programs. The aim of the review was:

> *"To ensure that the engineering education sector across Australia's universities produces in a sustainable manner, a diverse supply of graduates with the appropriate attributes for professional practice and international relevance in the rapidly changing, competitive context of engineering in the 21st Century.*" (King, 2008)

This paper reports on an assessment task in the School of Engineering and Science at Victoria University, Melbourne in which undergraduate engineering students were asked to reflect on their performance on the competencies deemed by their profession to be the "*appropriate attributes for professional practice"* as referenced above by King (2008). The assessment task in the unit of study ENE 2100 Engineering Design and Practice 2A in the Bachelor of Engineering (Electrical and

Electronic Engineering) asked students to audit their skill levels on Engineers Australia's national competency standards and reflect on their progress. A similar assessment was planned for another unit of study in a later semester and although this paper only reports on the first of these, it was thought worthwhile because a number of interesting observations about the students' responses emerged.

The attributes deemed necessary for professional engineering practice can be categorized into two complementary types, the technical and discipline-specific skills required for general and specialized engineering work, and the generic capabilities that enable engineers to serve as effective employees and team members in an organization. A review on engineering education noted that:

> *"Engineers have society's trust in conceiving, designing, implementing, producing, operating, maintaining, and ultimately disposing of physical and information assets, in the forms of infrastructure, systems, products and services. Engineers are thus concerned essentially with creating new futures and solving practical problems, safely and responsibly. Engineering is a key ingredient of innovation."* (Carrick Institute, 2008)

In addition to the specific engineering skills, employers also want graduate engineers to have generic skills such as:

> *"…a combination of in-depth knowledge and up-to-date technical skills in the discipline that they have studied … generic skills including teamwork, problem solving, communication, and the ability to utilise technology and to engage in self-directed learning"* (Business Council of Australia, 2011)

Engineers Australia (EA), the professional association for engineers, has underscored the necessity of these capabilities for both graduate engineers as well those already in the field. EA's National Generic Competency Standards apply to both cohorts. Stage 1 provides a starting point for entry into the profession and Stage 2 serves as the formal pathway to chartered status and/or national registration. As stated by EA:

> *"The Standards cover knowledge, skills and engineering application abilities as well as professional skills, values and attitudes, and provide detailed indicators of attainment for each element of competency. The Standards, by definition, are also the generic template of targeted graduate outcomes for any engineering education program aimed at delivering graduates fit to commence practice in the associated occupational category."* (Engineers Australia, 2011)

VU's engineering courses, which are accredited by EA, are very practice-oriented and strongly feature Problem Based Learning (PBL) and Work Integrated Learning in order to advance the students' technical and generic employability capabilities.

Purpose of Assessment Task

The purpose of the assessment task was to: 1) enable electrical engineering students to specifically become aware of the competencies required of graduate engineers by EA; 2) indicate how they ranked themselves on attaining these skills; 3) enable them to see how their perceptions and proficiencies changed over time; 4) develop strategies to improve their learning and 5) introduce them to reflective practice as tool to aid their learning. Reflective practice was introduced primarily because of the benefit to student learning attested to by the literature. Given that many engineering students at VU (as elsewhere) struggle with their studies it was believed that this learning activity and assessment would serve as a useful tool for students to identify and employ strategies to remedy their learning difficulties. As this first exercise was introduced in the second year of a four-year course, it was seen as providing students with considerable opportunity to tackle difficulties early in their studies. It was also hoped that the development of reflective practice skills would result in students continuing to practice them, whether or not formally required, while at University, and also aspirationally, once in the workforce.

The inclusion of reflection as a student assessment was based on the considerable literature that espouses the benefits of reflective practice. Many professions and educational disciplines, especially those in science, health and medicine, have long adopted this practice, but for engineering education it is a relatively recent and intermittently adopted practice. Research has shown that the major benefit of reflective practice is that it enables learners to make sense of their experiences and develop critical thinking skills which are essential for decision making and problem solving, especially in the workplace (Kolb (1984); Plack, Driscoll, Marquez, Cuppernull, Maring & Greenberg (2007); Boud, Keogh, & Walker (1985)). Duffy (2009) aptly stated that reflection requires '*skills of self awareness, critical analysis, synthesis and evaluation*'. Schön (1983) and Cowan (1997) cited in Jolly (2002) emphasised the reflection and action nexus and Dutton (2003) stressed that it provides students with an opportunity to take responsibility for their own learning. Hinett (2002) cogently captures how reflective practice promotes deep learning and helps learners through: 1) understanding what they already know; 2) identifying what they need to know in order to advance understanding of the subject; 3) making sense of new information and feedback in the context of their own experience; and 4) guiding choices for further learning.

It was not the intention of this exercise to assess the students' capability to reflect but rather to provide a guided forum through which they could begin to make sense of what they felt that they were mastering, what they weren't, and what strategies they might employ to improve their efforts. Students received feedback on their perceptions through written comments made by the teacher which provided them with a point of reference external to their own judgement.

The assessment task was comprised of two components, a self-audit on EA competency standards and a guided reflection in the unit of study ENE2100. These were offered at the beginning of semester 1, year 2 when the unit is introduced and at the end of semester when students have completed the unit.

Although the findings in this paper primarily present as a case study, some quantitative data was gathered from the competency audits and qualitative data was collected from responses to the open-ended reflective questions. A basic statistical analysis was conducted for the audit data and NVIVO, a software program, was utilised for the content analysis of the reflections.

Assessment Task Findings

a. Skills Audit

The audit questionnaire was based on the three categories in EA's Stage 1 Competency Standards: 1) Knowledge and Skills Base; 2) Engineering Ability, and 3) Professional Attributes. Students were asked to rank themselves on each of the 46 component elements of the competencies using the rankings in Table 1 below.

Table 1 Audit Ranking Levels

Ranking Levels	**Unsure whether competent or not** *(I am not certain whether or not I have skills in this area)*	**Not yet competent** *(I have not yet developed skills in this area)*	**Competent** *(I have a solid grasp of the skills required)*	**Very competent** *(I have a high knowledge and proficiency in these skills)*	**Expert** *(I am extremely well informed with an ability to integrate multiple skills in a holistic and seamless manner)*

The ranking levels used in the audit were based on W.C.Howell's Conscious Competence Model demonstrated in Table 2. This framework was selected because it was thought that students would progress through these stages as their perceptions about their proficiency levels changed. Of the progressive stages of learning, Howell's framework can be summarized as:

> *Unconscious incompetence is the stage where you are not even aware that you do not have a particular competence. Conscious incompetence -this is when you know that you want to learn how to do something but you are incompetent at doing it. Conscious competence -this is when you can achieve this particular task but you are very conscious about everything you do. Unconscious competence -this is when you finally master it and you do not even think about what you have such as when you have learned to ride a bike very successfully.* (Howell, 1982)

Table 2 Howell's Conscious Competency Levels (Howell, 1982)

Levels of Awareness	**Unconscious Incompetence** *Not aware of existence or relevance of skill*	**Conscious Incompetence** *Aware of the existence and relevance of the skill, but unable to perform it*	**Conscious Competence** *Ability to perform skill reliably at will*	**Unconscious Competence** *Ability to perform skill without consciously thinking about it – it is "second nature"*	**Reflective Competence** *Mastery of skills based on mature practice and ability to teach others*

Although the original framework was developed in a training context, rather than an educational one, a number of educators have added a fifth level to Howell's four. For the purposes of this paper, the fifth level has been interpreted to denote mature and reflective practice resulting in becoming an expert and being able to teach others.

There were 30 students enrolled in the unit ENE2100, with 26 students completing both the audit and reflection. Each student's response was recorded for each standard and tallied on an individual basis as well as on an aggregated level. However, for the purposes of this paper, only the aggregate findings are reported. Figure 1 shows how the students ranked their proficiency levels in the first two audits and Figure 2 shows the aggregated charted changes.

Audit/Survey No. 1					Audit/Survey No. 2				
Unsure	Not Yet Competent	Competent	Very Competent	Expert	Unsure	Not Yet Competent	Competent	Very Competent	Expert
79	348	558	216	36	22	111	598	417	42

Figure 1: Number of student response for each EA competency standard

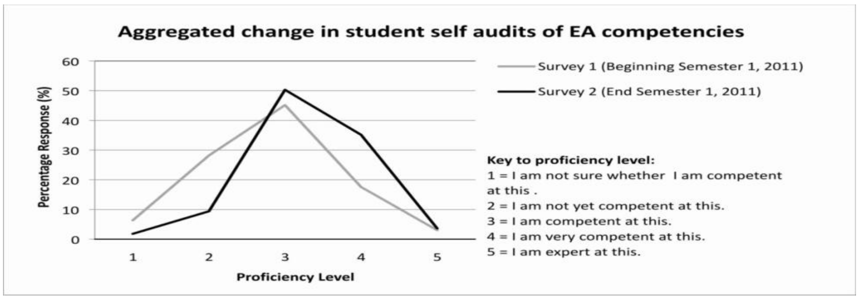

Figure 2: Aggregated change in self audits of competency levels

Figure 1 illustrates a number of things, and in particular that: 1) the "*Competent*" proficiency level was the one referred to most often by most students in both audits; 2) the "*Not Yet Competent*" ranking decreased by two-thirds over the course of the semester; 3) the "*Very Competent*" level was reasonably significant in the first audit and then almost doubled in the second; 4) the "*Expert*" category received as high a response rate in the first audit as it did and that it increased in the second audit; and 5) the "*Unsure*" category response rate declined considerably between the two audits. The improvements in skill level and confidence were expected because this is the anticipated outcome of students progressing though units of study taken during the semester. These perceptions, and reality, of skill improvement is a very positive outcome because it keeps the units of study interesting, rewarding and confidence boosting for students. It is also positive from the teacher's perspective because it may contribute to student engagement, retention and success which are important goals in all years.

The competency standard which ranked the highest "*Unsure*" score was "*Demonstrating intellectual rigour and readiness to tackle new issue in a responsible way*" which is understandable as students at this stage of their learning would not be expected to have grasped what this means. The six competencies most frequently scored as "*Not Yet* Competent" have to do with the intricacies of optimal and creative problem solving techniques and defences; understanding the interactions between technical systems and the social, cultural, environmental, economic and political context; and strong grasp of science. Lack of skill in most of these is not surprising as students have not yet reached the stage in their course where higher order problem solving or how this interacts with the broader context has been addressed. However the lack of science capability is a concern.

The most surprising element in the findings is the number of responses in the "*Very Competent*" and "*Expert*" categories, given that the students had only completed their first year of study. Equating these levels to Howell's framework, the Unconscious Competence level denotes an "*ability to perform a skill without consciously thinking about it*" and the Reflective Competence level prescribes "*mastery of skills based on mature practice and an ability to teach others*". From a teacher's perspective, student claims of this level of expertise are quite astonishing. How then can these claims be explained? A quick examination was made of the student demographics, especially ethnicity, sex and mature-age, to see if there were any indicators amongst these factors, but nothing stood out. Perhaps generalisations about the characteristics of Generation Y can be considered! We have an impression that generation Y is generally confident and ambitious, and perhaps this is what is reflected in these rankings. Another partial explanation could be that the explicit definitions used in this task did not especially resonate with students who may have interpreted the categories as a 1-5 Likert continuum, with the high end indicating "*Excellent*" rather than "*Expert*". The competency that received the most "*Expert*" scores was "*Meeting project deadlines*" and the next was "*Communicating frequently and effectively with other team members*". If students interpreted "*Expert*" as "*Excellent*" then this result offers a reasonable explanation. Other possible partial explanations might include: that they didn't really understand the categories very well; were hasty in their responses or truly thought that they were indeed that competent. Immaturity and inexperience, especially with self-assessment might have also played a role in this "over-rating.' Interestingly, this claim for superiority or over-rating did not appear in the students' reflections, even though they had scope to make equally bold claims. This may point to the fact that a tick-box self-audit does not hold as much value, and is not necessarily as accurate an indicator of skill level as is a guided, open-ended reflection. The sheer number of EA competencies … 46 in all, also appeared to diminish the audit's effectiveness as a diagnostic tool.

b. Reflection

There were two audits and two reflections for the unit of study, one at the beginning of the semester and the others at the end. The first reflective exercise provide three questions to guide the students' responses and asked: 1) what their thoughts were about the level of skill they currently have on the EA competencies; 2) which skills they wished to develop or improve upon; and 3) how they intended to go about this. The questions in the reflection that followed at the end of semester were designed to enable students to reflect more deeply on their level of competence, the changes they observed and how they accounted for these changes. They were also asked to develop a plan to address the improvements that they wanted to make. These questions captured the student learning that Hinett (2002) attributed to reflective practice. Students were free to answer the open-ended reflection questions in as much detail as they wished, using their own terms and phrases. In general the responses were thoughtful and often insightful and provided valuable information to the teacher about the students' struggles and strategies for overcoming them. The comments and tone of the responses also indicated that the exercise proved enlightening for the students themselves. In addition to the questions guiding their reflection, students were asked what grade they anticipated receiving for the unit. This was included so that students could have some measure of their perception with that of the teacher.

The responses were aggregated and coded and a content analysis was then conducted utlising NVIVO™ . There is no scope in this paper to examine the responses for all the reflection questions so only the responses for the skills gaps are tabled below.

Skills students wished to develop	Number of students who identified gaps in skills	
	Survey 1	Survey 2
Time management / organizing skills	12	11
Writing skills	14	9
Oral communication and presentation skills	11	12
Programming (Micro C and other)	8	11
Knowledge of science and engineering fundamentals	5	7
Maths	5	5

Figure 3: Skills gaps identified in student reflections

The numbers in each column represent the number of students who identified particular skills that they wished to develop and only those with more than five responses have been presented. It is interesting to note that students recognized the importance of both technical skills and generic skills. Self study skills and proficiency in oral and written communication ranked as the largest skills gaps. These are skills which employers want so it is good that students recognize their importance. Time management and organizing skills can be viewed as self study skills and these are important, not only for success at University but later as a part of continuous professional development in the workforce

The most significant change in the responses was the improvement in writing skills. This has been attributed to the support provided by a Language and Communications Advisor who met with student teams on a weekly basis. As to the increased deficiency in programming skills (Micro C and others), this may be influenced, in part, by the demands of a linked unit, ENE2102 Digital and Computer

Systems (Programming). In this case, although students felt that they had improved their programming skills they became much more cognizant of what proficiency in a skill actually entails. These comments were also true of other skills. As stated by a few students:

> *"This semester has given me a good idea of my limitations in programming, and [it] is something that I plan to develop further."*
> *"I would still like to improve on my time management because even though it has improved it is still one of my weaker skills."*
> *"My skills over the semester have improved, but also my understanding of my abilities…"*

In general, the reflections indicated that students had a much more grounded appraisal of their skill levels than what was illustrated in the audit. This may have been due to students honing in on the most pressing skills and the most visible gaps. Interestingly, a lack of math skills featured in a number of reflections but were virtually absent as a deficiency in the audit, further indication that reflection appears to be a more valuable and accurate skills assessment mechanism than a prescribed tick-box self-audit.

As stated earlier, the students were asked in their second reflection what grade they anticipated (recorded at a time when they had received only 25% of their assessment marks). Fifty percent of the students received the grade that they expected, 23% received one grade higher than anticipated, 23% received one grade lower. Interestingly the grades received by the students who checked off a high number of "*Expert*" ranks were a mixed group ranging from the student who attained the highest numerical score (> 90%) to a number of students who received a little more than a pass (~50 -60 %). A number of these students also received a grade lower than they anticipated which tends to suggest that they had a general tendency to over-rate their skills. However, most students were relatively on target in assessing their overall capabilities in the unit as a whole, which is encouraging.

Conclusion

This paper reports on preliminary findings emanating from an analysis of a reflective practice assessment task administered to electrical engineering students in a unit of study in their second year. Reflective practice is not common in engineering curriculum and the introduction of such an assessment task was aimed at: 1) enabling students to specifically become aware of the competencies required of graduate engineers by their professional association, Engineers Australia; 2) indicating how they ranked themselves on attaining these skills; 3) enabling them to see how their perceptions and proficiencies changed over time; 4) encouraging them to develop strategies to improve their learning and 5) introducing them to reflective practice as tool to aid their learning. The reflective exercise was introduced to a group of VU's engineering students because of the considerable literature and long-term practice in many educational fields and professions attesting to its benefits.

Improving student learning in VU's engineering courses is the goal of the University, its teachers and the students. It is also the goal of Engineers Australia and employers more broadly. Graduate engineers are expected to leave University with a complement of sound technical skills as well as all-round generic capabilities. The introduction of a reflective assessment was a means to make students more aware of the competencies required of graduate engineers, plus provide them with a learning mechanism to identify gaps in their skills and devise strategies to address them. The reflective assessment was composed of two elements, a self audit on EA competencies and a guided reflection in which students wrote about their skills were progressing, identified difficulties and designed strategies to overcome them. The skills audit provided students with the opportunity to heighten their awareness of EA competencies but was not entirely effective in honing in on deficiencies. The guided reflection proved to be a much more effective tool. A sound ability to reflect and accurately self assess is a valuable skill for engineers and the early findings in this paper illustrates that students in their second year of study have mixed self awareness and capability in this area. The next stage of this study will continue with the reflective assessment, administered to the same student cohort, but in a new unit of study in the upcoming semester. The assessment will comprise the same skills-audit but with more advanced reflection questions which will then provide for a comprehensive comparison and analysis.

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