2006-2161: DEFINING AND ASSESSING THE ABET PROFESSIONAL SKILLS USING EPORTFOLIO

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Defining and Assessing
the ABET Professional Skills Using ePortfolio

While most engineering programs are confident developing specific criteria and assessment tools for the technical skills described in ABET Criterion 3a-k, the question of how to define, teach and assess the professional skills (teamwork, professional and ethical responsibility, communication, impact of engineering solutions, life-long learning, and contemporary issues) remains much more challenging. This paper describes concrete, assessable expectations that connect student work to professional skills, broken down by level and organized into ePortfolio assessment matrices that reflect recognized classificatory schemes of how people learn. We will provide examples of how selected faculty in our College of Engineering are developing ways to integrate ePortfolio into undergraduate curricula as a device that (1) guides students to understand and take ownership of their education, (2) helps faculty define and teach the ABET program outcomes (both technical and professional), and (3) enables departments to assess specific programs and archive materials for outside assessment.

Rationale: E-Portfolio Tools for Assessing Professional Skills

As part of a larger NSF-funded Department-Level Reform (DLR) grant, we are developing mechanisms for using electronic portfolios to document and assess engineering outcomes. This paper reports the first phases of this project – the assessment of professional (rather than technical) skills of engineering students, guided by a subset of the outcomes defined by ABET Criterion 3:

 (d) an ability to function on multi-disciplinary teams
 (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.

We selected these six areas as the starting point for the larger project because, although the project is tied to the DLR for the Biological Systems Engineering (BSE) Department at our university, part of the goal, particularly with respect to assessment, is to develop methodologies that can be used across engineering departments nationwide. The precise nature of the technically-oriented outcomes varies to a great degree by discipline, and departments already have functional assessment methods to address those skills. The professional skills, in contrast, have more cross-disciplinary commonalities and, as Shuman et al. point out,[1] significant work remains in both teaching and assessment in these areas.

The assessment goals of the DLR grant dovetail with the current effort across our campus, working with an open-source consortium of universities and companies, to develop e-portfolio software usable for a full range of academic goals that include assessment, advising, career planning, core-curriculum integration, and student-directed learning. In addition, while the professional skills outlined by ABET are intended specifically for engineering programs, the issues identified by ABET in fact apply to most, if not all, disciplines at the university. Assessment of student outcomes involves two key components—the definition of concrete, measurable outcomes and the development of methods and tools for assessing those outcomes.

The first part of this paper describes a theoretical framework used to develop measurable outcomes, illustrated with specific examples; the paper then describes the use of the e-portfolio system as a tool for recording and evaluating those outcomes; the final section presents baseline data from the 2005-06 pilot study of student experiences and outcomes and issues that must be addressed when developing such tools.

Theoretical Framework: Learning Paradigms and Professional Skills

The first step in our project, as noted above, was to develop a set of measurable outcomes—"expectations" in the language of the e-portfolio software—used to assess students' professional skills. In developing these measurable expectations, we drew on two well-known learning paradigms: Bloom's taxonomy[2] and Baxter Magolda's schema of Intellectual Development[3] (which grows out of Perry's Scale of Intellectual and Ethical Development). These models are summarized in **Table 1**:

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Table 1: Learning Paradigms

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Bloom's Taxonomy of Learning	Baxter-Magolda's Schema of Intellectual Development
1. Knowledge 2. Comprehension 3. Application 4. Analysis 5. Synthesis 6. Evaluation	1. Absolute Knowing 2. Transitional Knowing 3. Independent Knowing 4. Contextual Knowing

Bloom's taxonomy reflects a series of abilities, moving from the basic ability to memorize facts about a subject, through the more advanced process of applying those facts to specific situations, to the highly complex ability to synthesize information from a range of sources and evaluate the truth-value and utility of information regarding the subject. His taxonomy is thus a useful framework for identifying the kinds of things students should be able to *do* at various stages.

Baxter Magolda's schema (Baxter Magolda 1992), in contrast, describes human intellectual stages in terms of epistemology—that is, how they know. Individuals begin in a state of Absolute Knowing, in which things are black and white, answers right or wrong, information true or false. As they develop intellectually, individuals move through stages in which they recognize that multiple ideas may be right, that individuals approach ideas and problems from many different perspectives, and "right" and "wrong" are contextual rather than absolute. In stage 2, Transitional Knowing, individuals see this multiplicity as applicable to certain areas (such as domains in the humanities and perhaps social sciences) but not other areas (typically engineering, hard sciences, mathematics). In Stage 3, Independent Knowing, they recognize that in most areas experts often have serious disagreements, even about "facts," but individuals in this phase adopt a relativist approach to this multiplicity, in which "everyone is entitled to their own opinion." Finally, in stage 4, Contextual Knowing, individuals recognize that while multiplicity exists, certain approaches are more "right" than others in specific contexts and, importantly, that in a given context one can test and evaluate evidence to make decisions and judgments based on more than individual opinion. This framework thus provides an important complement to the

more task-oriented approach of Bloom's taxonomy because it enables us, as educators, to consider how students think, which in turn impacts how they transfer task-oriented knowledge from one context to another.

With these paradigms as the theoretical grounding, we first expanded definitions of each professional outcome (written *to* students), and then created a staged series of expectations for each. While Bloom's taxonomy has 6 stages and Baxter Magolda's schema has 4, the e-portfolio software we are using (described in the next section) allows three levels of development for assessment purposes. Moreover, from an overall assessment point of view, three levels seems to provide a more manageable framework, particularly for larger departments, as well as a way to help students understand that these levels do not necessarily correspond to year in school. **Table 2** illustrates this approach through the expectations associated with multidisciplinary teamwork.

Table 2: Expectations for Professional Skills

Multi-disciplinary Teamwork: In practice, you will need to work with people not only from other engineering disciplines, but also people from fields such as the sciences, business, and economics. You will also work with people from different cultures who may understand the field differently.		
Level 1 Expectations	**Level 2 Expectations**	**Level 3 Expectations**
Describe personality types and the kinds of contributions, strengths, and challenges that various personality types bring to teams	Compare personality types of team members and use those types to inform interactions/work methods	Productively negotiate conflicting design ideas
Describe the different kinds of knowledge and methods of problem – solving that other disciplines (engineering and non-engineering) bring to teams	Identify explicit and implicit goals of individual members and the group	Manage strengths and weaknesses of individual group members
Identify important roles/functions that need to be filled in a team (leaders, reporters, consensus builders, task-masters)	Identify ways to build consensus regarding team goals	Conduct effective meetings
Identify phases of team projects	Function effectively in various team roles	Analyze and combine different disciplinary approaches
Identify the challenges and benefits of working in a team	Contribute to effective meetings	
	Describe conflict negotiation strategies in a team setting	

In general, the items in Level 1 typically represent factual information—things students should know—knowledge and comprehension skills in Bloom's paradigm, absolute knowing in Baxter Magolda's. In Level 2, the expectations reflect more complex kinds of knowledge (transitional and independent) and skills oriented towards application and analysis. Level 3 represents outcomes most closely allied with contextual knowing and with synthetic and evaluative tasks. Thus with respect to the expectations for multidisciplinary teamwork, Level 1 reflects students' knowledge about effective teams, Level 2 reflects the ability to apply that knowledge in practical situations, and Level 3 reflects the ability to combine knowledge and practice to lead and manage successful multidisciplinary teams.

In theory, the final column (Level 3 outcomes for most areas, Level 2 for Contemporary Issues) would be the only expectations that programs would need to assess student outcomes. In practice, however, the teaching and assessment of these skills is still a relatively new phenomenon, in a formal sense, for engineering programs. Programs can often show that

students gain experience and have opportunities to improve their professional skills throughout the curriculum, particularly skills such as teamwork and communication, but faculty generally struggle with documenting student achievement. The expectations give faculty a framework for documenting student learning related to these skills. Using three levels, moreover, provides a mechanism for assessing current performance and planning for continual improvement by enabling programs to move beyond a yes/no response to the ABET criteria and instead productively identify the degree to which students meet expectations.

Moreover, from a student development standpoint, part of the goal of the portfolio, as described elsewhere,[4] is to engage students in the process of their own learning, helping them to both direct and assess their progress over time. The three levels thus give students both a vision of where they are going with respect to these outcomes and a map of how to get there.

Curriculum Implementation: Stand-alone and Integrated Practices

Concrete, measurable expectations for the professional skills, however, are only the first step in the process of evaluating student outcomes. Once the outcomes are defined, the challenge for programs is to then teach and finally assess the skills. At our university, we are currently pursuing two alternate approaches to classroom implementation; both approaches will use electronic portfolios as the tool to facilitate assessment and programmatic record-keeping. The first is to use stand-alone professional development courses designed to focus on these skills directly (in the context of program-specific material). The second is to integrate these skills into technical engineering courses, identifying locations in the curriculum in which these skills logically dovetail with the technical content. Importantly, these two approaches are not mutually exclusive; two of the departments in this study combine the approaches, using the professional development courses to provide basic instruction oriented primarily toward Level 1 expectations (e.g. in communication or team organization), then using technical courses to provide practical, workplace-oriented experience designed to foster expectations associated with Levels 2 and 3 (application, evaluation, synthesis).

Professional Development Courses

Currently, three engineering departments at our university have or are developing professional development courses, as shown in **Table 3**:

Table 3: Professional Development Courses

Department	Course Level	Number of Credits
Electrical and Computer Engineering (ECE)	Fall - Sophomore	2
Engineering Science and Mechanics (ESM)	Fall - Sophomore	1
Materials Science and Engineering (MSE)	Fall -Sophomore	1
	Spring - Junior	1

This sample pool includes both very large courses (ECE—140 students) and very small courses (ESM—17 students). As Table 3 shows, one of the departments uses a single 1-credit course at the sophomore level. ECE has created a 2-credit course; MSE also uses two credits, but splits the courses between the beginning of the sophomore year and the end of the junior year. All of these courses were in existence prior to the development of the expectations described in the previous section, and although the goals of each course vary to some degree, overall each course serves to

introduce students to the field and ground them in a full range of professional skills, most notably communication, ethics, teamwork, and lifelong learning. Attention to contemporary issues receives limited attention in some of the courses. To date, however, none of the courses have rigorous, codified assessment schemas in place to consistently document student skills; all are thus appropriate venues for testing the assessment methodology under development.

Integrated Courses

The second implementation model involves integrating the professional skills into technical courses; this model is currently in place in the capstone design courses in both MSE and ESM. Both capstone design programs are full-year courses that address not only engineering design, but the larger project management issues surrounding design, including those related to communication, teamwork, ethics, contemporary issues, and lifelong learning.

As with the professional development courses, these capstone courses were in place prior to the development of the expectations. However, a number of existing assignments already map clearly to the expectations outlined above. For example, at the beginning of the senior design projects, students take personality tests (Myers Briggs, True Colors), compare results among team members, discuss the potential strengths and weaknesses of the team as a whole, and develop plans for addressing those weaknesses to insure project success. Using this assignment as part of the assessment project would simply involve having students submit the results electronically to the matrix as an element under Multidisciplinary Teamwork.

The BSE program is taking the process of integration a step further by linking the expectations for each outcome with courses throughout the curriculum, and identifying activities related to each expectation. The philosophy is to identify a minimum number of required courses and activities to ensure that all students have explicit opportunities to demonstrate meeting each expectation. Faculty will strive to incorporate references to the professional skills more often in elective courses as well, e.g., reminding students about expectations relevant to particular course work. Students will be encouraged to add to their portfolios from other BSE courses, as well as from courses from other departments. One long-term goal is that students will recognize the multi-dimensions of the work they do in a variety of courses related to both professional and technical skills. A second long-term goal is that the expectations will assist faculty in embedding the professional skills in their courses more seamlessly.

The activities related to the expectations can take different forms, from class discussion to formal written and oral assignments, including homework and tests. Some activities will be discrete, occurring one time in a single course. In other cases, the activity will recur periodically throughout the curriculum. For example, the first exposure and activities related to professional and ethical responsibility occur in the freshman engineering courses, where level 1 expectations can be met. Level 2 expectations, i.e., to identify different kinds of ethical and professional dilemmas, will be referred to in several BSE courses. A selection of courses will include instructions to students to add to their lists of dilemmas. In some cases, the instructor will raise dilemmas in class; in others, students will be assigned to identify dilemmas and add them to their portfolio. In the second semester of the junior year, in the required "transport processes" course, instruction will be provided about strategies for resolving dilemmas. The students will be given an assignment to link the strategies to several of the dilemmas that they have previously

identified. In the senior design course, there will be an assignment related to evaluating the resolutions of professional and ethical dilemmas. Students will be asked to describe how they applied particular strategies to resolving their own ethical/professional dilemmas.

Assessment: Developing and Using an Electronic Portfolio System

With the expectations and courses in place to test this approach, the final element in this research is the electronic portfolio system itself. The forthcoming generation of our ePortfolio tool, programmed by the Open Source Portfolio Initiative (OSP 2.0),[5] will include a dynamic matrix tool that students and faculty can use to track progress in a course or program. This tool will prove useful in several applications, including:

- Student awareness of program requirements
- Student ownership of learning process
- Creating portfolios for academia and industry
- Defining and meeting program goals
- Compiling evidence for ABET assessment requirements.

ePortfolio is flexible enough to facilitate all of these tasks. Perhaps the simplest function of the program is to serve as an online repository for students to store their work and provide a mechanism for students to share their work in "Presentations" to faculty and potential employers. However, using the matrix, it is possible to expand this functionality by populating the matrix with programmatic learning outcomes that cohere with ABET requirements. This type of detailed, content-infused matrix is typically referred to as an analytic matrix—a format that helps groups of evaluators agree on learning outcomes and criteria.[6] Expanded functionality will include the ability to make programmatic objectives consistent and reachable across courses (and potentially on a college-wide basis), present unified curricular goals that students can easily understand and adopt, and serve as assessment data for program and college reviews.

The matrix takes the simple physical form of a grid with ABET skills in the left column and skill levels along the top row (see Figure 1). A roll-over "short definition" and a pop-up "long definition" correspond to each ABET skill. For example, in Figure 1, rolling over "Multidisciplinary Teamwork" displays the following short definition:

> As an engineer, you will work with people from a broad range of technical and social backgrounds to complete projects.

Clicking on "Multidisciplinary Teamwork" displays the long definition listed in **Table 2**:

> In practice, you will need to work with people not only from other engineering disciplines, but also people from fields such as the sciences, business, and economics. You will also work with people from different cultures who may understand the field differently.

Each cell contains detailed verbal descriptions of each skill level outcome that appear as rollovers when a user mouses over a cell. For example, in Figure 1, the cell corresponding to Level 1 of "Multidisciplinary Teamwork" displays the rollover text:

Level 1
1. Describe personality types and the kinds of contributions, strengths, and challenges that various personality types bring to teams.
2. Describe the different kinds of knowledge and methods of problem –solving that other disciplines (engineering and non-engineering) bring to teams.
3. Identify important roles/functions that need to be filled in a team (leaders, reporters, consensus builders, task-masters).
4. Identify phases of team projects.
5. Identify the challenges and benefits of working in a team.

As students progress in their engineering education, they will complete assignments, or activities, that satisfy the requirements of each cell. The requirements do not have to be accomplished in a linear manner, and the skill levels do not necessarily correspond to years in a student's college education. To fulfill the expectations of any skill level, the student must upload items of evidence and complete the Reflection form provided online by ePortfolio (Figure 2). The Reflection form in ePortfolio is a synthesizing exercise that prompts students to reflect on work they have done to satisfy an entire skill level. So, all of the expectations of a cell/skill level are included in the Reflection, even though a student may work on a Reflection in progressive stages. The instructional value of this exercise is to have students connect their own work to their program's expectations and to critically argue for their own self-assessment. Moreover, the Reflections help assessors evaluate not only the more task-oriented expectations aligned with Bloom's taxonomy, but also those expectations that address ways of knowing and understanding aligned with Baxter-Magolda's formulation. They help demonstrate, that is, whether students *understand* what they are doing or whether they have simply learned to mimic performance.

Figure 1. Engineering Matrix

The assignments, in forms such as reflections, reports, and slide presentations, can be uploaded into ePortfolio's repository and submitted through the matrix for review by faculty for course or program requirements. The status of each cell is indicated by one of four codes (Figure 1):

- Ready (green): cell is open for student input
- Pending (yellow): student has completed and submitted a Reflection (Figure 2). The Reflection is completed by responding to each listed Expectation in the online form and clicking "Submit for Review." A cell in this state cannot be altered.
- Completed (blue): reviewer (faculty or advisor) has approved student work and Reflection. A cell in this state cannot be altered.
- Locked (purple): cell is locked and no input is permitted. This option is used in cases where no content is required (as in Contemporary Issues Level 3 in Figure 1), or when any further input (even by administrators) is not permitted.

Figure 2. Reflection format required for completion of a skill level

Students do not have to complete a particular skill level prior to submitting for review, but can submit for formative feedback as they are working on the level. Submission is presently accomplished through the Reflection form and students must upload at least one item of evidence to be permitted to access the Reflection form. While the Reflection is being reviewed, it is marked as Pending and cannot be altered by the student. The reviewer can add comments and evaluate the Reflection according to the choices provided by the ePortfolio system (Exceeds Expectations, Meets Expectations, Good Start, and Incomplete) (Figure 3). If the Reviewers mark the form "Incomplete" or "Good Start" the cell is returned to the Ready state and the student can continue work on that cell. When a student has satisfied the program requirements for a particular skill level, that cell is marked "Completed."

Figure 3. Reviewer evaluation page

Baseline Data: Student Perceptions and Performance Prior to Targeted Intervention

As noted, this research project is currently in the development phase; pilot testing of the e-portfolio system is beginning in the spring semester of 2006, with a larger-scale pilot slated for the 2006-07 academic year using the courses listed in **Table 3**. To fully evaluate the impact of the curriculum and the assessment tool, however, we will gather baseline data for use in full assessments beginning in Fall 2006. This data will measure students' self-reported assessments of performance with respect to these expectations, limited course grade data as a means to evaluate the self-assessments, and surveys of possible artifacts that, within the current course structures, students would use to support their self-evaluations. Because the larger goal of the portfolio is to provide a learning tool for students to foster their intellectual development, the reflections in which students connect specific artifacts (reports, design drawings, homework assignments, calculations) to the expectations, and critically argue for their own self-assessment, are key elements of the portfolio system. Thus understanding, even in the early phases of the research project, what kinds of artifacts students would choose to support their claims, and then tracking this use of artifact as evidence over time, will provide useful insights about students' engagement with the learning process as well as their ability to think critically and make arguments from evidence in a way that demonstrates their understanding of the expectations.

Issues to Consider in Developing Electronic Assessment Portfolios

While the Virginia Tech ePortfolio (VTeP) provides a convenient tool for tracking and documenting student progress, particularly when compared to maintaining paper records, a number of factors must be considered to insure that the tool is beneficial for both students and faculty. Critical will be the integration of the tool into the educational environment; it must become part of the learning culture for both faculty and students that has benefits both within and beyond the classroom. Key goals are focused on stakeholders, and deem that:
- Students must see the tool as facilitating learning and not as just one more piece of busywork.
- Faculty must see the benefit to student learning, while also seeing a benefit to teaching.
- Faculty development must help instructors implement appropriate pedagogical scaffolding to support the use of the tool

- The tool must be easily used by both students and faculty. Access, navigation, and general usability are all critical.

As such factors are addressed, however, we believe that an electronic portfolio built around education-appropriate, concrete, measurable outcomes is an important tool not only for enabling programs to implement an outcomes assessment process, but for enabling educators to more effectively foster student learning, particularly with respect to their professional skills.

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