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Using Project Portfolios to Assess Design in Materials Science and Engineering

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Abstract

This paper evaluates the effectiveness of capstone design project portfolios as tools to assess student performance with respect to ABET's EC2000 Criterion 3 outcomes. After reviewing the potential for comprehensive review inherent in capstone design projects, the paper describes the project portfolio approach that expands the traditional project report into a broader spectrum of communication activities to more fully capture the design cycle. It provides strategies for meaningfully implementing such assignments and summarizes the results of portfolio use over two years of capstone design sequences in a materials science and engineering curriculum. This approach leverages and expands the kinds of assignments common to many design courses (proposals, progress reports, final reports) to provide assessment information directed specifically to ABET. By carefully designing and evaluating capstone assignments with the full range of Criterion 3 outcomes in mind, departments can provide ample concrete evidence to document student performance.

Introduction: Capstone Design and Assessment

Communication assignments in capstone design courses traditionally range from a single comprehensive final project report (often with extensive appendices) at one end of the spectrum to a series of small documents that include proposals, progress reports, and final reports at the other end. Even in courses that include the full spectrum of written and oral documents, however, assignment design and assessment may not take full advantage of the broad range of information represented by those texts. By explicitly designing a portfolio of writing and speaking assignments to capture and assess student performance across the design process, faculty can create a concrete, measurable representation of student outcomes with respect to ABET a-k. Such portfolios, when combined with targeted assessment rubrics, can provide meaningful avenues to track program development and success over time.

In recent years, these capstone courses have been the subject of extensive discussion among engineering educators. The design, development, teaching, and assessment of these courses have provided a rich focus for presentations at both FIE and ASEE conferences as well as for articles in the *Journal of Engineering Education*, the *International Journal of Engineering Education*, and many disciplinary educational journals. In fact, the subject is so critical to engineering education the *International Journal of Engineering Education* devoted a special double issue to "Design Education for the 21st Century," drawing heavily on the Mudd Design Workshop conducted at Harvey Mudd College in California in 1999,[1] and has continued to publish a special issue for each subsequent biennial Mudd Design Workshop.

Most relevant for this discussion is the literature on design courses and assessment in light of ABET EC2000. As both Phillips and Duron[2] and Doepker[3], among others, note, design courses are particularly well-suited to assessing a large portion of the a-k outcomes of EC 2000 Criteria 3 at both the student and program levels. Though familiar to virtually all engineering educators at this point, the criteria bear repeating here for reference:

(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 system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve 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 engineering solutions in a global, economic, environmental, 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 engineering tools necessary for engineering practice.

While outcome (c) is the one that explicitly addresses design, the value of the course in terms of both student and programmatic assessment reaches far wider. Design courses typically offer a "capstone" experience in which students integrate concepts, techniques, and skills learned throughout the curriculum to complete an independent project. As such, design projects provide a vehicle for assessing student success with respect to many of the outcomes defined by a-k. When taken collectively, the projects also facilitate programmatic assessment across all graduates; by rating individual student performance on projects with respect to specific criteria, programs can average the results as a means to score programmatic success.

In reviewing capstone design courses in light of the Criterion 3 outcomes, Phillips and Duron cite b, c, d, f, and g as relevant to design courses, while Doepker cites a, c, d, e, f, g, and k. Schaeiwitz[4], in a 2002 article, takes the issue a step further and suggests that capstone design courses provide an opportunity to assess all of the a-k outcomes. Such assessment is clearly possible within materials science and engineering programs, where design projects typically require student teams reflect back through their coursework to determine the types of tests needed to evaluate material properties, and to design processes and experiments appropriate for modifying those properties according to defined project criteria. Because the projects draw on the full breadth of student learning, they offer a potential resource for comprehensive assessment of student performance, both individually and programmatically. The project cannot teach all of the relevant issues but, when managed with outcomes assessment in mind, can provide a strong series of data points for evaluating student performance with respect to Criterion 3.

Importantly, the value of capstone courses is not limited to academic assessment. Ronald Rorrer, in a 2003 column, argues convincingly that the capstone design reports can serve as important tools for employers in the hiring process: “When you look to hire an entry-level engineer graduating with a bachelor’s degree for a technical position, you need look no farther than the senior design report,”[5] Rorrer notes, because skimming the report and following up with a few brief questions about the project provides data to evaluate the student’s full range of engineering and professional skills.

Developing an Assessment Mechanism: Project Portfolios

Assessment in Capstone Design Courses: Given the recognized potential of capstone design courses in assessment, the critical question is how to tap such potential in ways that are manageable for both course instructors and assessment personnel. Again, the existing literature provides multiple examples. Doepker[3] provides a model evaluation form to solicit feedback from project clients and advisors; Phillips and Duron[2] suggest similar survey mechanisms. Shaeiwitz[4] expands the discussion to include specific rubrics for assessing the written reports associated with these design projects.

While these mechanisms provide useful strategies that merit further exploration and implementation, each is also limited by what it does not capture. Surveys, though useful for those involved at the time, record only evaluator perceptions and do not provide artifacts that can be re-evaluated later using different criteria or different evaluators. Because they reflect perception, they only indirectly record student performance, and cannot be re-used later to examine outcomes or issues omitted from the original survey. The design reports, of course, do provide artifacts that serve as data for subsequent assessments and allow for longitudinal comparisons by the same evaluators at the same point in time (i.e. a group of evaluators could review a subsample of three years worth of reports to check for improvement, thus providing stronger inter-rater reliability than evaluations done solely on an annual basis).

But design reports alone are also limited in the information they provide, particularly if the reports match common workplace practices. Capstone projects in materials science and engineering that, for example, rely heavily on scientific research, may yield results most appropriate for a journal article rather than for the type of technical design report common in disciplines such as mechanical or chemical engineering. The “design” may test the feasibility of using an existing material in a novel application or evaluate the impact of changes in specified material characteristics on a given property. Such has been the case in the course examined in this study; recent projects include two students investigating the feasibility of using high-temperature superconductors in multi-layered ceramics, two students examining the impact of processing on the in-situ strength distribution of fibers in a matrix, or three students investigating the relationship impact of pore size and film thickness on electrical impedance in nanoporous metals for biomedical applications. In each case, these projects require designing and conducting experiments, teamwork, attention to real-world constraints and impacts, awareness of current issues, the ability to research and apply prior work, and a host of other critical programmatic outcomes defined by a-k. Yet the final report, which would most naturally take the form of an article for the appropriate engineering journal, would necessarily exclude much of process the students enacted, and therefore limit the ability to assess these outcomes.

More industry-oriented projects, in which material selection and/or processing typically forms only part of a larger design project, could further limit the outcomes assessed through the report. For example, students engaged in evaluating multiple materials to select one best suited to a given industrial application would, in the workplace, typically produce a concise recommendation report that outlines the criteria used for the evaluation, briefly describe the testing procedures used, summarizes and compares the results for each material, and persuasively presents the conclusions. Yet the report itself, if suitable for an industrial client, may not address the broader social and environmental issues, describe the distribution of work across the team, include a literature review that reflects lifelong learning, or even accurately suggest the quality of the experimental design.

One possible solution, of course, would be to require an extensive final report that traces the team's entire design process and thus does provide grounds for evaluating multiple outcomes. At 60 pages or more, however, such extensive reports not only place tremendous burdens on course instructors and evaluators, but also fail to reflect current workplace practices. Though long reports do still exist in many places, changing technologies, globalization, time constraints, and related factors are increasingly pushing communication towards shorter documents, executive summaries, and presentations as the primary mechanisms for sharing information. Extended design reports thus become less and less valuable to both faculty and students.

Design Portfolios: Educators in composition and technical communication have long faced similar challenges because the final product (e.g. an essay, a research paper, a technical report) does not accurately reflect the development process. Yet as in engineering design, the process is often most critical, particularly to evaluators, because it more accurately indicates students' mastery of concepts and ability to transfer skills learned in one class to new environments. In response, these fields often rely on portfolios to assess student learning, and extensive research in recent years reflects the effectiveness of this approach. In addition to the broad literature on portfolios in a range of fields, J. Williams[6], C. Scott and C. Plumb[7], and N. Coppola[8] all address portfolios in assessing engineering communication, while K. Alha[9], Y. Bai and R. Pigott[10], and D. W. Dunn, C.R Corletto, and J. L. Kimball[11] look more broadly at the use of various types of portfolios as assessment tools in engineering. Clearly, as with research on the design course itself, research on portfolios with respect to student learning suggests that they can serve an increasingly important function in engineering education.

Portfolios, of course, take a range of formats and structures; in writing courses, where they have seen widespread use, they may include multiple drafts of documents, or a selection of the best work revised multiple times over the course of a semester. In terms of assessing a capstone design sequence, the most useful portfolio structure should gather material representative of the design process itself. This process, particularly as practiced in the workplace, usually involves multiple reports and presentations documenting the project for various stakeholders, including clients, coworkers, and supervisors. A typical workplace document cycle might include the following:

- Project Proposal

- Progress Reports
- Laboratory Notebooks
- Final Technical Report or Journal Article

Note that with the exception of the laboratory notebook, these texts may be either written or oral, and often in the workplace they take both forms. A researcher may visit NSF to discuss her proposal with the program manager prior to sending a formal proposal; a project engineer may send his client a written progress report before following up with a phone call about the project status and immediate concerns. Engaging students in a complete document cycle thus helps them understand more accurately the design process as it occurs in practice, where communication is central at every level. At the same time, by capturing the entire process, the document cycle, properly designed, provides a much fuller mapping of the ABET outcomes, as shown in Table 1:

Table 1: ABET a-k Criteria Mapped to Design Documents

Document	**Key Assignment Elements**	**Criterion 3 Outcomes Addressed**
Proposal	- Take cues from NSF and require information regarding broader impacts and intellectual merit - Include a literature review - Include a project plan and proposed budget	(b) – esp. *designing* experiments; (c) – esp. a recognition of existing constraints; (e) – esp. *identifying* and *formulating* problems; (f); (g); (h) – through broader impact/intellectual merit; (i) –through literature review; (j) – through broader impact/intellectual merit
Progress Reports	- Include a Gantt Chart to monitor progress - Include clear delineations of which team member performed individual tasks - Include discussions of problems encountered and solutions implemented	(a); (b) – particularly *conducting* experiments and analyzing and interpreting results; (d) –through work breakdowns; (e); (g); (i) – through research conducted during the project to address new problems; (k)
Laboratory Notebook	- Provide detailed records of team meetings as well as laboratory work	(b); (f); (k)
Final Report	- Define final structure in terms of appropriate professional models (journal articles, feasibility studies, recommendation reports, etc.)	(a); (b); (c); (e) with respect to *solving* engineering problems; (g); (k)

Importantly, as Table 1 shows, no single document encompasses all of the outcomes – or in some cases, even all of one outcome, but taken collectively, they provide a comprehensive view of each student's ability with respect to EC2000. Consider for example, that with respect to outcome (e), while final reports may address students' ability to solve engineering problems, the proposal reflects their ability to identify and define those problems. Well-designed proposal assignments also ask students to think broadly about the impact of their work and address how it satisfies a current need or contributes to the fields' knowledge, providing critical data for evaluating (h) and (j). Defining this broader impact is particularly useful for materials students who may still be learning the role of their profession in the broader engineering workplace. Given that materials engineers, unlike other disciplines, rarely produce end products, broader impacts may be less obvious throughout curricula. But by asking students to situate their work on specific material properties or processes within the context of larger engineering problems, proposals can help students see the potential impact of their work as it contributes to larger social, environmental, or economic concerns.

Similarly, progress reports that break down the work completed by each group member provide accurate pictures of teamwork across the project, especially when coupled with individual laboratory notebooks that record each member's work as well as any notes on group meetings. Given that much of a materials engineer's work occurs in the laboratory, texts that chart that work – including false starts, refined experimental plans, repeated data sets, and the like – represent important sites for evaluating (b), (d), and (k) in particular.

Oral versions of these texts provide further opportunities for faculty to evaluate student performance. For example, questions about a project plan during the Proposal Review can help evaluate how well student understand the constraints of their problem; questions directed towards individual students during oral Progress Reports can help evaluate individual contributions. Such avenues may limit the opportunity for archived results or longitudinal review, but videotaping presentations and collecting PowerPoint printouts are two increasingly popular options for archival data.

The portfolio approach thus provides faculty, administrators, advisory boards, and other interested parties with a broad range of outcomes-based data for evaluating student performance. A series of texts that track student work throughout a project and thus represent the full design cycle illustrate far more than students' abilities to "design a system, component, or process to meet desired needs within realistic constraints. . . ."

Assessment By Design

While such portfolios have the potential to provide comprehensive a-k assessment, that potential is realized only by explicitly designing assignments, and specifically grading rubrics, with the assessment goals in mind. Thus even capstone courses that already include a full document cycle may benefit from re-examining their grading rubrics and mapping the grading criteria to the full range of a-k outcomes suggested by Table 1. By designing rubrics that assess these texts in light of the outcomes themselves, faculty can gather a rich data set for student and programmatic evaluation.

Design assignments and grading rubrics to match assessment goals: While it is often tempting for faculty to respond in detail to every element of a group's document – be it the progress report or the proposal – in most cases, everyone's time is best spent by focusing specifically on those issues most directly addressed by the document at hand. Thus a proposal may be graded in terms of the merit of the project, the team's understanding of the project's broader impact, and the soundness of the project plan, with a grading rubric matched to specific programmatic outcomes. Similarly, instructors may grade (and respond to) progress reports solely in terms of how effectively they enable the course instructor to a) understand who on the team is responsible for what work and b) evaluate how the team is identifying and responding to problems encountered along the way in the design process. Faculty may skim laboratory notebooks to determine whether students appear to be recording all procedures and data appropriately.

Importantly, rather than writing copious comments throughout a document, or editing students' prose, instructors can develop checklists with specific criteria for individual documents, and then respond to the documents only in terms of the criteria at hand. The criteria for a progress report might rate the following elements on a numeric scale:

- Quality of the teamwork evidenced in the workload distribution (outcome d)
- Extent to which the report identifies problems encountered to date and provides reasonable solutions (outcome e)
- Quality of additional research conducted throughout the project to gather needed information (outcome i)
- Quality of the preliminary analyses and subsequent project modifications (outcome b, e)

As noted in the list, faculty can readily map such grading criteria directly to a-k to provide a numerical rating of student outcomes; averaging the performance of all students across a given criteria provides a basis for programmatic assessment and allows faculty to identify common areas of both strengths and weaknesses.

Detailed checklists of the grading criteria, once developed, thus serve a range of purposes. First, and most notably for this discussion, they provide a defined measure of student performance with respect to those outcomes targeted for ABET assessment. Second, they provide a clear contract between faculty and students to help students understand both the expectations for the assignment at hand and, when linked to a-k, the role of that assignment in achieving and/or reflecting the broader educational goals of the program. Finally, such rubrics also greatly streamline the grading process itself by codifying comments and concerns.

Implementation: Managing Workloads

One of the most pressing issues raised by this portfolio approach is the work involved in teaching, gathering, and evaluating a complete document cycle. Several strategies, however, can help not only minimize the work required of the course instructor, but actually enable the documents to productively contribute to the course management:

Limit the number of projects: In terms of sheer numbers, the typically small size of materials departments gives them a distinct advantage over other programs in implementing project portfolios. With typical class sizes in the 20s and 30s, instructors can create teams of 2-4 and thus manage fewer than 10 projects at a time. A smaller number of projects not only minimizes the workload, but also allows the course instructor to provide stronger and more detailed student feedback concerning both the technical and non-technical aspects of the work. Moreover, responding to 8 progress reports is a far less intimidating prospect than responding to 30.

Limit the number of graded assignments: Even when a course includes many different writing and speaking assignments, not every document or presentation needs to be graded with the same degree of scrutiny. The proposal and final report, for instance, may be weighted quite heavily, but the progress reports and laboratory notebooks may count as homework grades and require far less attention.

Make grading rubrics manageable: Because grading is often the most time-consuming part of implementing project portfolios, developing targeting grading rubrics, as described above, is critical to maintaining a manageable workload. Importantly, while such rubrics may include basic writing issues – grammatical correctness, for example –often those issues are subordinate to the larger communication goals of the document and may not require extensive comment or evaluation. As with any document, instructors should focus on identifying rather than resolving (editing) weak areas. Most importantly, instructors should limit the rubric to those elements most critical to the assignment itself and the outcomes being evaluated, and grade accordingly. Such focused rubrics not only limit the faculty time required for effective responses, but help students focus their energies on learning to communicate specific kinds of information for concrete goals with respect to a given project.

Provide document formats to support the document goals: A number of web and print resources provide formats for common documents such as proposals and progress reports that can serve as useful starting points for course assignments. But instructors should always adapt those formats to best suit the issues they seek to evaluate. Consider, for example, the NSF proposal familiar to many faculty: NSF evaluates proposals based on broader impact and intellectual merit, and the proposal guide now specifies that those two items should be clearly and individually identified in the 1-page project summary. Faculty may place similar constraints on their project proposals. In the same way, an instructor who wants to use the progress report to evaluate teamwork may require a table defining who did what during the reporting period. Explaining to students both how to organize information and what purposes that structure serves helps them not only produce documents that accomplish the instructor's goals, but also more accurately understand how documents function outside the classroom, again increasing student learning and course effectiveness.

In the same vein, instructors can limit document length based on their own available time and energy. Many managers ask for 1-page progress reports on major projects; NSF proposals for major engineering research are limited to 15 pages. Similarly, in design courses, proposals for student projects may reasonably be limited to 10 double-spaced pages; progress reports may be no more than 3 pages and still provide adequate information for evaluation. Moreover, a series of short reports throughout the project can also limit the length of the final report, and thus spread the grading out rather than require endless hours at the end of a semester to read 60-page final reports. This distributed workload can help both students and faculty manage course communication more effectively.

Encourage students to use multiple documents as building blocks: As in any project cycle, each document is not a "new" thing, but rather an extension of previously written work. Thus, a literature review in the proposal may provide much of the text for the introduction of the final report; similarly, discussions of individual results across progress reports can be gathered and compiled for the final report. By not only allowing but encouraging students to re-use their own work, faculty can limit the amount of "new" reading required for any one document and also give students a chance (based on prior feedback) to work through revisions of individual elements to produce more effective final reports. A "work completed" section in a progress report, for example, can also serve as a rough draft for the "results" section of the final report; instructors can identify weaknesses in writing and analysis regarding a single test or set of tests, and students can use that evaluation as the basis for improvement when writing the next set of analyses. The final report can thus incorporate a range of previously reviewed and revised results. Similarly, a proposal summary can be revised based on instructor feedback to create the introduction to the final report.

Use documents as project management tools: In many capstone design courses, the instructor functions in part as a project manager, helping students stay on track, solve problems, and complete projects on time. Proposals, progress reports, and laboratory notebooks help faculty address problems early in course of a given project, and thus, as in the workplace, can serve as important management tools. By using written and oral texts in this way, faculty not only give themselves a clear picture of each student project, but they also provide students with a clear picture of the ways in which many corporate workplaces function.

Results from Field Studies

Data collected from two recent capstone design sequences (2003-04 and 2004-05 – in process) in materials science and engineering bears out the value of the portfolios as assessment tools. The course, taught in the Materials Science and Engineering Department at Virginia Tech, is a two-semester sequence in which students work in teams of 2-3 with a faculty advisor (not the course instructor) to develop and conduct a research/design project. The course instructors provide classroom instruction on project management, present and evaluate communication assignments, and provide limited technical feedback on the design process itself.

The projects span the full range of materials science and engineering applications. Some teams work with outside clients (e.g. testing various metals to determine the optimum choice for a new machine design; selecting the material most appropriate for the College of Engineering's Human Powered Submarine project); some work on projects more closely related to their advisors' research efforts (e.g. designing a more efficient test package for LED research towards solid-state lighting; testing a specific set of light-curing resins as possible replacements for cyanoacrylate in medical procedures); still others build on prior design projects or develop their own novel projects (evaluating the effects of material characteristics on electrical performance in nanoporous metals; seeking alternatives to asbestos insulation in steam pipes).

Over the course of the year, each team writes a formal proposal, undergoes an oral project plan/proposal review, writes 3-4 progress reports, presents 3-4 oral progress reports, writes a "fall report" in December that summarizes the semester's work, writes a final report appropriate to the nature of the project, and presents the results of their work to the entire faculty. Together these texts comprise a comprehensive project portfolio. In previous years, all documents have been collected and graded during the course, but only the final report has been retained (it is a required element in students' Engineering Communication Portfolio). Beginning with the 2004-

05 class, the entire project portfolio will be maintained electronically through the university's e-Portfolio system (VTeP)[12]; though this system is still under development, it should streamline the process of archiving and retrieving project documentation for course and programmatic review.

A review of the documents collected to date supports the claim that the full portfolio, rather than a single final report, provides the clearest picture of student ability with respect to program outcomes. The following examples highlight critical information missing from final reports and presentations, yet central to assessing student performance with respect to a-k:

- A team examining the feasibility of developing a particular metal matrix composite via tape casting wrote a very successful final report, yet the report failed to illustrate the weakness of their experimental plan in creating a formula for the tape itself. The final report effectively summarized what their research showed, but only the progress reports – with copious detail about the problems encountered in the tape-casting process – highlighted the "scattershot" experimental approach and the missed opportunities for learning critical information about their material and its processing patterns. Thus while based on the final report, the team might receive high marks for the ability to design/conduct experiments and interpret/analyze results (outcome b), the progress reports point to a much weaker set of skills in this area.
- Two groups in the 04-05 course have had problems obtaining materials from suppliers, as documented in their progress reports. One group has developed effective strategies both for persistently contacting the supply (ability to communicate – outcome g) and for wisely using the time to master the techniques needed for their project using less expensive, readily available material (learning new skills – i, and using modern tools, k). The other group has done little to prod the supplier and little to advance their project. Only the progress reports reflect the differences in the ways these two groups designed and conducted experiments in the face of difficulties and learned (or failed to learn) the techniques needed for subsequent research.
- A team working on light-curing resins in medical applications provided a detailed discussion of the medical conditions and procedures related to their investigation, demonstrating their understanding of the impact of their work on contemporary social issues (h, j). The final report, however, geared towards an academic journal, will contain little or none of this information because the project itself focuses quite narrowly on the impact of resin viscosity on several critical mechanical characteristics. Similarly, a team examining factors influencing electrical impedance in nanoporous metals included a discussion of the use of nanoporous platinum in pacemakers, as well as other potential applications. Again, however, the final article written for a journal will exclude those components of the proposal's literature review because again, the project itself deals with the impact of a very narrow set of material properties on impedance.
- In a team with one quiet and one talkative member, the oral presentations and informal meetings could easily suggest that the one talkative team member shouldered most of the project work because he was more comfortable speaking. Yet the progress reports, which break down the work done by each team member, indicated the shared nature of the effort and provided ample evidence of significant contributions by the quieter teammate.

These examples suggest a range of ways in which a single document fails to capture the range of skills demonstrated throughout a capstone design project; in almost every case, significant information appears in early documents that ultimately have no place in the project's final report.

In addition to these cases, student responses on end-of-semester and end-of-year surveys bear out the ways in which these documents support elements of the a-k criteria. For instance, many of the comments concerning proposals reflect the ways in which students used them to "identify and define . . . engineering problems":

- "I think the proposal sets the work environment [at] the beginning [of the project] and gives us an idea of how to come out with a plan of action for a defined problem."
- "The proposal & project plan review forced us to define our plan."
- "I thought the written proposal helped us to pinpoint what we were trying to do."
- "Writing the proposal was needed to set clear goals and make sure we knew what we needed to do."

Similarly, comments on the progress reports reflect the ways in which the documents helped students deal with problems as they arose, monitor progress and adjust schedules and work plans accordingly, and make sure everyone on the team stays on the same page. Students also report using early texts (including lab notebooks) to construct final reports; one student noted that the "progress report and proposal pretty much compiled into the fall report" and another anticipates far less stress in writing the final report because many of the pieces are already in place. Equally important, students rated the various assignments highly in terms of their usefulness in completing (03-04 course) or working on (04-05 course) the project; on a scale of 1-5 (with 5 as "extremely useful"), students ranked the overall usefulness of all assignments at just under 4; class averages for the proposals were highest at 4.65 (03-04) and 4.38 (04-05) (note that because of small sample sizes, the statistical significance of any differences from one year to the next is negligible and a single outlier in any one category notably distorts the average; the numerical data provides a relative guide rather than an absolute measure).

In terms of continuous improvement, the survey data also point to key pedagogical weaknesses in the current course. Students typically rank oral reports as less useful than written reports for defining and managing their projects, suggesting that the reports are not being used as fully as possible in the course. Though almost all recognize the long-term value of oral reports based on what they expect in the workplace, they see those discussions as less productive in terms of their own work. Subsequent revisions to the course will thus incorporate strategies for helping students learn to use presentations to effectively locate and summarize the most critical elements in their work.

Future Work

The next steps in this study are as follows:

- Refine grading rubrics based on current models to more accurately capture a-k outcomes.
- Continue to gather survey data from students regarding the use of the design documents in project definition, execution, and management.
- In summer 2005, compile grade and outcome data from the two study years to assess programmatic success.
- Involve outside reviewers, including both engineering faculty and industry representatives, to deepen the quality of the portfolio evaluation.
- Refine the use of electronic portfolios as archival tools for project documentation.

- Compare results from the portfolio assessment model to a quantitative grade-based model being developed by the department. Beginning summer 2005, we will have a comprehensive numerical rating for each student's performance on a-k. This rating is developed through a matrix matching class performance to specific outcomes. The two models (portfolio and grade-based) will be compared to provide data on the effectiveness of the two approaches.

These steps should more fully take advantage of the project portfolio as an assessment tool and provide data for further study on the system's effectiveness. With the next ABET assessment scheduled for 2007, these portfolios will form a critical element in the department's ongoing assessment plan. As these portfolios assessments were not available at the most recent ABET visit, no data is yet available on the effectiveness of this approach in preparing for the assessment and documenting student outcomes.

Conclusion: Using Project Portfolios for Assessment

Based on existing literature about the value of capstone design courses and portfolios in student assessment, as well as the results of case studies in materials science courses, project portfolios that encompass not only final reports but also supporting texts such as proposals and progress reports provide useful tools for evaluating student outcomes not only with respect to design (ABET criteria c), but with respect to all of the a-k outcomes. In materials science and engineering in particular, where much of the engineering involved occurs in laboratories as students design and redesign experiments, master techniques, and discover novel solutions to problems, these portfolios help more accurately represent the full spectrum of student abilities with respect to their professional development. By effectively designing assignments and grading rubrics targeted to ABET assessment, faculty can help students develop project portfolios that provide a comprehensive reflection of a-k outcomes.

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