Use of Student Portfolios for Outcomes Assessment of a Software Engineering Program

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ABSTRACT

For ABET accreditation of software engineering programs it is necessary to have a process in place to assess program outcomes that have been specified by the faculty. Monmouth University began its undergraduate software engineering program in 2000 and had its first graduates from that program in May 2004. To assess student achievement of program outcomes the University put into place a process for students to build portfolios and to have those portfolios reviewed by the faculty. The first formal evaluation of the contents of completed portfolios was conducted in spring 2004. This paper describes the process, the results of the review and the actions that have been taken as a result of that review. Several program improvements were made, including changes to specific course syllabi, sequencing of courses and changes in the curricular requirements. Methods for assisting students in construction of their portfolios and assisting faculty in reviewing the portfolios have also been developed. These methods include providing students with more precise guidelines for what to include in the portfolio, availability of a sample portfolio and scoring rubrics for use by the faculty during the formal review. The paper concludes with an outline of lessons learned and recommendations for other programs that are considering the use of portfolios for this purpose.

Introduction and Background

Portfolios have been utilized for many years in fields such as art and architecture to compile and publicize the capabilities of artists and architects. More recently schools of engineering have become interested in using portfolios to evaluate student progress and effectiveness of programs.

Panitz (1996) reported that a variety of portfolio formats had been designed for use at five engineering institutions which she investigated. Olds (1997) described a portfolio program that was initiated at the Colorado School of Mines in 1988 and which has been used as the basis for numerous small changes in a variety of programs at that institution. Brodeur (2002) outlined a portfolio-based assessment program that was developed for evaluating outcomes of a revised curriculum of the Aeronautics and Astronautics engineering program at MIT.

A number of authors have proposed and used portfolios to assess student progress in single courses and to assess achievement of specific outcomes across subsets of courses in engineering programs. Gunn, et al. (1997) describe how a portfolio was used to assess the effectiveness of a first year integrated curriculum. In that approach students were required to keep their work, review it periodically and discuss ways of organizing it. At the end of the semester students were required to select items that showcased their performance and write an introduction. Mourtos (1997) and Mullin (1998) examined how portfolios can be used within single courses to make students more responsible for their own learning. In their examples students are given responsibility for demonstrating minimum levels of competence in basic skills while pursuing excellence in one of them. Mourtos' examples are closely related to technical engineering disciplines while Mullin's are more closely related to non-technical skills like English, Art, Sociology, etc. Plumb and Scott (2000) discussed a process for developing performance based outcomes for engineering student writing assessment using portfolio collections of writing examples from 13 students.

Most recently, a variety of engineering educators have been promoting the use of, and using, electronic portfolios to collect and review student work. Reis (1998) described the Stanford University Electronic Learning Portfolios project. This effort was intended to help individuals capture, organize, integrate and reuse the results of learning experiences throughout their careers. Rogers (1998) discussed the experience of Rose-Hulman Institute of Technology in the selection and development of an electronic portfolio designed to document, assess and evaluate student outcomes. Rogers and Williams (1999) state that the use of electronic portfolios at their institution was a significant departure from the use of hard copy portfolios at other engineering institutions and they found that in a pilot of their process both students and faculty members found the system to be reliable and easy to use. Faculty members did make several recommendations for changes in the performance criteria and reported that the wide range of student abilities was enlightening. Moore and Voltmer (2000) outlined one planned use of Rose-Hulman's electronic portfolio process to obtain both a horizontal view (through a particular course) and a vertical view (sophomore through senior) of an electrical and computer engineering departmental design sequence consisting of two one quarter courses in the sophomore and junior years and a three quarter sequence in the senior year. Upchurch and Sims-Knight (2002) report on the use of an electronic portfolio for computer science and computer engineering students in a software engineering course. Student interviews conducted by the authors found both advantages and disadvantages based on student perceptions.

During the 2000-2001 academic year Monmouth University initiated an undergraduate program in software engineering. At that time, the faculty developed a set of program outcomes that were compliant with ABET criterion 3 (EAC, 2004). We were then faced with deciding how to assess student achievement of those outcomes in a way that would also be compliant with the criterion. The criterion says that, "There must be.....an assessment process, with documented results, that demonstrate that these outcomes are being measured and indicates the degree to which the outcomes are achieved." As outlined above, for several years prior to 2000, numerous publications had appeared promoting the use of student portfolios as an assessment method. A white paper issued by the Joint Task Force on Engineering Education Assessment (1997) mentioned portfolios as one assessment method that correlated with a number of the ABET-required outcomes. The contents of that paper have gradually been worked into the ABET guidelines provided to institutions, team chairs and program evaluators for interpreting the standards described in criterion 3. Those guidelines currently say that possible evidence can include such things as student portfolios; subject content examinations; performance evaluation of work/study, intern or coops; and/or performance observations. They further say that surveys and other indirect measures provide secondary evidence and should be used in conjunction with direct measures such as those above.

Based on these constraints and the experience of this author as an ABET program evaluator, watching other institutions' engineering programs struggle with how to do their outcome assessment, our faculty chose to use student portfolios as our primary method for assessing the outcomes that we had specified. We decided to supplement the portfolio assessment mechanism with a senior exit survey that would not attempt to directly assess the learning outcomes, but would supplement the assessment findings.

The next section of this paper describes our program outcomes. The sections titled The Portfolio Building Process and The Portfolio Assessment Process outline how students develop their portfolios at Monmouth University and how the portfolios are reviewed and scored by the faculty. Results of the first round of analysis that was done in 2004 are contained in the section titled Assessment Results, Lessons Learned and Planned Process Improvements. Finally, we provide a short summary and some conclusions.

Program Outcomes

The faculty decided, in 2000, to establish the ABET outcomes a) through k) as the basis for assessment of the program. We believe that these outcomes, placed in the context of appropriate coursework for a software engineering program, are sufficient for our students to achieve the program's educational objectives. The outcomes that were specified are the following:

By the time students complete the BSSE program at Monmouth University must have demonstrated:

- a) an ability to apply knowledge of mathematics, science and engineering
- b) an ability to design and conduct experiments, as well as to analyze and interpret data
- c) an ability to design a software system, component or process to meet desired needs
- d) an ability to function on multi-disciplinary teams
- e) an ability to identify, formulate, and solve software engineering problems
- f) an understanding of professional and ethical responsibility
- g) an ability to communicate effectively
- h) the broad education necessary to understand the impact of software engineering solutions in a global and societal context
- i) a recognition of the need for, and an ability to engage in life-long learning
- j) a knowledge of contemporary issues
- k) an ability to use the techniques, skills and modern software engineering tools necessary for software engineering practice

The Portfolio Building Process

During the first course in our Software Engineering sequence of courses, students are exposed to the creation of a software engineering portfolio that is eventually used to evaluate their learning. This introduction relates the curriculum to the outcomes that will be used to evaluate their learning and explains how to start building their Software Engineering portfolio. Initially they are told to keep a file for each course in which they save all of the materials that they receive and all of the work that they do in each course, whether it is a software engineering course or a course offered by another department.

When they are welcomed to the Software Engineering Department for advising in the first semester of their sophomore year they are reminded of the need to file all of their coursework. Then, before advising begins in the spring semester of their sophomore year they receive a letter from the department that describes how they should organize their portfolio into sections corresponding to the outcomes specified above. When they meet with their advisor the advisor reviews the contents of the portfolio and helps them ensure that it is being appropriately organized according to the outcomes. The advisor broadly evaluates the student's progress in achieving the outcomes. When the advisor is satisfied that it is appropriately organized, that appropriate materials are being retained and that the student is making satisfactory progress the advisor turns on the student's capability for on-line registration.

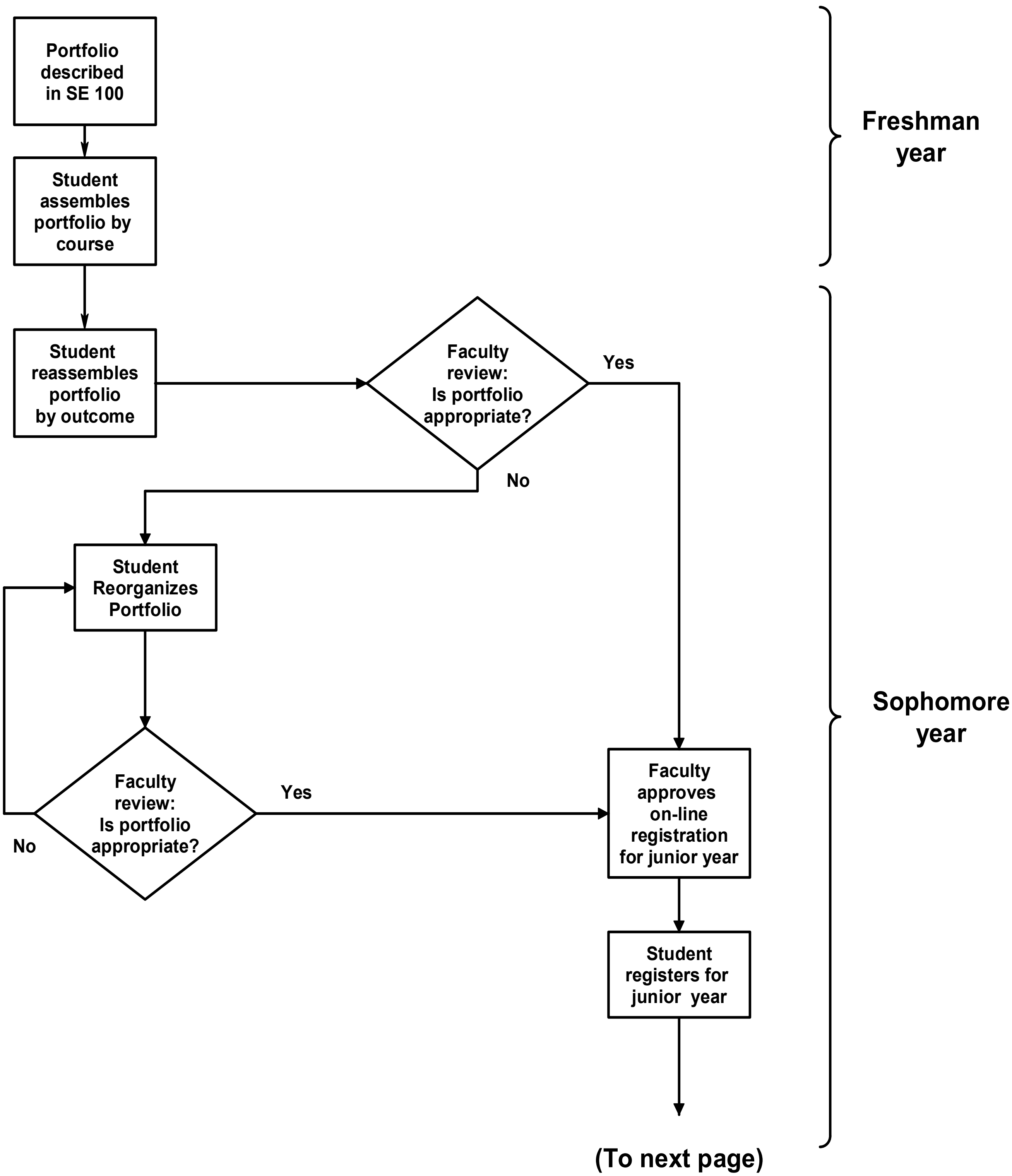
This cycle is repeated in the spring of the junior year. For students who are able to graduate in 4 years, those who have applied for graduation are asked to submit their portfolios for review by the whole Software Engineering faculty at the end of the fall semester of their senior year. Those who are not graduating go through an additional cycle of review and advising with their Software Engineering advisor.

The faculty reviews the contents of portfolios of graduating seniors during the winter break and early in the spring semester, at the end of which students will be graduating. Each faculty member is asked to "score" the contents of each outcome section of the portfolio based on the quality and quantity of its contents.

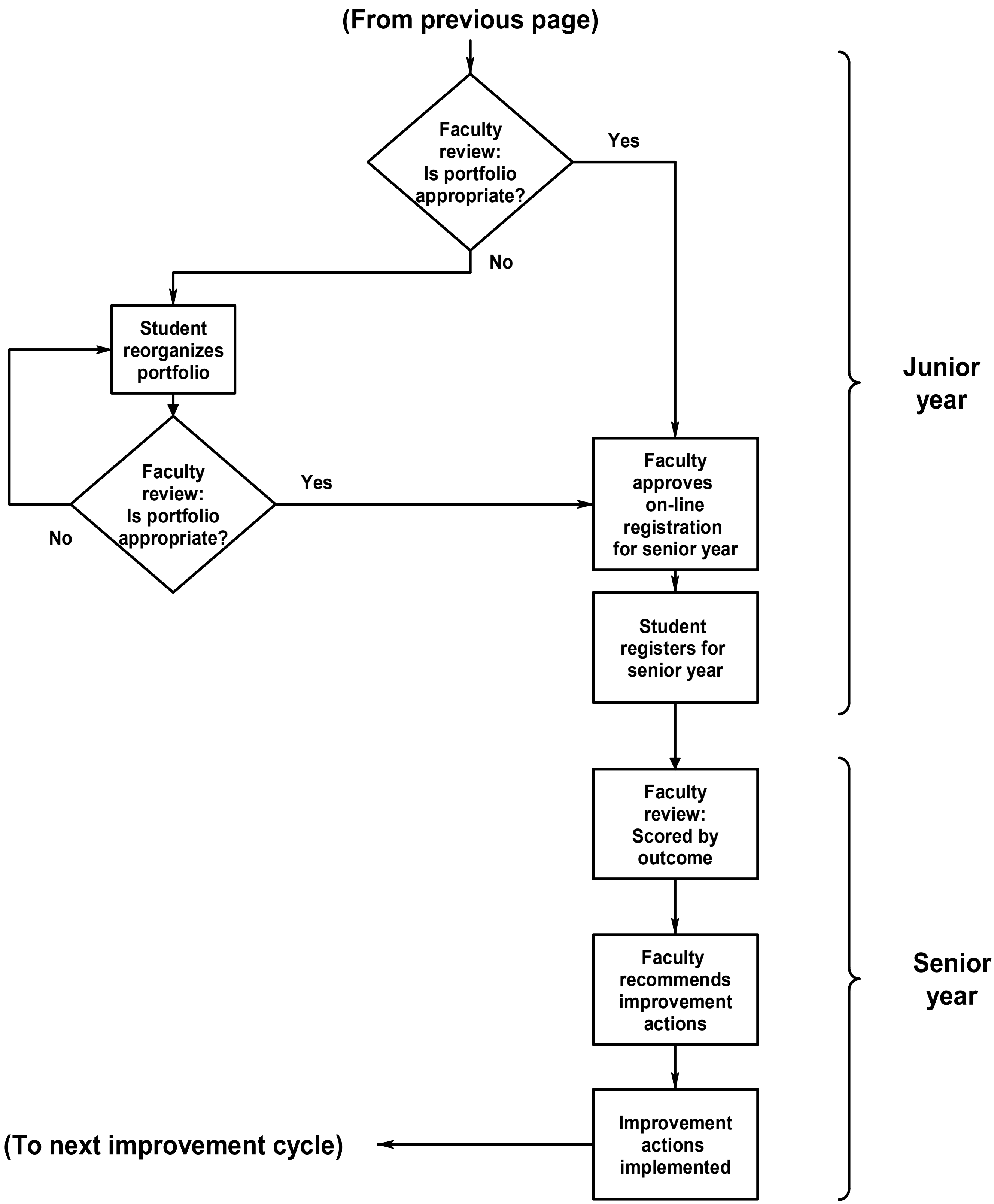
The schematic drawing which follows shows how this process is used to gather data, to advise students, to assess student achievement of the learning outcomes and to provide quantitative information during the spring semester prior to graduation. This process produces qualitative information during the student's sophomore and junior years. The first quantitative data were produced during spring 2004.

The Portfolio Assessment Process

During the winter break and the early part of the spring 2004 semester the portfolios assembled by our seniors who expected to graduate in May 2004 were reviewed and scored by each member of the Software Engineering faculty. The Software Engineering faculty was asked to score each section of each student's portfolio according to the quantity and quality of the contents of each section of the portfolio. They were asked to score each section on a scale from 0 to 10, with 5 being a satisfactory level of outcome achievement. Table 1 provides a summary of that data. The table provides the average score for each outcome averaged over all students whose portfolios were evaluated and over all faculty members who reviewed the portfolios. There were 6 student portfolios reviewed by 5 members of the faculty. The table also shows the absolute minimum score and the maximum score for each outcome.



Portfolio Assembly and Review Process - 1



Portfolio Assembly and Review Process - 2

Table 1

	a)	b)	c)	d)	e)	f)	g)	h)	i)	j)	k)
Average	7.9	7.9	7.6	4.9	7.9	4.2	7.6	8.2	7.5	7.4	7.0
Maximum	10	10	10	10	10	10	10	10	10	10	10
Minimum	6	6	6	0	5	0	5	7	2.5	0	1

Assessment Results

Outcome f), an understanding of professional and ethical responsibility, had the lowest average score (4.2), below the acceptable level, and a very wide variation (0 to 10) over students and reviewers. Outcome d), an ability to function on multidisciplinary teams, has the second lowest average score (4.9), slightly below the acceptable level, also with a wide variation over reviewers and students. Outcome k), An ability to use the techniques, skills and modern engineering tools necessary for engineering practice, while well above the acceptable level, has the third lowest average score (7.0) and quite a large variation (1 to 10) over students and reviewers.

These three outcomes would naturally be candidates for improvements to better ensure achievement of the outcomes. However, the question arises whether the scores for those outcomes were adversely affected by a lack of opportunity to learn, practice and demonstrate those outcomes in required courses or by the students' failure to include good examples of achievement of those outcomes in their portfolios. We requested our graduating seniors to provide additional examples of outcomes d) and f) before they graduated to help answer this question.

In the case of outcome k), regarding the use of modern software tools, the software engineering faculty collectively knew what was being achieved in our software engineering courses, which is the only part of the curriculum in which such tools are used. The use of engineering tools in those courses is under complete control of the software engineering faculty who teach those courses and who scored the portfolios. During the past two years the faculty has been increasing our students' exposure to and use of mechanized software engineering tools in our software engineering courses. They knew that students following those who graduated in May 2004 had received significantly more exposure to such tools than those whose portfolios were evaluated. Therefore, the faculty recommended a continuation of the addition of more tools into software engineering courses, more in-depth use of those tools in upper level courses and more repetitive exposure to those tools throughout the curriculum.

For outcomes d) and f) it was more difficult to determine the cause of the relatively low scores and what should be done to improve demonstration of achievement of those outcomes. Students did get some exposure to professional and ethical responsibilities and to teamwork in their software engineering courses and had an opportunity on exams to demonstrate achievement. However, the expectation of the software engineering faculty was that students would get significantly more exposure to ethical issues and responsibilities, as well as practice with multidisciplinary teamwork, in courses other than their Software Engineering courses. The portfolio contents did not support that expectation. Addressing both those areas would require action beyond the courses offered by the Software Engineering department and changes in the curriculum, which would require approval by the University's Undergraduate Studies Committee.

Before proposing changes that would require external approval the faculty recommended that they work with our students during the spring and fall 2004 semesters to gather additional examples of student achievement of these outcomes. We also explored these topics as part of our senior interviews during spring 2004 to get additional information from the students whose portfolios had been scored. As a result of this follow-up activity we found that students were able to provide ample evidence of outcome d), an ability to work on multi-disciplinary teams, from a business course that they took during the second semester of their senior year (which was taken after the portfolios had been submitted for faculty review). The faculty concluded that no action was required to address outcome d).

For outcome f), an understanding of ethical and professional responsibility, students were not able to produce additional evidence of achievement nor did senior exit interviews indicate that they remembered material that was included in courses that they had taken. The software engineering faculty proposed that to address this outcome we would develop and teach a "Perspectives" course titled Ethics and Professionalism. Perspectives courses are part of Monmouth University's general education program. They are courses that address issues from a multidisciplinary perspective. All University students are required to take a perspectives course during their senior year. The course that will be offered by the Software Engineering Department will address several aspects of ethics and professionalism and will be open to all engineering and science majors as well as students from other majors who are interested in its contents. All software engineering majors will be required to take that course. It was approved by the University's Undergraduate Studies Committee in February 2005 and will be implemented during the 2005-2006 academic year.

In addition to the formal results described above based on scoring the portfolios, the software engineering faculty observed, as a result of our yearly review of student portfolios prior to the senior year, that the number of examples of student work related to software verification, validation and maintenance was more limited than we had expected. It was, therefore, proposed that the title, course description and textbooks for a course that had been previously titled Software Construction be modified to emphasize contents of that course related to these topics. It is now called Software Verification, Validation and Maintenance. That change was approved by the University's Undergraduate Studies Committee in February 2004 and was implemented during the 2004-2005 academic year.

Finally, as a result of both advising students and reviewing the portfolios on a continuing basis, a need to change the timing for three particular courses required by the BSSE curriculum became obvious. We observed that several of our students had difficulties with a computer science algorithms course that was required during their junior year and that they were not ready by the start of the software engineering design experience required in their senior year to use appropriate software development processes and software project planning techniques. We, therefore, changed the sequencing of courses in the curriculum to move the CS algorithms course into the sophomore year (closer to the time when students completed their introductory programming courses) and to move two courses initially sequenced in the senior year (Software Process Improvement and Software Project Management) into the junior year. This change was approved in February 2004 and implemented during the 2004-2005 academic year.

Lessons Learned

There were several lessons learned about the portfolio building, reviewing and scoring process over and above the findings about the relationship of the overall program and the learning outcomes outlined in the sections above. These lessons can be outlined as follows:

1) Based on the limited instructions provided to students during their first software engineering course and two subsequent discussions with their advisors during their sophomore and junior years, students reported that they had a very difficult time organizing their portfolios and deciding what materials should be included in which sections of the portfolio.

2) Several students did not keep and file with their work the original instructions or exam questions that were given to them by their instructors at the time they were given an assignment. This resulted in some portfolio contents that could not be interpreted by the software engineering faculty members during their review of the materials.

3) There was a large degree of variability among the five faculty members who scored each section of each student's portfolio. This appears to have been partially due to the fact that some members of the faculty were very familiar with some of the assignments from which the work displayed by the student resulted while others were not. In addition, variability among faculty members' expectations about minimal, normal and outstanding work in each section of the portfolio appeared to influence the degree of variability.

4) Faculty members reported that they found it very difficult to provide an objective score for each section of each student's portfolio. However, they did report that their overall subjective impression of the quality of each student's total portfolio correlated reasonably well with what they knew of each student's performance in the 2 to 3 courses for which each had been the instructor.

Planned Process Improvements

The software engineering program faculty has decided that we need to make the following changes to the portfolio development and review process based on the lessons learned from this first iteration of the process:

1) Students will be provided with more complete instructions about what should be included in their portfolio and how it should be organized. This will include a one page description of the meaning of each learning outcome. It will specify what we are looking for when

we review and evaluate each section during the student's senior year. Finally, it will contain a list of examples of typical work that should be included in each section.

2) A sample portfolio has been built using materials which are a composite of the materials contained in the first set of portfolios that have been assembled and evaluated. All six students who participated in the first iteration have given their permission for us to use their materials. This sample portfolio will be available for review by both students and faculty when questions arise about appropriate content and organization.

3) A set of rubrics has been developed for use by faculty members when they are scoring the various sections of the portfolio. The rubric for each section is based upon the number of examples of each type contained in each section of the portfolio and the grade awarded by the instructor who taught the course in which the artifact was produced.

4) We may, at some future date, consider using an electronic portfolio to enter, store and review our software engineering portfolios. However, we do not believe that we are currently at a point where that would be practical. As more instructors of both our software engineering courses and the courses that our students take outside the software engineering department come to use on-line course management systems it may become more practical to require our students to submit all of their work to an electronic portfolio system.

Summary and Conclusions

We believe that the process described in this paper for building and assessing learning outcomes in a software engineering program has been the first complete use of student portfolios for that purpose. The learning outlined above and our subsequently developed process improvements will go a long way towards improving and simplifying the process. We believe that, while the process was difficult for our students and our faculty and while there was some uncertainty about the interpretation of the results, it clearly pointed us toward those parts of the program where improvements were needed most urgently. We would encourage other software engineering programs to consider using similar assessment processes and to report their results to the broader software engineering education community.

I would like to thank the members of the Software Engineering faculty and the students at Monmouth University who participated in the first iteration of this process. Their efforts have made this paper possible.

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