Int. J. Engng Ed. Vol. 24, No. 6, pp. 1078–1083, 2008
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Interactive Capstone Portfolios*

AARON S. BLICBLAU
Faculty of Engineering and Industrial Sciences, Swinburne University of Technology, Melbourne, Australia.
E-mail: ablicblau@swin.edu.au

Portfolios are a collection of student work over a period of time. Capstone project portfolios incorporate many forms of written artefacts, e-pages, oral presentations, journals and audio-visual material. Interactive capstone portfolios involve actions by both educators and students to establish a dynamic set of usable and tangible skills. These include the development of writing skills from minor project proposals to major reports or dissertations that are an ongoing learning exercise for the student. For the educator, portfolio development is a method of continuously and actively evaluating and commenting on a student's work, culminating in a final major report. This portfolio report may be in traditional format, or may take the form of several artefacts, viz. electronic portfolios, written report, computer program 3D model, paper poster, (WWW) web page and electronic posters, together with oral presentations. These activities develop communication skills for working within an industrial environment. However, for academic purposes stratification of assessment grades is required, by both peer group assessment and independent academic assessment. Examples of ongoing capstone portfolio content will be given showing that which is submitted formally, and that which remains for the students' creativity, learning and self evaluation.

Keywords: portfolio; capstone; projects

INTRODUCTION

THE WORK OUTLINED in this paper provides details of the activities involved with the design and development of a *portfolio* approach to the implementation of a 'capstone' or final year project undertaken by mechanical, and robotics and mechatronics (R&M) engineering students at Swinburne University of Technology. Developments in communications and dissemination of information have necessitated new approaches to activities that influence the outcomes of capstone projects. Engineering graduates are now required to be both proficient engineers and communicators utilising the latest technologies. The days of the traditional written thesis as the only major outcome of honours or capstone projects have been supplemented by requirements, especially of industry, which now expects graduates with skills (outcomes) not only in their areas of training, but also be adept with electronic, e-forms of communication and presentation. Electronic portfolios, commonly referred to as *e-portfolios* are a necessary part of an engineer's toolkit.

Details are given of an electronic portfolio, 'e-portfolio', which was developed for use by final year engineering students. The portfolio encompassed digital, electronic, audio/visual, oral and paper based content. Utilising a variety of portfolio content [1–8] would enable the student to both learn how to communicate in different media and self assess their work in different contexts.

At Swinburne University of Technology (SUT) all capstone student ongoing work and assessable material is uploaded on to a computer website or learning management site (e.g., BLACKBOARD, which is SUT's flexible e-learning and online communities system for students and staff®); this has altered the form of the active electronic learning by students. They transmit their data electronically, are assessed electronically and complete their studies electronically. Whereas within most industries and organisations, electronic (computer) tools are only used as an aid in communication; usually in the form of audio/visual presentations, and written and oral presentation reports as well as poster displays(albeit in electronic format) are still the key form of relaying information.

WHAT IS A PORTFOLIO?

> . . . *portfolio* . . . Italian portafoglio: porta-, from *portare*, to carry, from Latin portare + foglio, sheet (from Latin folium, leaf). . . . a portable case for holding material, such as loose papers, photographs, or drawings. The materials collected in such a case, especially when representative of a person's work: a photographer's portfolio; an artist's portfolio of drawings: *an engineer's collection of designs, calculations, digital media* [9, 10].

A student portfolio has recently been defined as a purposeful collection of student work that exhibits the student's efforts, progress and achievements in one or more areas. The collection must include student participation in selecting contents, the criteria for selection, the criteria for judging merit and evidence of student self-reflection [11]. However, not all portfolios are the same. Recent work done in developing portfolio concepts for

* Accepted 3 January 2008.

mathematics education, defined basically three types of portfolios: showcase (which focused on the student's best and most representative work.), teacher–student (the 'working portfolio') and teacher alternative assessment (specific portfolios items are selected for assessment). Each served a different purpose. Selections from each portfolio concept can further be incorporated to design a 'holistic' portfolio for engineering applications [12].

Furthermore, other workers [13] maintain that portfolios provide information about student progress and encourage students to be responsible for their own learning. In this way they feel as though they take more responsibility in their learning and assessment processes.

Especially in the engineering field, portfolios are produced for a variety of personnel and purposes. Portfolios are seen to assist students is developing skills necessary for life-long learning; and enable thinking skills with multidimensional forms of evaluation. These skills include many aspects necessary to function and integrate as an engineer into the surrounding society; for example being able to communicate, reflection on the role of engineering in society, and its ethical responsibilities [14, 15].

A well designed portfolio serves three main purposes: it allows academic staff to employ it as a tool for assessment and feedback, for prospective employers to evaluate the quality of their new employees, and for students to develop an ongoing understanding of their achievements. To assist students in the presentation of their engineering accomplishments and activities, an electronic portfolio system has been recently developed which showcase these activities in multimedia format on a website [8].

WHAT DO WE WANT STUDENTS TO KNOW FROM CAPSTONE PROJECT WORK?

The Institution of Engineers Australia (Engineers Australia) has developed a generic framework for developing specific education outcomes for programs and is provided in the generic attributes requirement of the Engineers Australia Accreditation Policy, and more specifically in the Stage 1 Competency Standards [16]. The generic attributes recognise the broad nature of professional engineering practice in today's world. In particular, these are specific to project or capstone project work in an active learning environment. Table 1 list skills identified and desired by Fortune 500 in comparison with generic skills required by Engineers Australia (EA), require the mastery of a number of significant skills [17, 18]. The last mentioned generic skill required by (EA) of lifelong learning is of vital importance to engineers, who never slow down in their thirst for knowledge. Students are often ill-prepared and may not receive explicit preparation in this area. A comparison of the attributes and skills indicates that the generic engineering attributes completely encapsulate those skills seen as necessary for a large organisation.

All components of the generic attributes criteria (and Fortune 500 skills) may be included in a capstone project, and assembled in a portfolio. Each attribute may be highlighted in electronic, paper, audio-visual or digital format. These in turn contribute to the requirements students need to master to be able to succeed in the outside world working in industry or business. Examples of this approach have been developed for capstone projects that integrated both engineering and business students, requiring an interactive approach by students to work in a group environment similar to a multidisciplinary industrial based project subject to financial and timeline constraints [19]. Electronic portfolios are now being utilized to impart lifelong learning skills because of their implementation in to many facets of the engineering profession [20].

THE ENGINEERING CAPSTONE PROJECT

Traditionally final year mechanical engineering projects at Swinburne University are conducted over the last two semesters of the final year of a

Table 1. Comparison of attributes required by graduates and 'big business' [16, 18]

Generic attributes of graduates (Engineers Australia)	Fortune 500 general skill mastery (in order of importance)
Graduates are expected to be able to: • function effectively as individuals and in multi-disciplinary and multicultural teams, with the capacity to be a leader or manager as well as an effective team member; • understand problem identification, formulation and solution; • have in-depth technical competence in at least one engineering discipline; • apply knowledge of basic science and engineering fundamentals; • communicate effectively, not only with engineers but also with the community at large; • understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development; • understand the principles of sustainable design and development; • understand professional and ethical responsibilities and have a commitment to them; • have an expectation of the need to undertake lifelong learning, and capacity to do so.	• Teamwork • Problem-solving • Interpersonal skills • Oral communication • Listening • Personal/Career development • Creative thinking • Leadership • Goal setting/Motivation • Writing • Organizational development • Computation • Reading

four year engineering degree. The project value is 25% of the total units studied by students for that year. The makeup of the project comprises a number of components, some of which can be transmitted in WWW electronic format (via BLACKBOARD) but are often viewed and presented in both oral and 'hard copy' or paper format.

A conventional capstone project would require groups of students to work collaboratively and so spend most of their time undertaking a specified form of research or design approach over two semesters, culminating in a minor thesis, poster display (electronic format) and oral presentation. The project often required significant commitment and resources by the university or the sponsoring industrial organisation.

This approach was based on the 'honours theses' approach common in the fourth year of science and humanities degrees. The only outcome was a 50–100 page report, often in a manila folder or sometimes hard bound. This report gave little indication of the student's overall abilities in a variety of areas and skills [21]. Other forms of representations were necessary for student assessment.

The compilation of the portfolio is spread over two semesters with specific requirements for submission of different artefact over a variety of dates. Shown in Table 2 is a typical portfolio content with submission and assessment requirements.

CAPSTONE PORTFOLIO PROJECT STRUCTURE

According to criteria developed by Paulson *et al.* [11] and established and codified by the Prince George County College System [22], the portfolio structure undergoes a number of phases of development:

- Phase One: Organisation and Planning,
- Phase Two: Collection, and
- Phase Three: Reflection.

Within the SUT Mechanical Engineering program the three phases require specific actions by all of the students, their supervisors and the subject convenor.

Phase one: Organisation and planning

This initial phase of portfolio development requires decision-making on the part of students and project proposers/supervisors, and approval by the convenor, and requires a comprehensive and well developed project proposal. By exploring essential questions at the beginning of the process, students and their supervisors can fully understand the purpose of the portfolio and its status as a means of:

1. selecting portfolio themes, then gathering materials and reflecting on their activities,
2. organising and presenting the items, materials, etc. that they have collected, and
3. maintaining, storing, developing and displaying the material.

The development of the portfolio project commences with the first time the students meet their project proposers. At the commencement of the first week of the first semester, all students assemble to hear their project sponsors 'spruik' the benefits of their project. Important questions that the student needs to consider and so learn about project proposals and tendering, include the following. How do I select the project? How do I design/analyse/organise and present the information, data, items, materials, etc.? Concomitant with these decisions is the requirement of portfolio content: how will portfolios be maintained and stored? Will they contain various forms of artefacts in a number of physical and multimedia formats? For example, written, oral, electronic, web based learning management systems, poster and audio displays and the traditional bound notebook.

Project proposal submission

The portfolio submission requirements are allied to that of a *tender* process that comprises many

Table 2. Content and details of the capstone portfolio

Portfolio content	Format	Assessment form	Submission
Summary of available projects	Paper, electronic, audio-visual	Students 'assess' project and select supervisor	A contract is submitted by both student and supervisor
Project proposal	Audi-visual, web based, written	Peer group, independent assessors	At end of specified time span, i.e., 10 weeks from project selection.
Written report Journal or conference paper e-poster—web page Electronic A/V presentation A1 size professional poster Computer programs, models, designs, CAD, FEA and 3D physical structures	Paper Electronic–digital Visual Physical model Computer model Oral presentation	Peer group Independent assessors Ranking Numerical	Subject to specific time constraints: All items submitted at the end of semester two but before the commencement of the exam period.

stages [20]. The students begin their portfolio collection on the very first day—with the oral presentations and associated written material describing the various projects. This concept of a portfolio is at first foreign to the students. They are used to submitting final pieces of work for assessment. Student need to evaluate comprehensive technical literature often in the form of complex documents and produce a persuasive and effective tender/project proposal [22, 23]. This is the first important stage in the portfolio comprising the capstone project.

All proposals are required to be submitted in electronic–digital format, with supporting written material by a specified closing date. The assessable items comprise an audio-visual presentation, an e-poster (a poster for display on the WWW and a written proposal). This is the first stage of the bid in the form of a preliminary tender submission. To enable students to take ownership of their assessment, they are peer assessed. At the end of ten weeks a colloquium is presented by all students in the form of a five minute 'project blitz' to all their colleagues and academic staff members, delivered under tight time constraints and on top of other student work.

Portfolio project proposal assessment

Portfolio capstone assessment can take many forms and is often dependent on the contents and outcomes of the project [25–28]. It is common for faculty staff to provide both critical assessments based on well constructed rubrics as well as constructive feedback [29]. For the capstone projects at Swinburne within the mechanical engineering discipline, the breakdown of marks for the various parts of the Stage One portfolio is distributed as follows: for the electronic audio-visual presentation—(20%), the 'e-poster'—(20%) and the supplementary written report—(60%).

The assessment technique for all three items is varied. Students 'vote' an assessment on each others' work [30], for example, oral presentations and e-posters. These e-posters are ranked from outstanding, very good, acceptable and not acceptable. The associated numerical marks (as required by the tertiary institution) start from ten, then eight and six to finally four, respectively. Posters are graded subjectively by a panel of academic and student assessors: the best poster gets the highest mark available, ten; whilst the worst poster gets the lowest mark available, four. The remaining posters are graded in between the maxima and minima. The students view all the posters electronically, know the assessment, and so learn from each other's work.

Students are required to deliver short five minute oral presentations, blitz presentations. They may utilise any means for their presentation, but they are not allowed to exceed the time limit. They have to convince the audience of the value of their project.

Assessment is by the whole cohort of student audience voting on the 'project blitz' presentations. Over the last few years, there have been over 60 individual assessments for each student project presentation, so that a normalised set of data is obtained with a minimisation of any bias. A binary form of grading is all that is required: i.e. is the project pass or fail? If a pass is delivered then the project proposal is acceptable and is able to proceed to the next stage of project development. There is no numerical grade attached to this form of assessment.

However, for the written supplementary report, a more comprehensive system is utilised [31, 32]. Two independent academic staff assess the reports based on specific criteria. Each component of the report is examined and a final numerical grade is attached to the written component. Further, the bulk of the portfolio content is yet to be developed and assembled for the final work. This involves a substantial amount of experimental/design/simulation items with associated artefacts for collation in the portfolio.

Phase two: Investigation and compilation

With the feedback from assessment of Stage One portfolio, the compilation of Phase Two of the portfolio now commences. This process involves investigations and development of meaningful designs, implementation and analyses, construction of physical artefacts and products that incorporate the students' engineering experiences and associated outcomes. From all the information obtained, decisions must be made at this phase about the context and contents of the portfolio based upon the intent and purposes of the project. At this stage the direction and specific targeting for project outcomes is assessed in light of the original proposal.

For the student this is also a time for reflection [33]. It is also a time for monitoring their comprehension of project related key engineering knowledge and skills. Because of capstone portfolio time and written submission constraints, these reflections often take the form of intensive oral debates with peers and supervisors, and submission of preliminary extensive written and digital documentation for 'comment' [34, 35]. For the student the results of these reflections are a learning and educative process, incorporating their own and colleagues' experiences, the thinking processes that they have used, and the different approaches to solving the problems that they employed at given points in time during the management of the project across time periods.

Capstone Project assessment

A major part of the second phase for supervisors and assessors is the actual assessment process. For capstone project assessment, all components selections included in the portfolio collection clearly reflect the criteria and standards identified for evaluation. The assessment technique for the second phase of the capstone project is similar to the first stage with the incorporation of indepen-

dent assessors for all facets of the portfolio submission. The assessable content are: oral presentation, audio/visual web based submission, an A1 poster as well as an electronic poster, either a written report(or theses), or a 'paper' suitably formatted for a conference submission together with a laboratory log book [35].

The variety of assessment techniques used comprise: peer assessment of oral presentations, 'ranking' of posters, and written report assessment. Students 'vote' on each other's e-posters. Various academic staff rank posters and assign a grade (the best poster always attains full marks; the worst poster attains a bare pass, whilst intermediate quality posters are assigned a grade according to their intermediate ranking. The students appeared satisfied with this approach, as no set criteria can be prescribed—the rankings are subjective. The assessment of the written theses or 'paper' is inherently difficult. It is not unusual to have large discrepancies between thesis/paper examiners—it happens all the time in Master's and Ph.D. theses—ultimately, any assessment of such documents has a degree of subjectivity [1, 2, 4, 8, 21, 32]. However, because of academic requirements for a numerical mark, a simple numerical average is determined for the theses. This mark is then summed with the remaining marks for the portfolio artefacts from the two stages and a 'final number' is obtained. This is not an altogether satisfactory outcome; since there is not one satisfactory method for providing a numerical grade. It would be more appropriate to 'rank' the theses and assign a 'comment', e.g. satisfactory, cum laude, magna cum laude, or summa cum laude (adequate, with honours, with great honours, and with greatest honours, respectively). This is similar to awarding overall honours in a full course.

Phase Three: Reflection

With the feedback from assessment of stage one and stage two of the portfolio, the students are able to reflect on the benefits and shortcomings of their submissions [5–7, 33]. These reflections take the form of reflective journals, which may include the thinking processes they have used, and peer group reflection (often verbal). Reflection is incorporated into all aspects: the organization, planning, investigation, compilation and submission aspects of the total capstone environment. In addition, supervisor and convenor discussions or deliberations about the capstone project portfolio implementation and outcomes whenever and wherever appropriate.

CONCLUDING COMMENTS

'Portfolios offer a way of assessing student learning that is different than traditional methods' [11]. Portfolio assessment provides the teacher and students with an opportunity to observe students in a broader context: taking risks, developing creative solutions, and learning to make judgments about their own performances [6].

The assessment process for capstone portfolio projects is ongoing and evolutionary, changing from year to year, from cohort to cohort. In order for thoughtful evaluation to take place, teachers must have multiple scoring strategies to evaluate students' progress. Criteria for assessment of a finished portfolio are extremely complex [21, 35, 36]. The final numerical assessment is only a compilation of numbers as required by university administration. In an industrial context, when project tenders are considered, there is only one winner, a final list and the also rans. It is proposed that in any student cohort competing for capstone project success, the portfolio should be used as the prime criterion for assessment. Moreover, in this matter, only one project is assessed as the winner (achieving a high distinction), there is a short list (achieving a distinction) and the remainder achieve either a credit or pass grade, with associated numerical qualifications.

As the academic semesters progress, students and assessors work together to identify especially significant or important artefacts and processes to be captured in the portfolio. They work collaboratively to determine grades or scores to be assigned. Rubrics, rules, and differing scoring approaches are designed for a variety of portfolio components. In addition, letter grades might also be assigned, where appropriate. Finally, some form of oral discussion or investigation should be included as part of the summative evaluation process. This component should involve the student, teacher and, if possible, a panel of reviewers in a thoughtful exploration of the portfolio components, students' decision-making and evaluation processes related to artefact selection, and other relevant issues. There is no one area of our current approach to assessment and evaluation of student progress that appears to be satisfactory.

REFERENCES

1. D. R. Brodeur, Using portfolios for exit assessment in engineering programs, in *32nd ASEE/IEEE Frontiers in Education Conference*. Boston: ASEE/FIE (2002).
2. T. J. Brumm, A. Ellertson, and S. K. Mickelson, Using ePortfolios to develop and assess ABET-aligned competencies, in *ASEE Annual Conference Proceedings*, Nashville Tennessee, ASEE (2003).
3. T. J. Brumm, *et al.*, Competency-based outcomes assessment for agricultural engineering programs, *International Journal of Engineering Education*, **22**, 2006, pp. 1163–1172.

4. L. Wilhelm, *et al*., Lessons learned from the implementation of electronic portfolios at three universities, TechTrends, **50**, 2006, pp. 62–71.
5. D. Spendlove and M. Hopper, Using 'electronic portfolios' to challenge current orthodoxies in the presentation of an initial teacher training design and technology activity, *International Journal of Technology and Design Education*, **16**, 2006, pp. 177–191.
6. C. C. Chou, C. A. Bagley, and A. Efolio, A rich internet application K-12 in-service teachers' attitudes toward electronic portfolios, *International Journal of Continuing Engineering Education and Life-Long Learning*, **16**, 2006, pp. 183–199.
7. T. W. Knott, *et al*., Using electronic portfolios in a large engineering program, in *ASEE Annual Conference and Exposition*, Portland, ASEE (2005).
8. M. I. Campbell and K. J. Schmidt, Polaris: An undergraduate online portfolio system that encourages personal reflection and career planning, *International Journal of Engineering Education*, **21**, 2005, pp. 931–942.
9. *Answers* [http://www.answers.com/topic/portfolio, accessed 17/12/2007].
10. *Wordsmyth*, [http://www.wordsmyth.net, accessed, 17/12/2007].
11. F. L. Paulson, P.R. Paulson, and C.A. Meyer, What makes a portfolio a portfolio? *Educational Leadership*, **48**, 1991, pp. 60–63.
12. L. Columba and K. A. Dolgos, Portfolio assessment in mathematics, *Reading Improvement*, **32**, 1995, pp. 174–176.
13. D. A. Gilman, R. Andrew, and C. D. Rafferty, Making assessment a meaningful part of instruction, *NASSP Bulletin*, **79**, 1995, pp. 20–24.
14. O. Eris, Insisting on truth at the expense of conceptualization: Can engineering portfolios help? *International Journal of Engineering Education*, **22**, 2006, pp. 551–559.
15. J. M. Williams, The engineering portfolio: Communication, reflection, and student outcomes assessment *International Journal of Engineering Education*, **18**, 2002.
16. Engineers Australia, National Generic Competencies Standards-Stage 1 Competency for Professional Engineers, Institution of Engineers Australia, Canberra (2005).
17. S. R. Axley, The practical qualities of effective leaders, *Industrial Management*, **32**, 1990, pp. 29–32.
18. Editors, Fortune, and 500, *Skills Desired by Fortune 500 Companies,* Fortune 500, Creative Education Foundation, Creativity in Action (1990).
19. P. Wellington, *et al.*, Authentic assessment applied to engineering and business undergraduate consulting teams, *International Journal of Engineering Education*, **18**, 2002, pp. 168–179.
20. E. Heinrich, M. Bhattacharya, and R. Raydudu, Preparation for lifelong learning using ePortfolios, *European Journal of Engineering Education*, **32**, 2007, pp. 653–663.
21. F. Webster, D. Pepper, and A. Jenkins, Assessing the undergraduate dissertation, *Assessment and Evaluation in Higher Education*, **25**, 2000, pp. 71–80.
22. Prince George County College System, *Portfolio Assessment*, [http://www.pgcps.pg.k12.md.us/~elc/portfolio.html, accessed 17/12/2007].
23. Tender Consulting Group. *Successful Tender Preparation*, [http://www.tenderconsulting.com.au, accessed 17/12/2007].
24. L. A. Krishnan and S. S. Kathhpalia, Literature reviews in Student Project reports, *IEEE Transactions on Professional Communication*, **45**, 2002, pp. 187–197.
25. B. Panitz, The student portfolio: A powerful assessment tool, *ASEE Prism*, **5**(7), 1996, pp. 24–29.
26. M. C. Paretti. Using project portfolios to assess design in materials science and engineering, in *Proceedings of the 2005 ASEE Annual Conference and Exposition*, Portland Oregon (2005).
27. C. C. Greene and J. A. Jalkio. Evaluation of the accuracy and effectiveness of portfolio based student self-assessment, in *Proceeding of the American Society of Engineering Education Annual Conference and Exhibition*, Salt Lake City, Utah (2004).
28. M. Bhattacharya and M. Hartnett, E-portfolio assessment in higher education, in *37th ASEE/IEEE Frontiers in Education Conference*, Milwaukee, Wisconsin (2007).
29. J. A. Shaeiwitz, Mining Capstone engineering experiences for Program Assessment Results, *International Journal of Engineering Education*, **18**, 2002, pp. 193–198.
30. D. C. Miller, Incorporating peer review in the chemical engineering laboratory, in *Proceedings of the 2004 ASEE Annual Conference and Exhibition*, Salt Lake City, Utah (2004).
31. B.M. Olds, The use of portfolios for outcomes assessment, in *Proceedings of the Frontiers in Education, 28th Annual Conference*, Pittsburgh, Pennsylvania (1997).
32. M. W. Ostheimer and E. M. White, Portfolio assessment in an american engineering college, *Assessing Writing*, **10**, 2005, pp. 61–73.
33. M. I. Campbell and K. J. Schmidt, An undergraduate online portfolio system that encourages personal reflection and career planning, *International Journal of Engineering Education*, **21**, 2005, pp. 931–942.
34. J. E. Sharp, Using portfolios in the classroom, in *Proceedings of the Frontiers in Education, 28th Annual Conference*, Pittsburgh, Pennsylvania (1997).
35. L. L. Snavely and C. A. Wright, research portfolio use in undergraduate honors education: Assessment tool and model for future work, *The Journal of Academic Librarianship*, **29**, 2003, pp. 298–303.
36. Y. Gulbahar and H. Tinmaz, Implementing project based learning and e-portfolio assessment in an undergraduate course, *Journal of Research on Technology in Education*, 38, 2006, pp. 309–327.

Aaron Blicblau is a senior lecturer at Swinburne University of Technology. His interests lie in both teaching and learning from first year to final year. In this capacity he is convenor of the capstone project in mechanical engineering, which has an enrolment of over 70 students each year. His pedagogical associations were rewarded with a Carrick Citation for Outstanding Contributions to Student Learning.