AC 2008-2257: USING THE DESIGN PARADIGM AS A STRATEGY FOR CURRICULUM ENHANCEMENT

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Using the Design Paradigm as a Strategy for Curriculum Enhancement

Abstract

Revisions in the criteria for accreditation of engineering programs by the Accreditation Board for Engineering and Technology (ABET), especially with regard to Criterion 3: Program Outcomes and Assessment, have the potential to significantly enhance engineering education. Several factors may inhibit these revisions from reaching this potential. Among these are the tendency of faculty to view assessment as means to the end of obtaining ABET accreditation and the recent tendency to view students as customers within a continuous quality improvement (CQI) paradigm. While neither viewpoint is entirely incorrect, when these perspectives dominate curriculum review, many of the advantages of true curricular assessment and quality improvement are lost. We believe it to be more advantageous to regard students as products within an engineering design and manufacturing paradigm when developing assessment and improvement processes for curricula.

In this paper, we will show how we have used the engineering design paradigm, coupled with ABET requirements, to develop an assessment and feedback approach that maps performance criteria in such a manner as to allow timely intervention at an individual student as well as programmatic level. We will demonstrate how to decompose student learning outcomes into performance criteria at a resolution geared for intervention rather than just assessment. Finally, we will describe a Web-based knowledge management system called AEFIS (Academic Evaluation, Feedback and Intervention System) which manages the data in such a way as to maximize the ability to provide continuous quality improvement while minimizing additional faculty labor.

Introduction

‘Is this going to be on the test?’ is a question faculty instructors often hear from students, usually asked with the hope of a negative response. It is also one of those questions which most instructors would rather avoid, implying as it does that the student has accepted learning as simply a means to passing tests for gaining a good GPA, and has forsaken a broader understanding of education. Consequently, one should learn as little as required and not waste time on items not being directly tested. Considered in this light, the student’s question makes perfect sense. From the faculty perspective, examinations are mechanisms of evaluating student progress towards the ultimate goals of obtaining knowledge, skills and wisdom. If only, faculty often lament, students would focus their attention on the real goal of learning the material, good GPAs would result as a natural consequence. Thus, students would both achieve the learning outcomes set by the faculty and a good GPA simultaneously.

Ironically, faculty who deal with this problem of student perspectives on an ongoing basis often seem to consider the issues of continuous quality improvement (CQI), assessment and accreditation from the same attitude as the student described above. Rather than approach the
process as having the potential to result in significant curricular improvement, many faculty resist the implementation of the CQI approach. They ask the equivalent of the student’s question about testing substituting assessment and accreditation in the appropriate spots. The result can be a minimalist approach, where the goal is to obtain and maintain ABET accreditation rather than implement a truly functional CQI system that monitors and improves the educational program. However, analogous to the student’s circumstances with learning outcomes and testing, if faculty could be convinced to focus on implementing a superior CQI system, then both program improvement and accreditation could be achieved simultaneously.

What are some of the barriers to implementing a superior CQI program? Numerous reasons can be supplied, some legitimate, others less so. Since faculty cooperation is essential to the success of any CQI implementation, the factors contributing to their reluctance to embrace CQI must be overcome in order to succeed. What, then, are some of the reasons given by faculty for their lack of enthusiasm for CQI?

A key factor is limited time and available resources. Faculty are called upon to accomplish multiple tasks involving scholarly activity, teaching and service. At major research universities, the emphasis for tenure and promotion can be focused primarily on scholarly activity and especially on the level of funding for that activity. Teaching may be viewed as being of secondary importance, able to influence tenure and promotion decisions negatively if inadequate but unable to improve a faculty’s position greatly even if clearly superior. Thus, when making decisions concerning the appropriate allocation of effort, especially in light of increasing competition for decreasing funding resources, faculty may feel compelled to limit their allocation to teaching to that needed to maintain the average level for their academic unit or institution. Even in those institutions where the emphasis on research is less intense, the amount of teaching and service responsibilities may be such that the effort to implement and maintain a high quality CQI system seems too great a task.

A second reservation of faculty, related to the first, is the suspicion that the implementation of a CQI system in their curriculum is actually a new method of faculty evaluation, a potentially punitive method of measuring faculty teaching ability. This is likely to be an especially sensitive issue in those research universities which emphasize research productivity to such an extent that faculty feel unable to devote adequate time to instruction. It may also be a particularly sensitive issue with new faculty who feel uncertain of their capabilities as teachers and prone to greater student scrutiny. A CQI system is thought to be part of a hidden agenda by which the university or department administration can collect data on faculty teaching performance.

A third reservation involves the field of assessment and CQI itself. In the application of CQI to education, a new kind of discipline is developing, with its own language, terms and jargon. When introduced to the language of program objectives, student learning outcomes, performance criteria and rubrics, the average faculty member can feel out of his or her depth. Subject matter experts in their own field, faculty members may not be comfortable trying to work in a field where they have only limited experience and where the terms are unfamiliar. In addition, assessment and CQI are thought to be a ‘soft’ discipline – rather than ‘hard’ and definitive as is engineering. Many engineering faculty view such ‘soft’ disciplines involving psychological or
sociological aspects of human behavior as unreliable – not real science and/or engineering – and therefore not worth any significant effort.

Other reasons seem less easily justified. Faculty have been heard to claim that student learning outcomes cannot be measured and thus creating a CQI system based upon such assessment is not possible. On the face of it, this claim seems patently ridiculous. What are grades but a method of assessing student learning outcomes? Are we to believe that there are no metrics available to assess student performance? In that case, how can an instructor evaluate their own performance? When developing lesson plans, laboratories or other instructional materials, on what basis does the faculty decide to use one or the other approach? This objection to CQI appears to reduce teaching to a random activity in which anything goes and no method is better than any other for conveying information.

It has also been claimed that a student learning outcomes-based CQI system is not needed since the ultimate function of an engineering education is employment upon graduation and the majority of the program’s graduates are getting jobs. This objection is reminiscent of those voiced by American automobile manufacturers when initially faced with potential competition from overseas manufacturers, especially Japan. Instead of embracing, Dr. W. Edwards Deming’s recommendations for management and quality improvement, American companies relied on the then current situation that Americans were buying American cars. They focused on the present and failed to see the future. The result is that Toyota is now the world’s largest automobile manufacturer\(^2\). The same can – and will – happen in engineering education. The market for engineers is global. The competition is global. The opportunities are global. If American engineering education does not embrace quality improvement, it will be left behind by those educational systems that do.

**An Approach to Assessment and CQI**

In light of the aforementioned issues, how can the problem of designing and implementing an effective CQI system be approached? One method would be through the appeal of ABET accreditation. There is no denying that the movement towards CQI in engineering education is at least partially in response to changing ABET standards and requirements for accreditation. However, to use ABET as the sole justification for CQI is likely to result in faculty doing only what is necessary to obtain accreditation. This is not an approach which will generate new ideas and innovations nor encourage faculty from taking any intellectual risks in system design. In effect, the program would be ‘teaching to the test’ with predictably marginal results. Thus, while the requirements associated with ABET accreditation are necessary for initiating CQI, they are not sufficient to generate a useful and sustainable design and implementation.

Another approach is to recast the issue as an engineering design problem. Most engineering faculty have an almost instinctive understanding of the issues surrounding engineering design and product development. Many are familiar with Deming’s ideas and the more recent Six Sigma\(^3\) approaches to quality control. The task is to convince the faculty that CQI in education is analogous to CQI in engineering design and manufacturing and to approach the issues of assessment and CQI as simply another design problem. The student upon graduating is the product of the curriculum. That product must meet certain design specifications. Therefore, a
system must be created which monitors product development so as to ensure that the final product does meet those specifications. This latter requirement implies a system which allows intervention to correct problems as they develop to prevent products from failing to meet design requirements.

Despite the attractiveness of such a transparent system, an immediate objection can be raised because students do not fit the usual definition of merchandise. One does not buy and sell graduates. While that is thankfully true, graduates do get hired, admitted to professional or graduates schools or they do not. There is a measure of success in that sense. Industry, professional schools and even the community at large are customers for the products of educational institutions. If they are not satisfied with the quality of the graduating students, then the curriculum which generated those graduates has failed.

Another, even stronger objection is that students must collaborate in their own education – they cannot simply be molded into whatever form is appropriate to be a successful engineer without their active participation. That does not invalidate the model but it does make the task of education more difficult than that associated with manufacturing or software development. The goal is still a product that meets design specifications but now the process has the additional challenge of motivating the raw material to participate in its own transformation. This would seem to make the necessity for successful assessment and CQI greater in education than any other activity since the potential sources of failure are greater in education compared to these other activities.

**Initial Planning Steps and Constraints on the Model**

In a typical engineering project, the initial steps include such items as a problem or vision statement (what are we trying to accomplish), business case (why are we trying to develop this process or product) and the specification of at least some of the product or process requirements (how do we know we have solved the problem adequately). In waterfall models, there is an attempt to specify the majority of requirements in advance of the design process whereas adaptive or agile methodologies rely on iterative development and consistent user feedback. Which style of development one uses depends on the specifics of the problem or opportunity assessed?

For existing engineering programs, the business case has already been made and accepted. To a great extent, the problem or vision statement is also already defined. In general, the goal is to educate individuals to be competent and ethical engineers. There is variation in the type of engineer being produced – electrical, chemical, biomedical – leading to a corresponding variation in the vision or problem statement and there can be slight variations in the exact nature of the mission – engineers primarily for industry vs. research oriented practitioners – but these differences are manageable because they are constrained by ABET accreditation.

ABET accredited engineering programs are required to have a mission statement, program objectives, and student learning outcomes. The mission statement can be considered as a type problem or vision statement which must be compatible with the overall mission statement of the college or university in which the program resides as well as the goal of educating individuals to
be engineers. Program objectives are characteristics or attributes displayed by graduates of the program three and five years post-graduation. ABET provides very little guidance on the nature of these objectives except to require that programs monitor their alumni to ensure that the objectives are being met.

The same is not true with student learning outcomes. These are characteristics or attributes of students at the time of graduation from the program. Here, ABET provides a list of requirements in the form of the famous a-k outcomes list applicable to all engineering programs and program specific requirements listed separately in Criterion 8. All accredited programs must demonstrate that they meet these minimum requirements and hence the need for assessment and CQI.

The ABET a-k and program-specific outcomes are the actual design specifications for the educational product of engineering programs. Programs can expand on this list but cannot reduce the number and remain accredited. The existence of these requirements constraints both the program objectives and mission (product/vision) statement. Since requirements determine if a problem has been solved, the existence of a requirements list presupposes that the problem itself is known. In addition, ABET requires that program objectives be supported by student learning outcomes. The learning outcomes themselves will naturally generate certain kinds of program objectives and the only way to expand the list of objectives would be to expand the corresponding student learning outcomes. Since most engineering programs are reluctant to add additional outcomes, program objectives in various programs will tend to be quite similar.

Despite these constraints, it is a useful exercise to review both the mission statement and program objectives with the various stakeholders. The list of stakeholders includes faculty, students and representatives from industry. Other possible stakeholders whose opinions would be useful are representatives from professional and/or medical schools and representatives from government units likely to employ program graduates. Any changes in the mission statement and/or program objectives should be vetted through all stakeholders with the constraint that any changes must be consistent with student learning outcomes, a minimal listing of which has been defined by ABET.

**Measuring Student Learning Outcomes**

Student learning outcomes should also be reviewed by stakeholders prior to development of any CQI system. Outcomes are the requirements for the educational process. In that sense, these requirements define what a graduate of an engineering program should be upon graduation. Reviewing the outcomes helps faculty and student clarify the goals of the educational process and what students are expected to be able to accomplish. After review, it may be found that the ABET requirements are not sufficient and additional outcomes are needed. For example, many engineering programs have different tracks or concentration areas within a single major. If there are no outcomes specific for one track as opposed to another, it is difficult to justify having more than one track. Either participating in engineering track A results in a different educational experience than track B or it does not. If it does, the success of the track should be monitored through specific learning outcomes. If it does not, then there is really only one track and students’ choices are essentially meaningless.
While student learning outcomes are a useful set of requirements by which to define success of an educational program, they are not easy to measure. Two examples of student learning outcomes are:

1. Ability to function on multidisciplinary teams (ABET d);
2. Understanding of Professional and Ethical Responsibilities (ABET f)

How does one measure these outcomes to determine if the engineering curriculum successfully educated students in these abilities?

The technique involves decomposing each outcome into measurable subcomponents. Recognizing that student learning outcomes are, in fact, product requirements, this process is analogous to that used in manufacturing. For example, suppose an automobile manufacturer is subjected to a government requirement for gas mileage. There are several different ways in which this requirement might be met, involving everything from the weight of the vehicle and the materials used to construct it to the efficiency of the fuel injection system. Added together, the various components result in a vehicle with the desired fuel efficiency. During the manufacturing process, each component is monitored to ensure it meets the specifications for that component and the final product, the vehicle itself, is also measured to ensure that the overall mileage requirement is met.

Student learning outcomes are not quite as simple as fuel efficiency – there is no mpg value for the ability to function on multidisciplinary teams, for example. However, the concept is similar and the measurable subcomponents of a student learning outcome are called performance criteria. Figures 1 and 2 display performance criteria developed for the two outcomes listed above.

A number of interesting aspects of the process are displayed in Figures 1-2. Each outcome is subdivided into a number of performance criteria. Each performance criterion is associated with a number of achievement levels. Each achievement level is described so that a student’s level of success in attaining each criterion can be measured in any given instance, for a particular paper, oral presentation, or team project. The achievement levels with their associated descriptions are called rubrics although metrics might be a more appropriate term. However, the field has adopted ‘rubric’ as the term for this kind of measurement and thus that will be the terminology used in this paper.

Developing Performance Criteria and Rubrics

How are performance criteria and rubrics developed? A number of publications exist which describe the process and many examples of outcomes with associated performance criteria and rubrics can be located by using those terms as key words for an Internet search. The important thing to keep in mind is the use to which the criteria will be put. The real purpose behind any assessment system is to enable productive intervention in cases where required specifications are not being met. This is the drawback of using final course grades as rubrics. Final grades are essentially a composite scoring of the entire course requirements. As such, they represent a broad measure of student performance and are most significant in identifying the student who is...
exceptionally deficient with a failing final grade. Final grades do not identify specific deficiencies that can remain uncorrected as long as the student achieves a passing final grade. In order to allow such intervention, the performance criteria must have the correct resolution - not so broad as to preclude precise correction but not so detailed as to generate so much data that timely analysis becomes impossible. Even with timely analysis, too many possibilities could exist, precluding focused and effective intervention. The performance criteria listed in Figures 1 and 2 represent an initial attempt to subdivide the associated outcomes into such manageable elements.

Figure 1. Performance Criteria Associated with Student Learning Outcome: Ability to Function on Multidisciplinary Teams

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Pts</th>
<th>Level 5</th>
<th>Level 4</th>
<th>Level 3</th>
<th>Level 2</th>
<th>Level 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL POINTS (30)</strong></td>
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<tr>
<td>Engages in group effort</td>
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<tr>
<td>Assumes leadership; Actively encourages participation from others as well as self</td>
<td></td>
<td>Regular, enthusiastic participation; May occasionally lead discussion</td>
<td>Regular participation; Comments in response to others</td>
<td>Seldom participates; Will respond to others rarely; Does not initiate discussions</td>
<td>Never participates; Does not respond to others; Hard to tell if person is even paying attention</td>
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<tr>
<td>Assumes and delegates responsibilities</td>
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<tr>
<td>Assumes leadership; Organizes and plans tasks for the group</td>
<td></td>
<td>Helps to organize and plan tasks for one or more group members</td>
<td>Cooperative and volunteers for tasks; Accepts tasks gracefully</td>
<td>Does not volunteer but will accept tasks with little enthusiasm</td>
<td>Uncooperative; Accepts few or no tasks in grudging manner</td>
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<tr>
<td>Follows through on tasks and assignments</td>
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<tr>
<td>Goes beyond the assigned tasks and takes on additional effort</td>
<td></td>
<td>Completes tasks and assignments on time</td>
<td>Completes most tasks and assignments but may be late</td>
<td>Tasks and assignments are not done on time and are incomplete</td>
<td>Completes few or no assignments or tasks; Always giving excuses</td>
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<tr>
<td>Operates as team member by aiding others</td>
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<tr>
<td>Displays concern for others and consistently seeks ways to help wide range of people achieve their goals</td>
<td></td>
<td>Displays concern for others; Helps friends and close associates achieve goals</td>
<td>Displays concern mainly for friends and aids them only when in obvious difficulty</td>
<td>Does not display overt concern for others; Will render aid if requested</td>
<td>Clearly interested in self and own interests; seldom renders aid under any circumstances</td>
<td></td>
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<tr>
<td>Shows ability to adapt to different group roles</td>
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<tr>
<td>Effectively performs multiple roles in group; Plays similar roles in different groups</td>
<td></td>
<td>Makes attempt to play more than one role with limited success; Tends to adopt same role in different groups</td>
<td>Makes little attempt to play more than one role; Will try secondary roles if asked</td>
<td>Rejects opportunities and/or requests to perform more than one role in same or different groups</td>
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<tr>
<td>Shows an appreciation for cultural diversity</td>
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<tr>
<td>Celebrates cultural diversity; Overly demonstrates that diversity is valued; Seeks out diverse ideas</td>
<td></td>
<td>Accepts cultural diversity; Displays appreciation for different cultural perspectives</td>
<td>Tolerates cultural diversity; Shows no overt hostility; Accepts different opinions</td>
<td>Shows no appreciation for cultural diversity; demonstrates bias on occasion</td>
<td>Rejects cultural diversity; displays intolerance and/or bias towards other cultures/points of view</td>
<td></td>
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<tr>
<td>Ability to interact productively with individuals of different disciplinary/educational experiences</td>
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<td></td>
</tr>
<tr>
<td>When on multidisciplinary teams, freely provides own insights and actively solicits opinions of others with different disciplinary and educational experiences</td>
<td></td>
<td>When on multidisciplinary teams, provides few insights even when asked but does listen to the opinions of others with different disciplinary and educational experiences</td>
<td>When on multidisciplinary teams, neither offers own insights nor listens to others with different disciplinary and educational backgrounds</td>
<td>When on multidisciplinary teams, provides few insights and does not always to the opinions of others with different disciplinary and educational experiences</td>
<td>When on multidisciplinary teams, freely provides own insights and actively solicits opinions of others with different disciplinary and educational experiences</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2. Performance Criteria Associated with Student Learning Outcome: Understanding of Professional and Ethical Responsibilities.

<table>
<thead>
<tr>
<th>Performance Criterion</th>
<th>Pts</th>
<th>Level 4</th>
<th>Level 3</th>
<th>Level 2</th>
<th>Level 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ability to apply the ethical and professional standards of a biomedical engineer in obtaining, reporting and analyzing data</strong></td>
<td></td>
<td>Always follows appropriate procedures (safety, IRB, IACUC) in conducting research; Reports data fully and accurately to all relevant stakeholders; Never fabricates, falsifies or misrepresents authorship, conclusions, data, evidence, or findings; All aspects of research (methods, data, analysis and conclusions) are reported accurately and in sufficient detail to allow trained researchers to replicate and confirm or deny the results.</td>
<td>Always follows appropriate procedures (safety, IRB, IACUC) in conducting research; Data reported with rare omission or inaccuracy to all relevant stakeholders; Never fabricates, falsifies or misrepresents authorship, data, evidence, conclusions or findings; Research is reported in sufficient detail, with minor omissions, that most trained researchers would be able to replicate the research and confirm or deny the results.</td>
<td>Always follows appropriate procedures (safety, IRB, IACUC) in conducting research; Data reporting is incomplete and may miss some important stakeholders; Never fabricates, falsifies or misrepresents authorship, data, evidence, conclusions or findings; Research reports lack sufficient detail to allow even best trained researchers to replicate the research.</td>
<td>Either violates a standard procedure or protocol (safety, IRB, IACUC) or misrepresents authorship, data, evidence, conclusions or findings.</td>
</tr>
<tr>
<td><strong>Ability to apply the guidelines for the ethical and responsible use of animals in research</strong></td>
<td></td>
<td>Able to describe the basic policies and procedures regulating animal research; Can fill out the appropriate research forms for submission to the Drexel IACUC with no errors.</td>
<td>Able to describe most of the basic policies and procedures regulating animal research; Can fill out the appropriate research forms for submission to the Drexel IACUC with minor errors.</td>
<td>Cannot describe the basic policies and procedures regulating animal research; Cannot fill out IACUC forms without any major errors.</td>
<td>Does not understand the meaning of conflict of interest and thus cannot apply it to our circumstances; Does not understand disclosure and may fail to disclose potential conflicts; Acts in a manner which indicates she might exploit research for personal gain; Disregards standards for appropriate release of information.</td>
</tr>
<tr>
<td><strong>Ability to assess situations in regards to conflicts of interest and other issues of trust and act in accordance with professional and ethical standards</strong></td>
<td></td>
<td>Able to explain the meaning of conflict of interest; Always discloses any personal situation where a conflict of interest might arise; Does not plan or participate in research which might exploit research populations or institutional setting for personal gain; Does not release research results or any other information in an inappropriate manner.</td>
<td>Able to explain the meaning of conflict of interest but has difficulty applying the principle to personal situation; May not engage in complete disclosure through misunderstanding; Does not exploit research populations or institutional settings for personal gain; On occasion, might release non-critical information in an inappropriate manner.</td>
<td>Does not understand the meaning of conflict of interest and thus cannot apply it to our circumstances; Does not understand disclosure and may fail to disclose potential conflicts; Acts in a manner which indicates she might exploit research for personal gain; Disregards standards for appropriate release of information.</td>
<td>Definition of confidentiality incomplete or in error; Cannot fully explain how confidentiality applies to either human subject or collaborative research; Definition of intellectual property may be incomplete or in error; Cannot fully explain policies and procedures governing intellectual property rights; Fails consistently to acknowledge the contribution of others to his/her own papers, reports and presentations.</td>
</tr>
<tr>
<td><strong>Ability to demonstrate an understanding of the rights and limitations associated with intellectual property and confidentiality intellectual property agreements</strong></td>
<td></td>
<td>Can define confidentiality and describe how confidentiality applies to human subjects research as well as collaborative research; Can define intellectual property and is able to explain the basic policies and procedures associated with intellectual property rights; Demonstrates respect for intellectual property by consistently acknowledging the role of others in his/her research papers, reports and presentations.</td>
<td>Can define confidentiality but has difficulty explaining how confidentiality applies to either human subject or collaborative research; Can define intellectual property and explain some aspects of the policies and procedures associated with intellectual property rights; Does not always acknowledge the work of others in his/her papers, reports and presentations but will easily correct these oversights when prompted.</td>
<td>Definition of confidentiality incomplete or in error; Cannot fully explain how confidentiality applies to either human subject or collaborative research; Definition of intellectual property may be incomplete or in error; Cannot fully explain policies and procedures governing intellectual property rights; Fails consistently to acknowledge the contribution of others to his/her own papers, reports and presentations.</td>
<td>Definition of confidentiality incomplete or in error; Cannot fully explain how confidentiality applies to either human subject or collaborative research; Definition of intellectual property may be incomplete or in error; Cannot fully explain policies and procedures governing intellectual property rights; Fails consistently to acknowledge the contribution of others to his/her own papers, reports and presentations.</td>
</tr>
<tr>
<td><strong>Ability to treat others with respect and does not discriminate on the basis of gender, race, religion, sexual orientation, social class, ethnic, background, physical disability, marital status, national origin or other attribute not related to academic or research performance</strong></td>
<td></td>
<td>Shows all students, staff, faculty and other individuals courtesy and respect; Does not engage in behavior or conversations demeaning to another group or population; Does not show any favoritism to any person or persons based upon attributes not relevant to academic or research performance. Freely associates with a diverse group of other people and actively listens to other's opinions.</td>
<td>Shows students, staff, faculty and other individuals courtesy and respect; Seldom engages in behavior or conversations demeaning to another group or population; Does not show favoritism to any person or persons based upon attributes or other than academic or research performance; Able to listen to the opinions of others.</td>
<td>Shows reasonable courtesy to students, faculty, staff and other individuals although this may be influenced by the relative rank compared with the student; Sometimes engages in behavior or conversations demeaning to other groups or populations; May show some favoritism to others not based upon performance; Does not always listen to others' opinions.</td>
<td>Shows does not always show others courtesy and respect; Often engages in behavior and conversations demeaning to other groups or populations; Shows definite favoritism based upon factors unrelated to performance; Often fails to listen to others' opinions.</td>
</tr>
</tbody>
</table>
In another example, suppose an engineering program proposes the following new outcome: Understanding of advanced mathematics, physical science, biology and physiology. At what level of resolution should the performance criteria be set? For example, should there be a single performance criterion for an understanding of advanced mathematics as a subcomponent of this outcome?

If there were a single performance criterion associated with advanced mathematics, problems would develop in setting the intervention should a student or program in general fail to meet the standard. If a student did not meet the criterion of “an understanding of advanced mathematics”, what abilities, knowledge or skills does he or she lack which need correction? Suppose the student is deficient in linear algebra. The criterion as stated is so broad that this deficiency might not even be detected if the student excelled in other mathematical techniques. If the student did fail to meet the overall standard, how does one intervene to correct the situation? Should a student be tutored, for example, in all aspects of higher mathematics even though the deficiency is limited to linear algebra? Still, the issue of resolving the one performance criterion into more meaningful components may also be achieved by parsing the rubrics in a manner that specifically identifies the deficiency area. For the given outcome, a level 4 performance rubric would indicate that the student is proficient in all advanced mathematics, and a level 3 performance rubric would indicate that the student is specifically deficient in linear algebra. But then we may be left desiring more information about the degree or nature of the linear algebra deficiency. An alternative then would be to create categories of performance criteria which naturally fit the potential corrective action. The performance criteria might be divided into specific mathematical subject categories with rubrics that delineate the level of proficiency and nature of deficiency in each category as shown in Figure 3. And so, decisions regarding a balance between the amount of desired information and the amount of processing effort become the challenge.

Figure 3: Performance Criteria associated with an Understanding of Advanced Mathematics

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL POINTS (16)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to solve problems which require calculus, including the application of basic techniques in differentiation and integration</td>
<td>Unable to apply the correct mathematical concepts to solving problems in differentiation or integration;</td>
<td>Major procedural errors; Incorrect solutions</td>
<td>Applies correct mathematical concepts to solve problems in differentiation and integration with no procedural errors affecting the solution</td>
<td>Applies correct mathematical concepts to solve problems in differentiation and integration with minor procedural errors which may affect the solution</td>
<td>16</td>
</tr>
<tr>
<td>Ability to apply the methods of differential equations to problems and compute accurate solutions</td>
<td>Unable to apply the correct mathematical concepts to solving problems using differential equations. Major procedural errors; Incorrect solutions</td>
<td>Applies correct mathematical concepts to solve problems using differential equations with minor procedural errors which may affect the solution.</td>
<td>Applies correct mathematical concepts to solve problems using differential equations with no procedural errors affecting the solution</td>
<td>Applies correct mathematical concepts to solve problems using differential equations with no procedural errors affecting the solution.</td>
<td>12</td>
</tr>
<tr>
<td>Ability to analyze and apply the methods of linear algebra to problems and compute accurate solutions.</td>
<td>Unable to apply the correct mathematical concepts to solving problems using linear algebra. Major procedural errors; Incorrect solutions</td>
<td>Applies correct mathematical concepts to solve problems using linear algebra with major procedural errors leading to incorrect solutions.</td>
<td>Applies correct mathematical concepts to solve problems using linear algebra with minor procedural errors which may affect the solution.</td>
<td>Applies correct mathematical concepts to solve problems using linear algebra with no procedural errors affecting the solution.</td>
<td>12</td>
</tr>
<tr>
<td>Ability to understand basic probability theory</td>
<td>Unable to apply the correct mathematical concepts to solving problems using probability theory. Major procedural errors; Incorrect solutions</td>
<td>Applies correct mathematical concepts to solve problems using probability theory with major procedural errors leading to incorrect solutions.</td>
<td>Applies correct mathematical concepts to solve problems using probability theory with minor procedural errors which may affect the solution.</td>
<td>Applies correct mathematical concepts to solve problems using probability theory with no procedural errors affecting the solution.</td>
<td>8</td>
</tr>
</tbody>
</table>
It should be understood that the creation and use of performance criteria and rubrics is an iterative process which requires periodic feedback and reassessment. The initial criteria may prove to have too high or low an effective resolution or too many or too few rubrics to work optimally in a program’s academic environment. The initial development represents an estimate of the appropriate rubrics and should not be expected to be perfect on the first attempt.

Mapping Performance Criteria into the Curriculum

After establishing what is to be measured, the next step is to determine where within the curriculum these measurements are to take place. The curriculum in this context is broadly defined as all aspects of a student’s educational experience, including but not limited to classes, research experiences, internships or co-operative education, and activities such as membership in student organizations, advisory committees, etc. The purpose of mapping is to determine at what points students are taught the knowledge and/or skills needed to meet the performance criteria. By identifying these milestones, the CQI system can monitor student progress and determine where intervention is needed. Again, this is analogous to a manufacturing process where aspects of the process are monitored to ensure components meet specifications and determine where corrective action should be taken if needed.\(^\text{13}\)

Although many kinds of mappings are possible, two specific types of maps often provide the most useful information. The first is a coverage map. In this map, each performance criterion is associated with a specific course or other curricular event (ex. Co-operative education). The assessment approach is described, along with the timing of data collection and most important, a plan for intervention. Such a mapping for a single performance criterion is given in Figure 4.

Figure 4. Example of a Coverage Map for a Single Performance Criterion

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Courses/Educational Experiences *means used to assess</th>
<th>Assessment Tool(s)</th>
<th>Last Evaluation Result (Date)</th>
<th>Collection Time(s)</th>
<th>Intervention Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrates Knowledge of Current Technological Issues</td>
<td>BMES 221 BMES 381 Co-Op*</td>
<td>Co-Op Employer Survey</td>
<td>Dec. 15, 2007</td>
<td>Twice/Year</td>
<td>Additional Class in ethical issues related to human relationships</td>
</tr>
</tbody>
</table>

In the coverage map, all educational experiences related to the performance criterion are listed to the extent possible but only one or two are selected for data collection. In Figure 5, the asterisk indicates that the primary source of assessment data for this performance criterion will be a survey given to supervisors of student employees during a co-operative education experience and that this survey will be conducted twice a year.

The second type of map is a tracking map. This is more closely analogous to CQI or Six Sigma in the manufacturing sense. In this case, performance criteria are charted over the curriculum in terms of when and how each criterion is introduced, reinforced, and emphasized. This provides a
second kind of guide for constructive intervention and provides assistance for curriculum design. An example of a tracking map is provided in Figure 5.

Tracking maps show how well each performance criterion is represented throughout the curriculum. In the process of creating such maps, it is often surprising how the distribution actually maps out. Some criteria are often represented in numerous experiences (such as seen in Figure 6) while others may be limited to a few classes or perhaps only one. The very process of mapping reveals aspects of the curriculum design which are not apparent under normal circumstances and provides significant insight into how the curriculum might be improved to provide a more reasonable coverage.

Figure 5. An Example of a Tracking Map showing Educational Experiences which Introduce, Reinforce or Emphasize a Student’s Ability to Satisfy the Performance Criteria

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Introduction Level</th>
<th>Reinforcement Level</th>
<th>Emphasize Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to evaluate existing models of physical and biological systems</td>
<td>BMES 212</td>
<td>BMES 375; BMES 411; BMES 412</td>
<td>BMES 477; BMES 478;</td>
</tr>
<tr>
<td></td>
<td>ENGR 231; ENGR 232</td>
<td>BMES 441; BMES 442; BMES 451</td>
<td>BMES 483; BMES 484</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BMES 460; BMES 471; MEM 202</td>
<td></td>
</tr>
<tr>
<td>Ability to simulate or represent biological systems via a mathematical or physical model</td>
<td>BMES 221; BMES 222;</td>
<td>BMES 375; BMES 332; BMES 440</td>
<td>BMES 443; BMES 477; BMES 483</td>
</tr>
<tr>
<td></td>
<td>BMES 301</td>
<td>BMES 441; BMES 442; BMES 472</td>
<td>BMES 484</td>
</tr>
<tr>
<td></td>
<td>BIO 122</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to conduct experiments</td>
<td>BIO 122; CHEM 102;</td>
<td>BIO 215; BIO 219; BMES 221</td>
<td>BMES 461</td>
</tr>
<tr>
<td></td>
<td>CHEM 103; ENGR 101;</td>
<td>BMES 222; BMES 301; BMES 302</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PHYS 101; PHYS 102</td>
<td>BMES 304; BMES 315; CHEM 244;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHEM 245; ENGR 231; ENGR 232</td>
<td></td>
</tr>
<tr>
<td>Ability to analyze experiments using statistical, mathematical and/or computational methods</td>
<td>BIO 122; CHEM 101;</td>
<td>BIO 215; BIO 219; BMES 221</td>
<td>BMES 461; BMES 421</td>
</tr>
<tr>
<td></td>
<td>CHEM 102; ENGR 201;</td>
<td>BMES 222; BMES 310; BMES 315</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENGR 202; PHYS 101;</td>
<td>BMES 401; CHEM 244; CHEM 245;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PHYS 102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to make observations and devise hypotheses to explain those observations</td>
<td>BIO 122; ENGR 201;</td>
<td>BMES 221; BMES 315; CHEM 244</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ENGR 202</td>
<td></td>
<td>CHEM 245</td>
</tr>
<tr>
<td>Ability to design an experiment to test a hypothesis</td>
<td>BIO 122; ENGR 201;</td>
<td>BMES 310; BMES 315; BMES 381;</td>
<td>BMES 461; BMES 491-3/THESIS</td>
</tr>
<tr>
<td></td>
<td>ENGR 202</td>
<td></td>
<td>BMES 461; BMES 491-3/THESIS</td>
</tr>
<tr>
<td>Ability to identify and categorize the biological/physiological phenomena being measured</td>
<td>BMES 301; BMES 302;</td>
<td>BMES 391; BMES 392; BMES 421;</td>
<td>BMES 422; BMES 442</td>
</tr>
<tr>
<td></td>
<td>BMES 304</td>
<td>BMES 423; BMES 432; BIO 215</td>
<td></td>
</tr>
<tr>
<td>Ability to describe the specifications and operation of measuring equipment</td>
<td>BMES 302; BMES 303;</td>
<td>BMES 391; BMES 392; BMES 401;</td>
<td>BMES 422; BMES 442</td>
</tr>
<tr>
<td></td>
<td>BMES 304; ENGR 201;</td>
<td></td>
<td>BMES 422; BMES 442</td>
</tr>
<tr>
<td></td>
<td>ENGR 202</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How are such maps created? While there is no one best method, a reasonable approach begins with course syllabi. Every course should have a syllabus and as part of that syllabus, course objectives. Many of these objectives can be directly related to the performance criteria set up as components of the student learning outcomes. A first pass at mapping performance criteria into classes can be done by a faculty committee, such as the curriculum or assessment committee, based upon available syllabi. After preliminary maps for coverage and tracking are generated, the position of each course is confirmed through discussions with the course instructor. After confirming that a given performance criterion is indeed a goal of the class, an assessment tool can be suggested by the course instructor. The tool can then be refined through interactions between the instructor and the appropriate faculty committee. After the first preliminary maps are created, the mapping is further refined through faculty review and the appropriate assessment targets (courses, projects, internships, etc.) are selected.

This process is somewhat labor-intensive and may take 6-12 months or more. It is also, like all aspects of CQI, iterative and there is no absolute final product. As the maps are used, it is likely that some assessment tools may be found to be more revealing than others, or that fewer or more assessment targets are needed to get the correct amount of data for analysis. A flexible system incorporating user feedback and change is essential to keep the CQI system functioning at a high level of effectiveness.

**Evaluating Performance Criteria with Assessment Tools**

Assessment tools come in a variety of forms, including student course evaluations, senior exit interviews, portfolios, standardized examinations, focus groups, external reviewers, employer surveys, alumni surveys and so on. ABET categorizes these tools into two kinds: direct measures and indirect measures. Indirect measures are evaluations done by individuals on themselves. For example, a student course evaluation can include a section in which the student estimates the amount of each course objective that he or she learned. Alumni surveys that ask how well the program curriculum prepared the individual for his or her current position are another example. Generally, survey instruments that collect student opinion about their own capabilities are tools that collect indirect measurements.

Direct measures evaluate a person from an external perspective. Examples include standardized tests, external reviewers and employer evaluations. There is a tendency to redefine indirect and direct measures as subjective and objective respectively, but that is not how the terms are used in practice. An employer evaluation of a student is clearly subjective but also a direct measure since it involves a source external to the student.

Some assessment tools contain a mix of direct and indirect measurements. Senior exit interviews, for example, collect indirect measurements when questions concern the interviewees’ own abilities and knowledge but direct measures when questions concern such matters as library services and advising.
The primary goal of assessment is to determine if students and graduates meet the requirements set forth in the student learning outcomes and program objectives respectively. Direct measures should be used whenever and wherever possible since those measures are likely to be more reliable, but that does not invalidate information gained from indirect measurements. Indeed, a comparison of the two can provide valuable insights into a program. Recently, a student at our institution stated during his senior exit interview that he had believed that his level of actual learning was inadequate until he participated in the Professional Engineers examination and found he could easily answer the majority of the questions. This was evidence that while the program might be achieving its goals in regards to student learning outcomes, the students themselves did not recognize that fact. In the long run, this could lead to the program failing to meet its objectives. Students who lack confidence in their own knowledge and skills are less likely to take the challenging positions and thus less likely to achieve significant success. In this case, a comparison of direct and indirect measures of student learning outcomes uncovered a problem that could lead to difficulties in meeting program objectives despite the fact that, by most direct measures, the program was meeting its requirements in terms of learning outcomes.

It should be noted that every performance criteria requires a standard to determine if program is successfully educating its students. Such a program standard might be that 75% of graduating students rank at a minimum of 3.5 out of 4 on performance criterion 3 for student learning outcome 5. For program assessment, one is looking at population effects – for example, did 80% of the students who took a standardized examination pass with a score of 75% or higher. If that is the standard, and greater than 80% of the students did score higher than 75%, then no intervention is required at a programmatic level. On the other hand, what about the 20% of the students who did not score above 75%? It is still possible to intervene at a personal level for these individuals by arranging tutoring or some form of remedial activity to bring their performance up to the standard. When analyzing assessment data, one should clearly differentiate between general problems in meeting requirements which require changes at the curricular level and the difficulties of individual students which require intervention at a personal level but do not necessitate changes in the curriculum or program.

A Problem in Knowledge Management

The program for CQI described above raises several issues, not the least of which is what organizational structure is required to implement and maintain such a program. Again, there is no one answer, no ‘magic bullet’ or ‘one size fits all’ approach that will work in every case. Each program has its own history, organizational structure, strengths and weaknesses, personalities and politics which will help determine the optimum organizational configuration. However, there are general considerations that merit discussion.

For any project to succeed, there must be a knowledgeable advocate. This is especially true in this case, where resistance can be expected. This resistance need not be limited to faculty. Some administrators may be reluctant to embrace CQI, thinking that the expense and resources needed, especially in the start-up stages, are not justified. Administrators can also mix up ends and means, assuming that the reason for CQI is accreditation rather than programmatic excellence. In such cases, both faculty and some administrators may need convincing and thus the advocate must be in the position to argue the case. A respected senior faculty member, program director,
or assistant department head may be in the best position for such a role although that will depend
on the circumstances of the institution in question. Insofar as CQI involves active participation
form faculty, a faculty advocate will have the best chance of making the case for CQI. Such an
advocate can reduce the suspicion that CQI is some sort of administrative ploy to collect more
data on faculty performance. In addition, a faculty advocate is also a participant in the system
and will have a user’s perspective on the time and effort needed to initiate and maintain any CQI
system.

Eventually, there will have to be support from the upper administration – Department Chair,
Dean and/or Provost depending on the circumstances – for the project to proceed. Resources will
be needed. How the advocate approaches this requirement again depends on the specific
circumstances. It might be effective to convince a small group of additional faculty and develop
an initial plan before approaching a Department Chair or Dean. On the other hand, it may be
to have the Dean or Department Chair’s backing when approaching the faculty. In either
case, the advocate for CQI in engineering programs has one significant advantage – ABET
accreditation.

The use of ABET accreditation requires very careful management. Like using an explosive, it is
good for moving mountains but can also blow up in your face. As indicated above, too much
emphasis on accreditation and that becomes the goal rather than an effective CQI process and
curricular enhancement. Another problem may be senior faculty whose experience with the
accreditation process is out-of-date. They remember a kinder and gentler ABET before the
current emphasis on truly establishing that performance criteria are being met. If accreditation is
the only reason for CQI, such faculty can undermine an advocate’s efforts by suggesting the
advocate is overstating the case. The resulting disagreements over ABET’s actual requirement
distracts from the real issue of establishing CQI.

That being said, use of ABET accreditation requirements can be one way of opening discussions
on CQI. ABET requirements provide guidance on the overall structure and an initial justification
for expending time, effort and resources. At some point, however, it will be necessary to move
beyond ABET and consider CQI as justified in and of itself. To do this, CQI must be efficient
and useful. Using the engineering design paradigm for product development and quality
management applied to curricular enhancement provides a model for such a transition.

Another factor is faculty workload. Any significant increase in the average faculty workload
associated with CQI is very likely to meet with significant resistance. For CQI to work, faculty
must be willing participants. The emphasis is on ‘willing’. CQI is not a process that can be
imposed in a top-down manner and be effective. At every level of design, planning and
implementation, faculty involvement is critical. Faculty should be considered as significant users
of CQI and their perspective and experience will play a vital role in creating a viable design.

The best CQI systems are diversified. A variety of assessment tools and targets should be used.
When using a specific course as an assessment target, work with the faculty instructor on the
correct tool to use. The chances are that the instructor is already assessing student performance
and may have the tool already in place. In such cases, all that needs to be done is to collect the
data in a useable form for later analysis. Also, the number of performance criteria assigned to
any specific course for assessment purposes should be limited to no more than 3. Sometimes, faculty become enthusiastic when mapping performance criteria, believing that there is a direct correlation between the number of criteria assigned and the importance of the course to the curriculum. As a result, they assign dozens of criteria to their courses without considering the burden required to collect measurements of student performance for each criterion. Set priorities and limits for assessments.

With these factors in mind, one possible organizational structure for CQI is presented in Figure 7. In this case, CQI is managed by faculty through the Curriculum Committee and specifically by the Assessment Subcommittee.

Figure 7 shows the assignment of responsibilities. Figure 8 displays the flow of information in a potential CQI system.

**AEFIS (Academic Evaluation, Feedback and Improvement System)**

To manage data through such a system is a daunting task. To ensure the utility and accessibility is even more problematic. Early in the evolution of CQI at the School of Biomedical Engineering, Science and Health Systems at Drexel University, it was recognized that automating as much of the information flow as possible held the promise of better knowledge management coupled with significant savings in terms of faculty workload. Design began on an automated system called AEFIS. The initial stages focused on indirect measures and survey tools while current design work involves incorporated numerous additional assessment instruments and more direct measures.

As the development of AEFIS has proceeded, feedback has led to changes in format and system design. In addition, it was recognized that not all elements of the CQI process could be completely codified. In addition to students filling out the on-line senior exit interview form, for example, an actual interview with a faculty member is considered essential to the process. Similarly, it has become a standard practice for the Chair of the Curriculum Committee to interview faculty about their courses as part of the faculty course evaluation process. Forms simply do not provide all the necessary information and personal interaction remains a vital part of the CQI process.

**Course Offerings, eSyllabi and Course Evaluations**

The first step was to create a system to provide standardized and archived syllabi associated with course offerings. The objectives were:

- a. To standardize all syllabi associated with the School's coursework;
- b. To maintain a continuous electronic archive of all School syllabi;
- c. To provide electronic syllabi for students and faculty of the School;
- d. To link objectives for a course listed on its syllabi directly with student course evaluations;
- e. To provide layered, secure access to the syllabi and evaluations.
**Figure 6: Organization Chart Showing Various Curricular Responsibilities**

**ORGANIZATIONAL CHART – UNDERGRADUATE CURRICULUM COMMITTEE**

**UNDERGRADUATE CURRICULUM COMMITTEE**

Responsible for:
- a. Curriculum Development and Revisions
- b. Curriculum Proposals to Faculty Senate
- c. Communication with Faculty concerning Student Learning Outcomes
- d. Communication with Students concerning Student Learning Outcomes
- e. General Administration of Undergraduate Curriculum
- f. Interaction with Administration on Matters concerning Undergraduate Curriculum
- g. Enforcement of Policies and Procedures concerned with Delivery of the Undergraduate Curriculum

**ASSESSMENT SUBCOMMITTEE**

Responsible for:
1) Designing and Implementing all Assessment Instruments for the Undergraduate Curriculum
2) Collecting and Analyzing Assessment Data
3) Communicating Analysis of Assessment Data to Curriculum Committee
4) Making Recommendations for Improvements to the Curriculum
5) Managing all Assessment Procedures for ABET

**STUDENT ADVISING SUBCOMMITTEE**

Responsible for:
1) Communicating all changes in the Undergraduate Curriculum to Appropriate Advisors and Staff
2) Forwarding Students Comments on the Curriculum to the Curriculum Committee
3) Ensuring that All Proposed and Actual Changes in the Undergraduate Curriculum are Rapidly and Effectively Communicated to All Students
Figure 7: Basic Schematic Diagram of CQI Knowledge Management System
The flow of information and activities associated with course offerings and assessments is as follows. A course list is created for the upcoming term. Each course is associated with one or more faculty. From the database, an instructor is assigned to each course. Each instructor thus chosen is sent an e-mail alerting him or her that they are teaching that course for that quarter. The instructors then go into the database and select the course, requesting the most recent syllabus. This syllabus is presented in a series of dialog boxes requesting such information as textbook, course objectives, grading criteria, etc. Each box contains the archival information, which can either be accepted or modified. After the faculty completes the syllabus for the upcoming term, a copy is forwarded for review and format approval. Once approved, data within the syllabus are used to create: 1. The course objectives will be used to create questions on the student evaluation form (i.e., what was your level of knowledge objective \( X \) before taking the course and after taking the course?); and 2. the pre-requisites are included as part of the faculty course evaluation. The completed syllabus is then given a URL which is provided to students by the course instructor. The new syllabus is automatically archived and linked to the results of both the student and faculty evaluations at the end of the term. This is also the syllabus that the instructor of the course will be sent the next time this particular course is taught.

During the 8th week of each term, e-mails are sent to students and instructors informing them that course evaluations are now available on-line. Students log on to the School's Web site and access their classes, each one of which has a specific course evaluation form. Students fill out the form and submit to the School. An e-mail confirmation is sent to each student with an ID# for each evaluation. The ID# is to create a temporary and confidential identification of each student. This is done to prevent a single student from submitting more than one evaluation per course taken.

Instructor course evaluations are also accessed via the School's Web page. Again, each instructor is presented a form to fill out as part of the course evaluation. These evaluations are primarily for use by the Curriculum Committee but can be accessed by appropriate administrators.

**Meeting Minutes**

Another important source of information comes from various gatherings of faculty, staff, and students. Foremost among these are the Curriculum Committee, Faculty, and Student End-of-Term meetings. The minutes from these meetings are archived and accessible to students, faculty and staff through key word searches.

All meeting minutes relating to the CQI process are currently entered into the AEFIS. In this way, the development and evolution of any proposal can be tracked through the database, its origin determined and final outcome retrieved. Thus, the reasons for any decision can be analyzed and re-evaluated in light of new data or changing circumstances. Meeting minutes from faculty meetings, curriculum committee meetings, student meetings, senior design committee meeting, etc. are all stored electronically and easily searchable by key word.
Senior Exit Interviews

Senior Exit Interviews combine in-person and Web-based evaluations. All seniors are contacted by e-mail in the final term of their senior year and directed to fill out a questionnaire located on the School's Web site. Once the form has been submitted, each senior is assigned to a faculty interviewer with whom they will meet and discuss the comments made on the submitted form. Once the interview is completed, the faculty signs off on a secure place on the original form indicating that the senior has satisfied the interview requirement. The data is archived in the database and evaluated by the Curriculum Committee.

Alumni Surveys

Alumni are requested to complete an online survey to assess how well the biomedical engineering academic experience has served them in their careers. The survey assesses the achievement of the School’s educational objectives, and complements the existing post-graduation survey given by the University at the time of graduation. Contact information is obtained from the Senior Exit Interview forms and updated as needed. Once per year, alumni are contacted, ideally by e-mail, and requested to complete the online Alumni Survey form. The data are archived in the database and evaluated by the Curriculum Committee. The format of the Alumni Survey Form and the response rate from our e-mail requests are currently being evaluated.

Planned Improvements

Currently, efforts are proceeding to implement modifications to the AEFIS system. The purpose of the modifications is to store numerical information on the performance of students associated with direct measures related to performance criteria. Performance is determined using assessment tools such as project grades, homework, oral presentations, test questions or other assignments associated with specific courses, general examinations, external reviews, electronic portfolios, reviews of written work by faculty committees, etc. These data will be used to determine the efficacy of the curriculum in allowing students to achieve designated learning outcomes by the time of graduation.

After review by various stakeholders, the School established 14 student learning outcomes incorporating ABET a-k, ABET program outcomes for biomedical engineering and 2 additional outcomes suggested by the School’s Student Advisory Board and modified and approved by the faculty. Each outcome is subdivided into performance criteria which are characterized by 3-5 rubrics per performance criterion (see Figures 1-4 for examples). A performance criterion can be mapped to a specific class and assessed on the students in that class. On the other hand, performance criteria can be mapped to various classes but assessed by giving all third-year students an independent examination.
Performance criteria are typically assessed at 2-3 locations within the curriculum. This serves to assess at an early, intermediate, and advanced stage of the students’ academic careers in order to intervene in the process should the assessment results indicate that students learning outcomes are not being achieved. Thus, the design of AEFIS will be modified to keep track of the students’ progress through the curriculum and the efficacy of any intervention that has been implemented.

Performance assessments will be kept in the new AEFIS performance database associated with at least the following: time of assessment (term, year,), source of assessment (course, independent examination, co-op employer survey), student characteristics (number of freshman, sophomores, etc; number in each concentration area), assessment level (early, intermediate, late), success/failure (calculated percentage from data), intervention status (pre or post intervention, type of intervention). This is a minimal list, which will inevitably expand as the system evolves.

Some typical queries would involve tracking performance criteria across assessment levels, measuring the success or failure of specific interventions, monitoring whole outcome results, among others.

Since many of the performance criteria are assessed through specific classes, AEFIS will be modified to collect and store such data. All electronic syllabi (eSyllabi) will be modified to include performance criteria in a new section entitled 'ABET performance criteria'. This section will be a fixed part of the course description not accessible for faculty modification, and will contain all of the performance criteria pertinent to that course. The CQI administrator will have the power to add or modify the performance criteria as part of the course creation module at the direction of the Curriculum Committee. Therefore, the performance criteria will be selectable in the following sense: if selected for assessment within a given course, the performance criterion will be designated on the Instructor Course Evaluation (ICE); if not selected for assessment in that course, the criterion will still appear on the eSyllabus but will not appear on the ICE. All other aspects of the eSyllabus remain as currently implemented. This structure allows a modular assignment of performance criteria within the curriculum so that assessment targets can be flexibly designated to achieve optimal data collection.

Assessment results reported by faculty instructors will be submitted through the ICE. Only the selected performance criteria from the eSyllabus will appear on the ICE. A single course can have as many as 2-3 performance criteria for which data will be submitted each term. When a faculty member clicks on a criterion, the rubrics for evaluating that criterion appear as an Excel-style spreadsheet (Figure 9). The faculty will enter the number of students at each level and then click on a submit button to save the data. The data will be saved with the identifiers of course, term, year, instructor, outcome, and performance criteria. Once the data are provided and submitted, the system will store the results as both raw numbers and as percentages of the total number of students listed.
In addition, there will be a new response field on the ICE that will be used by the CQI administrator to input the feedback recommendations of the Curriculum Committee and/or Assessment Subcommittee. These recommendations will be made to improve the course after review of the Student Course Evaluations and performance criteria by the Curriculum Committee. The response field currently asking how faculty responded to previous evaluations will specifically refer back to the recommendations in this new field to show the actions taken. All other aspects of the ICE will remain as currently implemented.

The majority of faculty will input course data through the ICE using the performance criteria rubrics. However, the mapping of performance criteria into the curriculum has other sources, including certain aspects of the senior design (external reviews), co-op employer surveys, per-junior exams, faculty review of research papers and lab report, etc. The CQI administrator will have the ability to enter data from these other sources following a protocol similar to the faculty submissions.

**Assessing Incoming Students**

One aspect of the design paradigm which has not been discussed as yet is the problem of determining the characteristics of the raw material, in this case, the incoming students. While the student learning outcomes are somewhat constrained by ABET requirements, the methods by which a curriculum attains those outcomes will vary greatly. Part of this variation will be due to the attitudes and attributes of the incoming students with whom the faculty and staff will work. It is suggested that some evaluation of these students be taken as early as their arrival on campus will allow. Among the kinds of evaluations which could be relevant are the Grasha-Reischmann Learning Styles Inventory\(^\text{20}\), multiple intelligences assessments\(^{21}\), and/or a personality inventory, such as a Myers-Briggs test\(^{22}\). It will important to consult with the Institutional Review Board for human research before administering such tests, especially if the results might lead to
publication. The purpose of these evaluations would be to determine if certain styles of teaching and learning are associated in ways that can be used to improve students’ opportunities to meet the programs outcomes and performance criteria.

Conclusion

Although changing ABET requirements have made CQI a necessity for programs in engineering education, the value of a well-designed and implemented system goes far beyond accreditation. A good CQI system provides a framework for rational curriculum enhancement by supplying a foundation of real data to either justify current conditions or indicate a proper direction for change. The creation of performance criteria and their associated rubrics provides guidance to both faculty and students regarding the program’s expectations, which can result in improved student performance. And in conclusion, the key to successfully achieving a CQI system that can be implemented without excessive increases in faculty workload is using the engineering design paradigm and incorporating information systems and technology in strategic segments of the process.

Bibliography


