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The Engineering Portfolio: Communication, Reflection, and Student Learning Outcomes Assessment*

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According to the Accreditation Board for Engineering and Technology, portfolios are one possible data collection method that engineering programs may use to document student learning outcomes. Despite the apparent endorsement by ABET of portfolios, ABET materials offer little concrete description of how the portfolio concept should be adapted to the documentation of engineering students' learning. This article traces the development of portfolios in the field of writing assessment and then discusses how portfolios are being adapted in engineering education. The documentation of learning outcomes in communication is the test case used to show the five necessary steps in portfolio development and maintenance: defining engineering communication (or any other learning objective); identifying appropriate skills and mapping them in the curriculum they are currently (or should be) developed; correlating portfolio learning objectives to course and program objectives; facilitating opportunities for students to reflect on their learning; and assessing student learning so that students, faculty, and programs can benefit and improve.

INTRODUCTION

IN A RECENT article entitled 'The View from the Top: Leaders' Perspectives on a Decade of Change in Engineering Education,' researchers at the Pennsylvania State University's Center for the Study of Higher Education interviewed 27 national leaders in engineering education to determine what they believe are 'the two most significant changes in the field of engineering education during the last decade' [1]. Their top five responses will not surprise anyone who has been involved in engineering education for the last ten years: design, emphasis on effective teaching, computer technology, broad-based curriculum, and, last but certainly not least, accreditation/assessment. Accreditation and assessment actually ranked higher among some of the faculty, deans, and industry representatives who were interviewed for the study; according to one industry representative, the 'number one [change] would have to be the ABET engineering criteria because that actually changes the way that programs are evaluated and changes the way courses are put together'. Rather than looking upon ABET and EC 2000, however, as insurmountable obstacles that restrain engineering programs and circumscribe faculty, one interviewee claimed that the new accreditation policies 'allow much more flexibility and encourage innovation and also accountability' in engineering programs. Interestingly, the group of 27 shared a common view with regard to implementing changes for the future. Each of the five changes, they argued, must be accompanied by changes for faculty in the promotion and tenure structure, as well as increasing opportunities for additional training so faculty can incorporate new teaching and learning strategies in their classrooms.

While only a handful of engineering programs have been accredited under the new criteria to date, innovation, accountability, and flexibility remain the watchwords that ABET uses to sell EC 2000 to engineering faculty, department heads, and deans. In particular, language used in Criteria 3: Program Outcomes and Objectives (see Table 1) seems, at first, quite open-ended.

As a result, ABET provides engineering programs the opportunity to define themselves, their students, and their methods of data collection.

> 'Evidence must be given that the results [of program assessment] are applied to the further development and improvement of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program, including those listed above [ABET a–k, see Table 1], are being measured. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates' [2] (my emphasis).

The authors of the ABET materials shown above are careful to state that evidence collection 'may

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Table 1. EC 2000 Criterion 3: program outcomes and assessment [2]

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
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 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

include . . . but is not limited to' the methods listed. Unfortunately, given that engineering programs are struggling to accommodate the new accreditation process, faculty have latched on desperately to ABET's suggestions. Not surprisingly, since they are first in the list, portfolios have garnered a prodigious share of attention as engineering faculty charged with developing assessment plans have attempted to figure out exactly, to use their words, what ABET wants.

'What does ABET want?' has become a common refrain among engineering faculty charged with developing assessment plans for their departments. During the Best Assessment Processes Conference III, held at Rose-Hulman Institute of Technology in April 2000, for example, one panel responded directly to that recurrent question: 'Lessons Learned During EC 2000 Visits,' moderated by Richard Seagrave, past chair of the Engineering Accreditation Commission (EAC) and Distinguished Professor of Chemical Engineering at Iowa State. Panel members included EAC team chairs and program representatives from engineering programs that had already experienced accreditation visits under the EC 2000 standards. During the session, Seagrave 'asked each panelist from their perspective to name three good things and three things needing improvement' in ABET evaluators' site visits. With much candor and some humor, the panelists confirmed what the EAC is discovering through its own feedback mechanisms during this phase-in period [3]:

- Just do it! [referring to assessment]
- Be creative! Take risks! Experiment with new ways to teach and learn!
- Be consistent! [from the web site through the self-study to the on-site visit]
- EC 2000 provides opportunity for innovation and program improvement.
- Faculty needs to get involved.
- Focus on the trees instead of the forest!

From engineering faculty presenters who had either survived an EC 2000 visit or were working as site visitors (those who go to the campus and evaluate the department), the response was always the same: you have to decide for yourself which criteria are important for your department, how you are going to measure them, how you are going to collect evidence of student learning, and how you will feed data back into your program in order to improve it. Counting required courses will not, it was agreed, suffice in proving that the program's graduates have the skills necessary to work effectively in 21st century technological industries.

In many ways, then, ABET has created a double-bind for faculty: in order to receive accreditation under EC 2000, they must create a legitimate assessment process but the materials provided by ABET do not offer much concrete guidance. While the national effort to improve students' skills (both in communication and the other objective areas) are laudable, many engineering programs encounter difficulties with assessment plan development, particularly after deciding to use portfolios to document student learning. The move to portfolios was clearly inspired by ABET documentation that cited portfolios as one means of data collection. In response, engineering programs have attempted to use portfolios for data collection, but often the results are mixed. Faculty complain of increased workloads, students do not see the correlation between course goals and portfolio objectives, and administrators envision portfolios as merely another means of grading student work. I contend that if portfolios are to be of use to engineering programs, to improve both faculty pedagogy and student learning, then we need to devise a portfolio that meets the needs of engineering education. By this I mean that many of the portfolio models we are working from come from the language arts and education fields; while these portfolios meet the needs of certain faculty and students, they are less applicable to engineering students, faculty, and programs.

In designing an engineering portfolio, I believe we can, however, adopt several portfolio principles that seem to be common across disciplines. For the purposes of this paper, I am focusing on documentation of student learning in communication, but I have evidence from the portfolio project at my institution that an engineering portfolio can be used to document student learning in more technical areas, such as engineering practice, experiments, design, and so on. At first glance, assessing student learning outcomes in communication effectiveness via a portfolio would seem an easy task. For some engineering departments, good communication is distilled in the instruction to students that they must write and speak 'clearly' in order to 'communicate effectively.' For others, good communication is defined by the department writing manual and can be assessed by counting up the number of grammatical errors in a document. Unfortunately, these two definitions lead students into misapprehensions regarding what constitutes effective engineering communication, how they should develop those skills, and how their skills will be assessed. In addition, further misunderstanding is caused by collecting a student's work into a manila folder portfolio that is buried in a department storage room, never to be viewed again until ABET evaluators appear on campus.

What follows in this paper is a set of design principles that can assist engineering faculty who wish to explore the possibilities offered by engineering portfolios. Since engineering portfolios at several institutions are still relatively new, the design principles are subject to change; in fact, as more programs experiment with them, I expect that we will be able to share information regarding what does and does not work.

Engineering portfolio development should be based on five principles, a foundation that will ensure that, once in place, portfolios function effectively and produce information that is useful to students and faculty. Given my project here, I have related the principles to engineering communication:

- **Defining** engineering communication (or any other learning objective).
- **Identifying** appropriate skills and mapping them in the curriculum where they are currently (or should be) developed.
- **Correlating** portfolio learning objectives to course and program objectives.
- **Facilitating** opportunities for students to reflect on their learning.
- **Assessing** student learning so that students, faculty, and programs can benefit and improve.

This paper will address these five principles in order to offer faculty guidance in assessment plan development and maintenance.

PORTFOLIOS IN WRITING AND IN ENGINEERING

The history of portfolios in the context of engineering education assessment has been brief. Portfolios have had a longer history in other fields, such as architecture and art, where every student collects samples of his/her best work into a portfolio for the purpose of evaluation by a teacher or review by a prospective employer. While this portfolio concept has some bearing on engineering portfolios, the portfolio model drawn from most often in engineering is the writing portfolio that was initially developed at the elementary and secondary education levels. Calfee and Freedman recount the beginnings of the Bay Area Writing Project in 1972 and the National Writing Project in 1974 as projects that changed the course of writing assessment and brought portfolios to the fore [4]. In response to demands by administrators and politicians that schools be held accountable for student achievement, participants in a series of summer institutes sponsored by NWP devised an alternative assessment strategy to standardized testing. The alternative assessment reflected more accurately the innate nature of the writing process. In a standardized test, a student's abilities are not assessed authentically; the student writes to a prompt, has no time to write and revise, and often writes more poorly than authentic assessment would indicate [5]. Portfolios offered an important alternative. Students collected samples of their writing that were created over time—a semester, a year, or the student's entire elementary school career.

The writing was done in the context of real assignments, rather than as a response to an artificial prompt; for example, students might collect several different essays that were written for different courses, rather than completing a timed essay on one academic subject. Students were encouraged to revise their work, and then to select their best work for inclusion in the portfolio. As a result, evaluators were able to assess students' abilities more accurately, while students were given the chance to reflect on their learning through the process of revision and portfolio selection.

From these early experiments in writing portfolios, a common definition of portfolios has emerged [6]:

> 'A portfolio is a *purposeful* collection of student work that exhibits to the student (and/or others) the student's *efforts, progress*, or *achievement* in given areas. This collection must include: student participation in selection of portfolio content; the criteria for selection; the criteria for judging merit; and evidence of student self-reflection.'

Given their promise of authentic assessment, as well as increasing demands for accountability in higher education, it is not surprising that portfolios have also been used for writing assessment at the college level [5].

College and university educators have also seen the benefits to students that are the hallmarks of portfolio practice:

- the opportunity for reflecting on his/her own writing process;
- the picture of his/her progress in writing over time;
- the portfolio as a showcase of his/her best work.

How then did the portfolio method gain interest in the field of engineering education?

DEFINING ENGINEERING COMMUNICATION

The call for engineering graduates who possess effective communication skills represents a significant dimension of current industrial and accreditation demands. The call is not, however, new and may be traced to calls for engineering curricular reform from the 1950's and earlier [7–11]. Historically, industry has exhibited a recurrent interest in ensuring that the engineers they hire possess communication skills that will serve their technical work. And yet, even the language with which this demand is expressed, for example in EC 2000, creates an inaccurate picture of what constitutes successful writing and speaking. 'The ability to communicate effectively' suggests that engineering communication is itself uniform, no matter whether one is writing a report to electrical engineers or giving a presentation to design clients [12].

Consider the following comparison: Analyze three different articles from three different engineering journals and magazines, for instance, an article on materials failure from *Handbook of Case Histories in Failure Analysis* published by ASM International, a conference paper on the subject of DVD from the IEEE Transactions on Consumer Electronics, and a Student Research Award article in the Doctoral Degree Candidate Category from proceedings of the Society for Biomaterials. The significant differences in engineering communication—word choice, arrangement of information, level of detail, style, and so on—will be apparent even in the articles' abstracts. The elements that constitute effective communication in each discipline are certainly second nature to the engineering practitioner in the field, either the professional or the academic engineer. The conventions are also obvious when one performs the side-by-side comparison. Unfortunately, students are not often asked to adopt this kind of analytical, rhetorical perspective as they develop their communication skills; in addition, since the engineering practitioner takes these conventions for granted, he or she may not highlight these elements that actually constitute 'effective communication' for students. In fact, the current trend to incorporate communication tasks into engineering courses, while in itself a positive curricular change, has often taken the form of focus on grammar, mechanics, and punctuation, rather than the critical thinking and audience analysis that underlies truly effective engineering communication.

In order to lay the foundation for successful communication skills development, I would argue, the faculty responsible must first define engineering communication as it is appropriate for the specific discipline and context in which it will be used. Such grounding of communication has been the subject of recent studies in the field of technical communication. Using principles of genre theory and situated learning, Artemeva, Logie, and St-Martin, for example, designed a discipline-specific communication course for engineering students at Carleton University [13]. The major goals of the course are as follows:

> To facilitate the acquisition of rhetorical skills and strategies necessary for students to successfully integrate into their engineering school environment and to facilitate their transition to the workplace. These skills and strategies are acquired through typified writing practices [memos, reports, RFPs] in situated contexts of the engineering discipline, interactions with existing texts, and interactions with relatively experienced writers . . .

Noting that 'conventional pedagogical discussions of technical communication often overlook the social forces that affect the engineers' and engineering students' views of rhetoric,' faculty defined engineering communication in this course by assuming that disciplinary knowledge in all fields is 'negotiated between people rather than passed from one to another.' As a result, course components were designed to allow students to 'develop an understanding of audience and purpose through the exchange of written and oral feedback, the analysis of existing documents, and audience proximity' in an attempt to 'overcome the challenges that teaching writing to engineering students presents.' Additionally, the March 1999 issue of *IEEE Transactions in Professional Communication* focused on the role of engineering genres; according to the editor, the purpose of the special issue is 'to locate what is particular to each kind of writing and what skills and knowledge students need in order to be able to communicate effectively within each kind' [14].

I would contend that defining each learning outcome for an engineering program is a crucial first step in revising a curriculum, developing courses, and creating a useful portfolio as part of an assessment plan . Definitions need to be shared by faculty teaching in the program, and so generating them together can establish shared notions of exactly what the program is attempting to develop in its graduates. Essentially, faculty must ask themselves the question, what constitutes effective engineering communication within our discipline? I suggest that the easiest way to answer the question is to ask each faculty member to share a piece of writing that he or she believes is a good example of engineering communication. This may be a piece that the faculty member has written, or an article or report that he or she has encountered in either professional or academic practice. The results of such collecting are often surprising: despite the diverse genres or kinds of writing the faculty may bring to the discussion, these pieces often have more common features than one would initially expect. The exercise of defining engineering communication should demonstrate to participants that they know good communication when they see it and they share a common notion. These definitions should also be shared across departments, so that engineers in different departments can understand the disciplinary differences that obtain between chemical engineering communication, civil engineering communication, mechanical engineering communication, and so on. In addition, this exercise fulfills an important ABET criterion, in that each program must define the criteria appropriately for its own department, recognizing its mission, goals, objectives, and focus in educating students.

The process of defining engineering communication is not an exercise for faculty only. This information must be shared with students, so they too can recognize the elements of effective engineering communication. Students will likely want to know the bottom line: what do you want, may be their question. And they should be told what features should be included in their writing, i.e. standard memo format, appendices that include tabled data in a design report, etc.

Faculty should resist, however, allowing students to believe that following a format is the only requirement for producing effective engineering communication. A faculty member's focus should also be on the context in which the writing is completed: who the audience is, what information the audience needs, what constraints the document must follow, what reactions the information may produce. Students should be allowed to study models of effective engineering communication, and class time should be spent discussing and analyzing the models. Unfortunately, merely instructing the students to 'follow the department writing manual' will ensure that the faculty member receives identical assignments that show minimal engagement by the students in either the written or technical dimension of the assignment.

In order to remain true to this article's focus, I also wish to stress the significance of defining activities for all learning outcomes. Whether the portfolio will assess communication or ethics, design or experiments, the same process should be followed. Only by defining what constitutes the particular learning outcome for the engineering program can portfolios be useful to students and faculty alike.

IDENTIFYING MAPPING APPROPRIATE SKILLS

Given the promise of engineering portfolios for data collection and evaluation, faculty are often tempted to demand that portfolios do it all. In other words, faculty expect that a student's portfolio will transform him or her into a professional engineer after one course. If, in the case of communication, the portfolio does not show that the student knows how to handle every communication situation with the appropriate format, audience analysis, and grammar, then the portfolio project is itself a failure. I would argue that such disappointment is a failure on the part of faculty who overestimate what a portfolio can do, rather than an inherent flaw in the portfolio itself.

Like technical skills, communication skills must develop in stages, from understanding basic principles to applying those principles to a variety of communication situations. For this reason, faculty should identify the skills set they wish students to develop but also specify the courses and stages in the curriculum where this development will take place. This specification begins with defining engineering communication and then identifying the places within the curriculum where the specific elements of communication will be stressed. The same mapping should be done for all skills that an engineering program wishes its graduates to possess.

One way to accomplish this identification is via a curriculum map. In the case of Rose-Hulman Institute of Technology, the Curriculum Map project was established in conjunction with the RosE-Portfolio, the electronic portfolio system that we began developing in 1996. Faculty are asked to use an electronic system to record three data points. Using the list of nine objectives that constitute the Institute's student learning outcomes, faculty are asked to respond to the following three questions:

- Is this learning objective a stated goal of your course?
- Are students asked to document their learning regarding this objective during the course?
- Are students given feedback on their work toward this objective during the course?

Analysis of the results of the Curriculum Map reveals exactly where students are provided with opportunities to develop their skills, the classes in which these opportunities occur, and when students receive feedback about their work. The data provided by faculty has also shown us specific gaps in the curriculum. For example, students have the opportunity to work on their communication skills in the freshman and junior year (via the first-year composition course and third-year technical communication course), but there is no consistent opportunity for students to reinforce those skills in their sophomore year. A yearlong gap in communication skills development opportunities contributes to a significant deterioration of the skills base that students established in their first year. We are currently in the process of identifying courses in the sophomore year that could, with minor content revision, provide the necessary reinforcement.

Faculty may also approach the task of identifying skills via course development. Gruber, Larson, Scott, and Neville, for instance, have developed a sequence of four courses that span the four-year engineering program at Northern Arizona University. The purpose of the *Design4Practice* curriculum is to 'prepare students for future jobs by emphasizing, throughout their four years in college, engineering attributes considered important by industry' [15]. The authors contrast their course sequence to the traditional curriculum, in which professional skills like communication and design are not included until the capstone design course, a point at which a host of skills must be applied simultaneously:

> 'The new courses [in the *Design4Practice* sequence] are structured around the design cycle to emphasize

> process over product not only in the technical areas but also in the communicative processes. Instructors use real, hands-on problems to convey technical and professional content to the student and to create a situated-learning environment and promote the socialization of learners into a specific discourse community. All courses are taught by cross-disciplinary teams of faculty and industry representatives. In addition, instructors require students to work on both large and small cross-disciplinary teams and integrate and synthesize the technical knowledge learned in traditional courses. Most importantly, students are encouraged to develop managerial and professional skills with an emphasis on verbal communication and technical writing.

Whether the faculty focus on established courses or on the development of a new course sequence, they must plot out specific sets of skills at specific points in the curriculum in order for portfolios to function accurately, efficiently, and effectively.

While identifying and mapping are important steps in the development process, attention must also be paid to the data collection method selected to document student learning. Even though ABET has listed portfolios as a possible data collection method, this does not mean that portfolios are right for every student and every engineering program.

CORRELATING OBJECTIVES

Given that engineering portfolios are still in an early stage of development, they can often be misused or misapplied to learning situations. Unfortunately such misuses may ultimately threaten the future of engineering portfolios. If faculty believe that portfolios are merely tacked onto existing courses in order to fulfill the accreditation demands of higher powers, if students believe that portfolios are simply busywork that has nothing to do with learning, then portfolios will never become a part of the engineering education culture. For these reasons, I believe we must demonstrate the efficacy of portfolios to faculty pedagogy and student learning. The way to accomplish this is to correlate portfolio objectives to objectives/goals of an engineering course or program.

First let me define what correlation does *not* mean. Correlation does not mean adding a portfolio to an existing course and using it merely as a new means of collecting students' homework. Correlation does not consist of requiring students to place particular materials into a manila folder that then goes into departmental archives never to be unearthed until ABET evaluators appear on the scene. Correlation means ensuring that, for the student, the engineering portfolio is an ongoing project, a part of his or her learning experience, a changing artifact that looks different from year to year, and a dynamic object that is useful in the individual's academic and professional life. For the faculty member, the engineering portfolio is a key component of his or her pedagogy, a way of teaching that encourages reflection and critical thinking, and helps the faculty member draw clear relations between classroom practice and engineering applications.

Correlation can take place at two levels. Having followed the earlier stages of defining communication and identifying appropriate skills, then the third stage of correlating objectives will be easy to accomplish. Each faculty member will have shared in defining communication for his or her course and department. The learning objectives for his or her course will have been part of identifying skills and where they will be taught in the curriculum. The work that precedes correlation is thus preparation for establishing what documentation the portfolio should contain, since the evidence in the portfolio will show the student's progress toward a particular set of objectives.

There are two valid approaches to determining what will be collected in the portfolio: the course instructor can require that certain documents, assignments, project, and reports are included; or the student can decide what materials showcase his/her best work. The first option is quite appropriate for a class portfolio that is documenting a student's learning in a particular class. Even if the faculty member determines the portfolio contents, however, he/she should invite student feedback regarding the appropriateness of these decisions. From feedback I received from engineering students in the Technical Communication course, I realized that students wished to include more evidence of their work, not only the final research report that was required.

Instructors will make students feel more engaged in the portfolio process if they have some say in what goes into the portfolio. At the program assessment level, it may be sufficient to allow students to decide for themselves what materials represent the best evidence that they are meeting the objectives of the department. In this case, the student takes full ownership for his/her portfolio; in addition, because the portfolio is based on a showcase principle, the portfolio is an effective job searching tool that each student can use when meeting with industrial recruiters [16]. A student can make a better case for the superiority of his/her communication skills when he/she can provide documentation of those skills with his/her portfolio.

FACILITATING REFLECTION

Unlike surveys, standardized tests, or other data collection methods, engineering portfolios offer students the opportunity to reflect on their learning. We should not underestimate the importance of reflection as a dimension of learning, and we should also recognize how infrequently such reflection is part of the undergraduate engineering student's experience. The best students are constantly reflecting on their learning. They are the students who set goals for themselves, take notes, write in journals, and generally self-assess throughout their education. For the majority of students, however, reflection is not something they do naturally, and the rigors of an engineering curriculum leave little room for it. In fact, the traditional engineering curricula encourage just the opposite behavior; students are rewarded for memorizing formulas and spitting back the lecture notes, rather than making connections, reflecting on what their learning means, and deciding which areas in their learning need development.

In order to provide students with an opportunity to reflect on their learning, engineering portfolios must take their cue from writing assessment portfolios. Murphy and Smith describe a classroom climate that encourages students to reflect on the writing they have selected to showcase in their portfolios [17]. Students are required to prepare a cover letter to accompany their portfolios. The cover letter explains why these pieces were selected, how they were revised, how they represent the students' best work, and how the students' skills as a writer have developed over time. In a comparable approach, students submitting materials to the RosE-Portfolio must provide a reflective statement for each document. In the reflective piece, students must make the case for the relevance of their documents to the particular learning objective. In the case of communication, for example, a student needs to discuss specific sections of his/her technical report in order to show that it has been prepared with an actual client in mind. In the act of reflecting on the process he/she used to create the report, the student reviews the principles of audience analysis and accommodation (one of the performance criteria for the communication learning objective) and argues for the ways in which his/her document is an effective example of the criteria.

Despite its educational value, reflection is not an activity that most students pick up easily or readily. In fact, just as we must remind students of the link between portfolio objectives and course goals, we must remind students of the link between classwork and reflection. Students enrolled in the Technical Communication classes at Rose-Hulman are given repeated opportunities throughout the quarter to reflect on the relation of class assignments and communication skills. Before we provided class time for reflection, students often did not see the relation of a group exercise on audience analysis (comparing and analyzing a company's webpages for different customers, for example) and the course goal of improving student's communication skills. Reflection—whether in the form of brief writing at the beginning of class, or cover letters to accompany class assignments, or reflective statements included with portfolio materials—provides students with a significant learning opportunity that only comes with the use of portfolios.

ASSESSING STUDENT LEARNING

The last stage of engineering portfolio development may discourage faculty from using portfolios. Once again, however, if the initial stages are adhered to, then assessing the contents of the portfolio becomes more manageable.

There are two keys to successful evaluation of portfolios:

- limiting the scope of what learning the portfolios must document;
- developing evaluation rubrics that accurately assess that learning.

Until recently, models for evaluation rubrics have come primarily from the fields of language arts and secondary education. Experimentation at Colorado School of Mines and Rose-Hulman has provided more specialized rubrics that address the assessment needs of engineering programs. The important thing to remember about rubrics is the need for those who will evaluate portfolio materials to develop rubrics based on their program's objectives, rather than adopting unquestioningly the models adopted by other programs. Just as defining engineering communication, for example, brings faculty to a shared sense of how they want their students to communicate, developing assessment rubrics provides comparable benchmarks by which faculty can judge the progress of their students.

Take, for example, the following learning objective. A chemical engineering program identifies oral communication as an important skill for its graduates to possess. Acknowledging that 'oral communication' is a broad and vague skill, the faculty in the program further define oral communication as the ability to give effective oral presentations, specifically informal presentations to peers, team members, and immediate supervisors that are typical of chemical engineers working in industrial settings. Then the faculty identify the traits of a successful presentation of this type:

- The presenter provides a summary of the project he or she is working on.
- The presenter reviews the current status of the project.
- The presenter identifies key challenges, difficulties, or concerns that have developed since the last presentation.
- The presenter concludes the presentation, responding to questions for the audience.

The faculty who identify these traits base their rubric on their own experience, the demands of industry, or the standards of professional organizations. They may also begin their discussion with a much longer list of traits. Negotiating the final list helps the faculty gain a sense of what matters most to their department and what they hope to instill in their graduates. Evaluating a student's performance on each trait can then be made on a variety of scales. A yes/no scale will only denote the presence or absence of the trait: the student did begin with a summary/the student did not begin with a summary.

Most faculty and programs will require more detailed information. Thus, the rubric may use a three-point scale, but each level must itself be defined to denote exactly what constitutes performance at that level:

1. The presenter's summary is brief, well-organized, and provides the audience with key background information, such as project start date, client, links to related projects.
2. The presenter's summary is disorganized and does not provide a concise, accurate picture of the project.
3. The presenter provides a summary of the project he or she is working on.
4. The presenter provides no summary.

Using these rubrics produces a number of significant advantages. First, faculty evaluators recognize that the standards by which students will be judged are based on priorities established by the engineering program itself. Rubrics are not, in contrast, imposed on the program. Second, faculty can measure student achievement qualitatively while still retaining quantitative data that are necessary for accreditation and constituency purposes. Third, rubrics can be used in a single course as well as across a curriculum. They can also be modified as their efficacy dims or the program's focus changes. Fourth, and perhaps most important, they can be shared with students from the first day of class. Students can see what they will be judged on and how they will be judged. Furthermore, they can participate in the development of these rubrics, contributing their own ideas of how their work should be evaluated.

ENGINEERING PORTFOLIOS AND FUTURE ASSESSMENT CHALLENGES

What lies ahead for engineering portfolios? Clearly there is more work to do if engineering portfolios are to gain wider acceptance for assessing engineering education. In an informal survey I conducted at the American Society for Engineering Education Conference in Albuquerque, New Mexico, I asked those audience members who were using portfolios at their institutions to stand. Only two audience members stood up, and this session was a part of the Education and Research Methods Division.

The future may proceed this way. First, many more engineering programs will attempt portfolios as one data collection method. Their work in adapting the portfolio model to meet their assessment needs will mean more experimentation with the form. As a result, we may see a proliferation of engineering portfolios, with program results being shared with others. Unfortunately, there seems to be resistance among some programs to learn the pitfalls of portfolios from other engineering programs or other disciplines, like writing assessment. Portfolios may gain a reputation that they do not deserve. More research is needed that demonstrates the benefits of portfolios over other data collection methods.

Of course many programs will wait to see how other engineering programs fare with engineering portfolios. In October 2000, engineering programs at the Colorado School of Mines and Rose-Hulman Institute of Technology were both accredited, and both institutions rely on engineering portfolios for the documentation of some student learning outcomes [18, 19]. Only after more institutions are recognized for their efforts in portfolio development will the engineering portfolio gain wider acceptance. Finally, the most important transformation must occur within the culture of engineering education itself. Until engineering faculty, programs, and industry commit to this assessment method, engineering portfolios will remain a great idea and not a practical reality.

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