Developing competence portfolios in engineering undergraduates

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This evaluation aimed to identify the student view of activities based around engineering graduate attributes and the presentation of these to potential employers. This included the introduction of an ePortfolio, activities to identify students' strengths and a reflection framework to help students analyse their strengths. Students are required to do work experience throughout this degree. It was thought that this would motivate the students to collect evidence of their strengths so they could present them to potential employers. Overall the ePortfolio activities had a limited impact. The evaluation collected evidence about the ePortfolio aided activities and the barriers and enablers to students learning. The questionnaire had a section to identify the level of student reflective thinking. Students who were straight from school had a similar level of reflective thinking to older students.

Keywords: Engineering, graduate attributes, ePortfolio, e-portfolio, reflection

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Introduction

The paper focused on a sample of first year students studying the Bachelor of Engineering with Honours [BE(Hons)] degree at a New Zealand (NZ) University. The BE(Hons) consists of 13 different majors that are designed to focus on certain disciplines and are accredited with the Institution of Professional Engineers New Zealand (IPENZ). The common majors that this class planned to graduate in were, in order of popularity: Mechatronics, Electronics and Computer Systems, Industrial Automation, Software, Product Development, and Telecommunications and Network Engineering.

IPENZ represents the engineering profession in NZ and is the Registration Authority for professional engineers in NZ. IPENZ is responsible for ensuring that accredited engineering programmes produce graduates who have acquired the expected academic capabilities and meet the requirements of the international Accords to which IPENZ is a signatory. For the engineering profession this is an important step as it is a basis for international comparability and graduate mobility (IPENZ, 2006).

The BE(Hons) has a prescribed set of papers that ensures graduates meet the graduate capability profile stipulated by IPENZ; essentially competencies that describe what students are expected to know or be able to do at the completion of the programme. Table 1 shows IPENZ's graduate capability profile.

In addition to ensuring the BE(Hons) graduates meet this profile students must augment their study at the University by 900 hours of approved employment in relevant organisations, which is termed practical work experience. Practical work experience is normally full time work, completed in three (300 hour) periods, in preferably three different work environments. It is normally carried out during the summer vacation periods. The practical work periods are undertaken after the completion of the first, second and third years.

The graduates of the BE(Hons) are at the beginning of their career. As a graduate engineer the next step is to meet professional competence. This occurs over a period of 4 to 5 years of on-the-job learning and professional development activities to progressively develop the competencies of competent engineering practitioners (which could mean achieving Chartered Engineer status). An engineer must prove that they have met this professional competence by developing a Graduate Development Portfolio. To build a portfolio graduates are required to keep records of work history, continuing professional development and a reflective review of how they've achieved the professional competence standards. The ability to produce reflective accounts of the competencies a graduate obtains whilst undertaking any major work project or encountering difficulties at work is an important skill to ensure that they become a professional engineer.

Table 1: IPENZ graduate capability profile for professional engineers

1. **Understand and apply** mathematical and engineering sciences to one or more of the broad, general engineering disciplines
2. **Formulate and solve** models that predict the behaviour of part or all of complex engineering systems, using first principles of the fundamental engineering sciences and mathematics synthesise and demonstrate the efficacy of solutions to part or all of complex engineering problems
3. **Synthesise and demonstrate** the efficacy of solutions to part or all of complex engineering problems
4. **Recognise** when further information is needed and be able to find it by identifying, evaluating and drawing conclusions from all pertinent sources of information, and by designing and carrying out experiments
5. **Understand the accepted methods** of dealing with uncertainty (such as safety factors) and the limitations of the applicability of methods of design and analysis and identify, evaluate and manage the physical risks in complex engineering problems
6. **Function effectively** in a team by working co-operatively with the capacity to become a leader or manager
7. **Communicate effectively**, comprehending and writing effective reports and design documentation, summarising information, making effective oral presentations and giving and receiving clear oral instructions
8. **Understand the role of engineers** and their responsibility to society by demonstrating an understanding of the general responsibilities of a professional engineer
9. **Understand and apply project and business management**, recognising and using the appropriate project and business management principles and tools for complex engineering problems
10. **Demonstrate competence in the practical art of engineering in their area of specialisation** by showing in design an understanding of the practical methods for the construction and maintenance of engineering products, and using modern calculation and design tools competently for complex engineering problems

As graduates must possess self reflection and portfolio development skills the authors questioned how undergraduates could achieve these skills, so that by graduation it is an easy transition for a graduate to begin building their Graduate Professional Portfolio. The authors decided to trial the use of ePortfolios as a way to support students as they move towards obtaining the skills and attributes required for professional engineers. This trial is in the first year. Each student has been given the opportunity to develop an ePortfolio over the 2009 academic year. It is envisaged that ePortfolios will help students:

- develop study skills that are needed at University and in their professional work
- to reflect on their experience and identify goals they need to achieve
- collect evidence about the skills they are developing

It is also envisaged that by using an ePortfolio to document their work and skill attainment it will make it much easier for students to create a curriculum vitae that will impress potential employers and help them gain practical work experience over the forthcoming summer period.

This is a case study on the implementation of ePortfolio activities that intended to develop graduate attributes. The study aimed to identify the impact of the ePortfolios on engineering students' understanding of developing themselves towards achieving specific graduate attributes and ways to improve the implementation. Part of the study was to identify the extent of students' reflective thinking. The analysis compared students who were straight from school with older students. It was hypothesized that older students would have higher scores for understanding, reflection and critical reflection.

How to implement ePortfolios

There are good reasons for students to use ePortfolios. They have been used successfully in engineering education (Blicblau, 2008; Campbell & Schmidt, 2005) and have been used to help students understand engineering graduate attributes (Palmer & Hall, 2006). Campbell and Schmidt (2005) outline a number of benefits of ePortfolios including providing students with a way to store work so the students can identify their development over time; ePortfolios help students reflect on their development over time; and ePortfolios can showcase student work to potential employers. In the current study students were given a number of opportunities to use ePortfolios. For example students were asked to consider which graduate attribute they were good at and collect evidence of these strengths in an ePortfolio. Collecting evidence and reflecting on it could help the students develop their strengths and help them get work placements which are a requirement for the degree.

Advice in the literature offers direction on implementing ePortfolios. Butler (2006) outlines success criteria that are listed in Table 8, and similar advice is provided by the Australian ePortfolio Project (2009a) and JISC (2008). This implementation was guided by questions on pedagogy, administration, and support for staff and students (Milne & Heinrich, 2009). An outline of the success of this implementation is presented in the results section.

There is debate about the need to assess ePortfolios (Mossop & Senior, 2008, Stefani, Mason, & Pegler, 2007, Chapter 5). In a survey of lecturers at an Australian University about one third of the examples of ePortfolio use did not have an assessed component (Australian ePortfolio Project, 2009b).
JISC 2008 found that students are more likely to respond to ePortfolios if they are assessed. Students state that a lack of time is a large barrier to using ePortfolio. Other activities, which are assessed, may cause students to assign less priority to those that are not.

A review of ePortfolio use in medical education found effective use required careful implementation into the curriculum with support for teaching staff and students (Driessen, Van Tartwijk, Van Der Vleuten, & Wass, 2007). Their review found that where portfolios were not formally assessed use tailed off as the student prioritised other summative assessments. They identified that portfolios should be part of the assessment procedures.

Some students do not recognise the value of reflection in their learning even when it is a well implemented part of a course (Hedberg, 2009; Heinrich, Bhattacharya & Rayudu, 2007). Students can find reflection difficult as it can be complex and requires concentrated attention. Some students think that they do it already in their heads and do not need to use a more structured approach that requires time and effort. Some students value traditional approaches to learning and do not see the relevance of reflection (Moon, 1999). To help students recognise the value requires careful planning to ensure that students are clear on the benefits they are likely to get and they are well supported in their use.

Methods

Students in the course were given a number of opportunities to use an ePortfolio to develop their graduate attributes.

During the first week of semester 1 the authors gave a presentation that outlined:

- Contextualising the BE(Hons) within the engineering profession and what it means to be a professional engineer
- An introduction to IPENZ's Graduate Capability Profile
- The requirements of practical work experience and the importance of building evidence throughout 2009 to demonstrate their capabilities to employers
- A list of top 10 skills and attributes that employers want in a graduate (Vic Careers, 2006). These are: strong interpersonal skills, strong verbal communication skills, strong written communication skills, flexible and adaptable "can do" attitude, sound academic achievement, self- motivated/self- starter, team player, energy and enthusiasm, problem solving skills, and analytical and conceptual skills.

In this session students were shown: examples of ePortfolios and their benefits, quotes from employers saying that they would value an ePortfolio and examples of how an ePortfolio would help them in their learning. Students were also given exercises that allowed them to experience focusing on strengths and providing evidence for that strength.

The students were then asked to set up their own ePortfolio and discuss a strength that is either associated with the IPENZ Graduate Capability Profile or the Graduates' skills employers seek. Setting up their ePortfolio was an optional activity and it was not assessed.
After three weeks only 16 students from a class of 66 had set up an ePortfolio. As the response was sluggish an email was sent to the class re-emphasising the benefits of generating an ePortfolio and the

additional support they would get from the authors in preparing for their practical work experience. This had no effect on the take-up of ePortfolio.

The authors decided on another route of implementation which was to focus the trial on the 16 students who had engaged initially. These students were invited to a free lunch where support would be given to help develop their ePortfolios further. After many attempts to arrange this (as many students did not bother to respond to any emails) only 4 students turned up.

The authors were quite surprised by the lack of interest so decided to seek an understanding of this non-engagement. The authors arranged another session with the students to reiterate the benefits of ePortfolios and to discuss the reasons behind the lack of engagement. Students were also invited to complete an anonymous questionnaire about their experiences. There were 66 students in the class of whom 39 students returned the questionnaire. Three questionnaires were incomplete but were included for the questions where data was supplied.

The questionnaire aimed to identify the impact of the ePortfolio activities and ways to improve the implementation. Part of the questionnaire identified the level of the students' reflective thinking, as this could be a barrier to uptake and needed further investigation (Heinrich et al. 2007). The analysis compared students who were straight from school with older students. This was a first year course with most students coming straight from school. There were 10 older students; seven had a one year gap with three having up to a five year gap since school. The means were compared with a one-tailed, two sample equal variance t-test.

Results

Students were asked to list three attributes of graduate engineers. Overall the respondents struggled to answer this question. Of the thirty nine returned questionnaires, twelve respondents gave three correct attributes, nine respondents listed three but some were incorrect and eighteen listed less than three attributes.

The most common attributes listed were problems solving skills, communication, team working and leadership skills (Table 2).

Table 2: Attributes of graduate engineers listed by respondents (number of respondents)

Problem solving skills	11
Communication	11
Ability to work in a team	7
Leadership skills	6
Subject specific knowledge	5
Flexible, reliable, committed	5
Creative	4
Practical	2
Confident	2
Logical	2

Most of the respondents think that graduate attributes are important (Table 3, Q3.1). Most respondents did not want to use an ePortfolio for assessed work and most did not use the ePortfolio that was made available to them (Table 3).

Table 3: Respondents views on graduate attributes and the MyPortfolio software

	Yes	Unsure	No	No answer
3.1) Are graduate attributes important to you?	26	11	0	2
3.2) Did you use the MyPortfolio software?	10	3	25	1
3.3) Should My Portfolio be used for assessed work in your engineering papers?	3	14	21	1

About the MyPortfolio software

The MyPortfolio system (http://myportfolio.ac.nz) is freely available to the students with helpdesk support. The students were asked about the MyPortfolio software. The questions were on what they feel about the software (Table 4), guidance to use the software, perceived value and ease of use (Figure 1).

Table 4: What respondents' feel about using the MyPortfolio software (number of respondents)

Enthusiastic	0
Positive	0
Neutral	14
Uncertain	14
Confused	6
Anxious	2
No answer	3

Respondents were less than positive about using the MyPortfolio software (Table 4). About one third of respondents thought that they did not have enough guidance on its use (Figure 1a). Most respondents were unsure if it was of value (Figure 1b) and most were unsure if it was easy to use (Figure 1c).

Differences were explored between those who used MyPortfolio and those who didn't. There were minor differences but generally the groups showed similar trends. A similar number of respondents thought that they had enough guidance with those who didn't (Figure 1a). Most respondents in both groups were unsure if the ePortfolio was of value (Figure 1b).

Advantages and barriers to using MyPortfolio

Students were asked to list two advantages of using MyPortfolio. The responses were that it provided a record of achievements (13 respondents), helps in applying for a job (13 respondents), helps in the development of professional skills (9 respondents), five respondents said they don't know and twelve respondents did not fill in this section.

Respondents listed the barriers to using MyPortfolio (Table 5). These are around perceiving the benefits to be of low value or not identifying the benefits. The respondents gave reasons that it was not a high priority and other commitments were more important. Some respondents were unclear how to use the software.

Table 5: Barriers to using MyPortfolio (number of respondents)

Time	11
Concern that employer may not be able to access or understand it	5
Confusing to use	7
Can not see benefit of it	7
Too lazy to use it	4
Internet access is required	3

Note: nine respondents did not give any answers to this question

Identifying levels of reflective thinking

An instrument to describe the respondents' level of reflective thinking was applied (Kember, Leung, Jones, & Loke, 2000). Respondents replied to questions about their actions and thinking in the previous semester. As this was a first year course it was considered that they would not have much experience on reflection. The instrument had four scales: habitual action, understanding, reflection and critical reflection (Table 6).

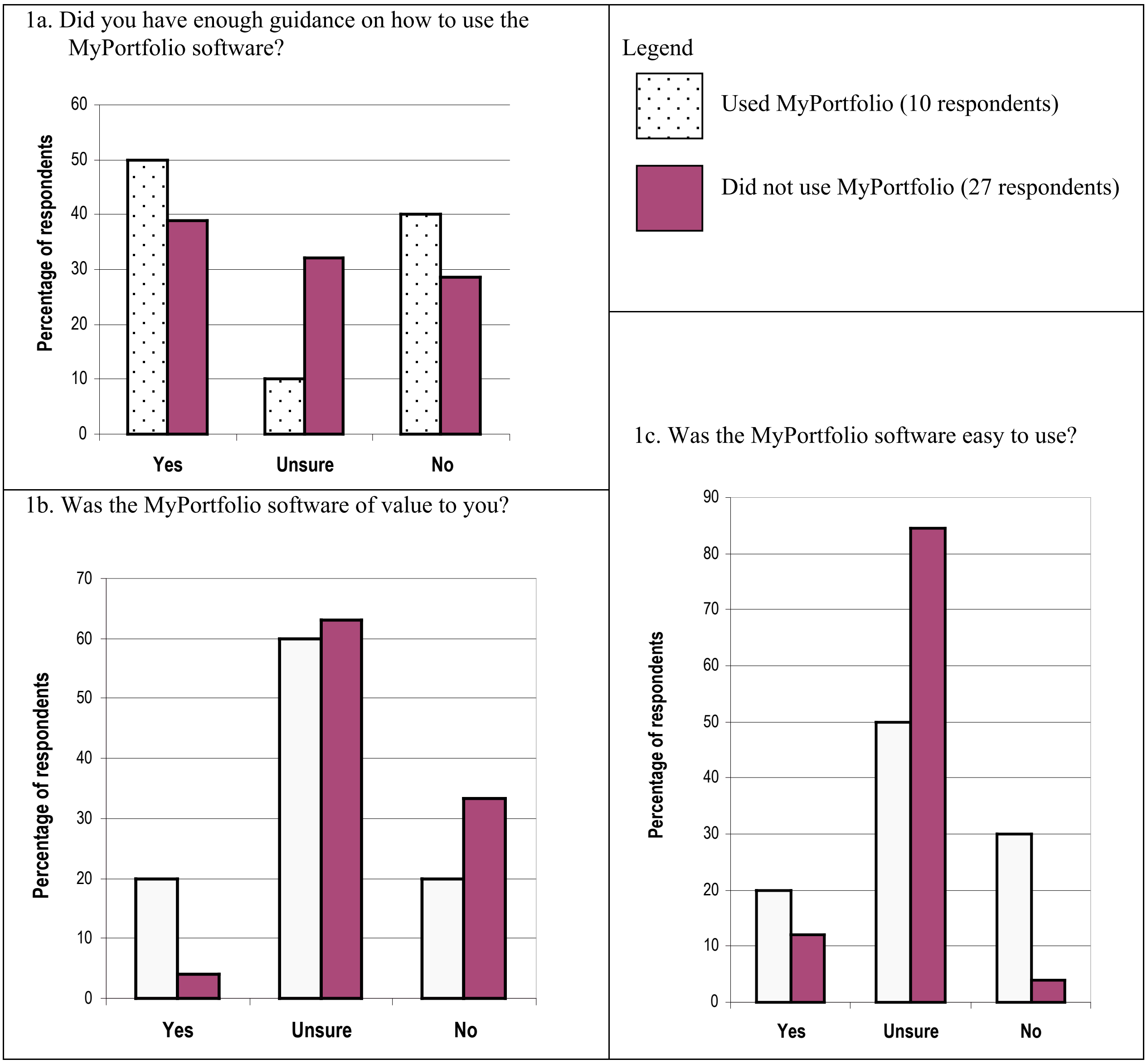

Figure 1: Respondents views about the MyPortfolio software

The instrument's four scales have a hierarchy moving to critical thinking that has greater potential impact on personal development (Kember et al. 2000). Habitual action describes actions that do not require much thinking. There is no reflection in this scale and actions occur almost automatically. There was a wide spread of responses to the habitual action questions with the mean being neutral (Table 6). The understanding scale was described as understanding a concept without reflecting on how it relates in personal or practical situations. The respondents strongly agree to these questions. They focus on learning content. The reflection scale involves thinking about content and comparing this to what the student already understands. The students question their understanding in the light of what they have learnt. Most of the respondents agreed with these questions. Critical reflection is deeper reflection that results in more of a change in the students perspectives so that their future action will be different as a result of the reflection. There was a wide distribution of these responses with the mean tending towards a more neutral response. Kember et al., 2000, suggest that critical reflection is less likely to occur in a course as it takes time to achieve the more major changes.

Each scale has four questions. These were summed to get a scale score for each respondent. Means were calculated for the respondents who came straight from school and compared to older respondents. It was hypothesized that older students would demonstrate deeper levels of reflection based on their greater life skills. No statistical differences using the one-tailed t-test were identified (Table 7).

Table 6: Frequency of responses with means for each question

Habitual action	Strongly Agree			Strongly Disagree		Mean
1) When I am working in some activities, I can do them without thinking about what I am doing.	9	14	3	8	3	3.49
5) In semester one we did things so many times that I started doing them without thinking about it.	5	9	12	9	2	3.16
9) As long as I can remember handout material for examinations, I do not have to think too much.	2	4	11	13	7	2.49
13) If I follow what the lecturer says, I do not have to think too much on this course.	2	10	14	6	5	2.95
Understanding						
2) Semester one required us to understand concepts taught by the lecturer.	22	12	2	1	0	4.49
6) To pass in semester one you need to understand the content.	24	12	0	0	1	4.57
10) I need to understand the material taught by the teacher in order to perform practical tasks.	15	15	3	4	0	4.11
14) In semester one you had to continually think about the material you were being taught.	9	16	8	3	1	3.78
Reflection						
3) I sometimes question the way others do something and try think of a better way.	22	12	2	1	0	4.49
7) I like to think over what I have been doing and consider alternative ways of doing it.	8	21	5	3	0	3.92
11) I often reflect on my actions to see whether I could have improved on what I did.	14	13	8	2	0	4.05
15) I often re-appraise my experience so I can learn from it and improve for my next performance.	5	19	6	6	1	3.57
Critical Reflection						
4) As a result of this semester one I have changed the way I look at myself.	10	12	10	4	1	3.70
8) Semester one has challenged some of my firmly held ideas.	2	9	12	13	1	2.95
12) As a result of this course I have changed my normal way of doing things.	7	10	7	10	3	3.22
16) During semester one I discovered faults in what I had previously believed to be right.	8	11	9	5	4	3.38

The responses were coded with a 5 for strongly agree through to 1 for strongly disagree.

Table 7: Summed mean (standard deviation) for each scale

	Overall	First year from school (n=26)	Older students (n=10)	Difference
Habitual action	12.14	12.38 (3.02)	11.50 (2.32)	ns
Understanding	17.06	16.77 (2.80)	17.80 (2.10)	ns
Reflection	16.03	15.92 (2.35)	16.30 (2.21)	ns
Critical reflection	13.31	13.42 (3.75)	13.00 (2.91)	ns

An appraisal of the implementation

Implementation was guided by questions on pedagogy, administration, and staff and student support (Milne & Heinrich, 2009). An appraisal by the authors using Butler's 2006 success criteria helped to identify some strengths and weaknesses of the implementation process (Table 8). Strengths were the steps taken to make sure that the student could take ownership of the ePortfolio. It was hosted outside the organisation so students could access it after the course and students had to register for the site to get access to reinforce that this was not an institutional system. The students were given written instructions with demonstrations to show what they were to do and how to do it. Feedback was given and there were clear links with the need to develop graduate attributes. There were weaknesses in the implementation that became evident from the students feedback. These are described as developing in Table 8. These items were considered in the planning process but the student feedback indicated that more needed to be done in these areas.

Table 8: Success criteria for implementing ePortfolios

Criteria	Achieved in study?
• Student ownership of the portfolio	Yes
• Clear framework and guidelines on what to do and how to do it	Yes
• Feedback during the evidence collection process	Yes
• Making connections between the portfolio content and the outside life of the student	Yes
• Consideration of the target audience	Yes
• Understanding of the value of the portfolio for future use, such as employment	Developing
• Familiarity with the portfolio concept, including an understanding of both the process and the product of portfolio construction	Developing
• Understanding of the value of reflection	Developing
• Sense of achievement at overcoming initial struggles to understand the portfolio concept	Developing
• Structure tempered with freedom for creativity	Developing
• Motivation to learn and achieve good marks	Developing

Discussion

It is evident that whilst first year students have made a choice to study engineering they had very little idea as to what happens at the end of the degree; at graduation. Students did not know about graduate attributes and the mechanism to become a professional engineer after graduation. It is therefore essential that early on in an engineering degree that some form of contextual discussion outlining the degree and professionalism is presented to students. Once presented students have demonstrated that they find this process important to them.

Respondents had a reasonable understanding of the benefits of the ePortfolio. The students have to do a work placement to gain the degree so the need to gain employment over the summer would have been important to them. They were given exercises on how the ePortfolio can help them develop professional skills. Even when they know about the benefits it was not enough as the ePortfolio had a limited impact.

The students were given access to online videos and paper manuals. It was assumed that the engineering students would easily be able to learn to use the ePortfolio. This was not the case and students reported that they needed more support with the software. Practical sessions in a computing room would have provided more support.

Students voiced concern that employers will not want ePortfolios or know what to do with them. Surveys of employers have found that the use of ePortfolios as part of recruitment is low but over half of those surveyed said that they will use them in the future (Ward & Moser, 2008). Brammer (2007) reports that employers are enthusiastic about ePortfolios saying that they make the applicant stand out and they get a better understanding of them. In the engineering industry, particularly in software engineering there is likely to be a faster uptake of technologies such as ePortfolios.

Most respondents said that graduate attributes were important yet most did not use the MyPortfolio software. The authors explored differences between the respondents who used the ePortfolio and those who did not use it. Both groups showed similar responses with most respondents being unsure if the software is of value. The respondents may not have used it enough to have formed an opinion. It is suggested that the motivation to spend time using the ePortfolio was driven by assessment. By not having formal assessment the students got an implied message that this is not important.

It is a large challenge to motivate students to use an ePortfolio when they are not assessed (Heinrich et al. 2007). This is especially the case in science students who do not have a culture of using portfolios. Heinrich et al. suggest that the importance of ePortfolios need to be reinforced from academics, professional bodies and industry to create a change in mindset of the students. While this will have an impact assessment does clearly focus students and well structured activities that are assessed are likely to have greater impact on the students.

This study agrees with Chappell and Schermerhorn's rules for implementation (quoted in Meyer & Latham, 2008). Specifically that ePortfolios should be mandatory in order to overcome resistance from students and that ePortfolio assignments should have due dates and that students get feedback on their assignments. The way to reinforce this is to allocate marks to the final grade based on ePortfolio work.

There were some gaps in the implementation process. The activities were not assessed so the students did not place a high value on them. Students need further support to reflect and this should be embedded in the course.

Kember et al. (2000) found that undergraduate students differed in their scores to postgraduate students. The older students in this study had the same scores as those straight from school. Most of the older group students were only one year older so the age gap was small.

Conclusion

The use of ePortfolios has the potential to help students develop their engineering graduate attributes. This work shows that even with clear benefits, if the activities are not assessed students will not make the most of the opportunities.

Students need support not only in using the ePortfolio but in understanding how reflection can help them learn. Students need practice on reflection throughout their course. It can not be an activity that occurs only in one course but should occur across a number of courses over the duration of the degree.

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Please cite as: Goodyer, J. & Milne, J. (2009). Developing competence portfolios in engineering undergraduates. In *Same places, different spaces. Proceedings ascilite Auckland 2009*. http://www.ascilite.org.au/conferences/auckland09/procs/goodyer.pdf