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Direct and Indirect Assessment Methods: Key Ingredients for Continuous Quality Improvement and ABET Accreditation*

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The new accreditation criteria, better known as ABET EC 2000, require that each program 'must have an assessment process with documented results.' Furthermore, a white paper by the Engineering Accreditation Commission's Executive Committee states, 'The assessment process should include direct and indirect measures and does not rely only on self-report surveys and evidence that the material is 'covered' in the curriculum.' This paper presents: (a) an overview of an assessment process to make engineering programs ABET accreditation compliant; (b) assessment methods that are used to collect data, interpret them, and utilize the results to improve engineering programs; (c) a process to choose the appropriate mix of direct and indirect assessment methods/instruments, and (d) implementation of assessment methods to an electrical engineering program. As an example, the paper presents a sample of recent changes that have led to improvements based on program assessment of the University of Portland School of Engineering electrical engineering program.

Keywords: accreditation; direct assessment; indirect assessment; outcomes assessment; continuous quality improvement (CQI); performance rubrics or criteria.

INTRODUCTION

IN 1992 ABET invited academic, industry, and professional society leaders to participate in a review of the accreditation process, and the Accreditation Process Review Committee was formed. In 1996, after thousands of hours of hard work by hundreds of engineering professionals, the ABET board of directors approved a set of new criteria for engineering education, the ABET Criteria 2000 [1–4]. The new criteria provide more flexibility to individual programs, allowing the engineering schools to be more responsive to the needs of their students as well as to the mission of their institutions and programs. A number of publications have been prepared by a variety of individuals and groups that have been helpful to all of us in the engineering community [5–10, 15–18].

In this paper we focus on criterion 3 of the new ABET Engineering Accreditation Criteria, namely program outcomes and assessment. A program is described by the program objectives, outcomes, and curriculum. Program outcomes describe what the program's graduates will know and be able to demonstrate upon completion of their degree program. Program outcomes provide the link to the program curriculum and they relate to program educational objectives as well. Program outcomes should include those outcomes described in criterion 3 of the ABET criteria for accrediting engineering programs, as well as outcomes unique to the character of the institution.

In addressing criterion 3, it is important that we watch for and avoid the following situations and issues:

- insufficient evidence demonstrating achievement of one or more outcomes (inadequate data records, inadequate metrics defined for assessment, or limited indication of how results were used to improve and further develop the program);
- outcomes not assessed objectively (taking a course does not guarantee achievement of an outcome, anecdotal results versus measurements, over-reliance on course grades as assessment of outcomes, or over-reliance on self assessment);
- insufficient systematic assessment process in place (inadequate or undocumented process, plans developed but not implemented, or little or no faculty support for the process);
- insufficient evidence that results of the assessment process are being applied to improve the program (assessment results not used; changes being made ad hoc, or assessment and improvement cycle not complete)

Program outcomes are assessed using a variety of instruments. Examples of assessment instruments are: student transcripts indicating successful completion of the courses in the curriculum;

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capstone design projects; Fundamentals of Engineering examinations; graduating senior surveys; and comprehensive examinations. The results of outcomes assessment are utilized to improve the program (program objectives, program outcomes, or program curriculum).

This paper is organized as follows: overview of the outcomes assessment process we recommend; description of direct and indirect assessment methods; choosing an appropriate mix of direct and indirect assessment methods for each program outcome; performance criteria (rubrics) for assessing program outcomes; course embedded assessment and documentation of its results; annual documentation of program assessment results, and it closes with a summary and conclusive remarks.

OVERVIEW OF OUR OUTCOMES ASSESSMENT AND PROGRAM IMPROVEMENT PROCESS

The purpose of assessment is to gather data that can be used to: (1) document the success of an educational program in assisting students to achieve the desired outcomes, and (2) identify aspects of the program that may need improvement.

At our school, the relationship between the assessment instruments and the program outcomes is determined by the faculty of each of our degree programs. Many of the assessment instruments are designed to assess more than one program outcome.

A matrix mapping program outcomes against select required courses in the curriculum was developed by the faculty of each program. Each curriculum was reviewed/revised to ensure that all program outcomes (11 by ABET plus one added by the faculty of the School of Engineering to reflect the nature of the University of Portland) were addressed by the curriculum.

At the end of each academic year, the faculty of each program prepares a report that summarizes the results of all assessment activities. Included in the document are actions taken to improve the program, as well as changes to be implemented, based on assessment of the program outcomes, and other changes determined by the faculty.

DIRECT AND INDIRECT ASSESSMENT METHODS

When selecting an assessment method, the most important criterion is whether it will provide useful information [11–13]. Useful information demonstrates whether students are learning and developing in ways the program faculty agrees are important. Interpretations of assessment results enable the program faculty to verify how well the program is achieving its desired outcomes, as well as to determine how to improve the quality of education to achieve the desired outcomes.

- **Direct Assessment Methods (DAMs) that Provide Evidence of Student Learning.**
  DAMs require students to demonstrate their knowledge and skills, and provide data that directly measure achievement of expected outcomes. In other words, DAMs refer to assessing students' learning by observing or examining their performance first hand.
  Examples of DAMs that can be utilized to assess program outcomes, as well as course learning objectives, include: course embedded (course-based) assessments, examinations, capstone or senior level projects, internships, portfolios (collections of student work), intercollegiate competitions, and performance on a case study.
- **Indirect Assessment Methods (IAMs) that Provide Evidence of Student Learning.**
  IAMs such as surveys and interviews gather reflection about learning. These methods are likely to suffer from validity and reliability problems as individuals' perceptions of their actual performances may be difficult to candidly or accurately assess and report.
  Examples of IAMs used as outcomes assessment instruments include: graduating senior surveys and exit interviews, alumni surveys, student evaluations of courses, student focus groups, faculty surveys, employer/recruiter surveys, graduate follow-up studies, and job placement statistics.
- **Assessment Methods that do not Provide Evidence of Learning.**
  Examples include: enrollment trends, patterns of how courses are selected by students, faculty to student ratios, percentage of students who graduate within a certain period of time, diversity of the student body, percent of students who study abroad, size of the endowment, and faculty publications.

PROGRAM OUTCOMES AND ASSESSMENT METHODS

At the University of Portland School of Engineering we have chosen the following three direct assessment methods; namely, course embedded assessment, comprehensive examination, and capstone design. Indirect assessment methods that we use include graduating senior exit surveys, industry advisory council surveys, and alumni surveys. Table 1 shows a matrix of program outcomes and the assessment methods.

PERFORMANCE RUBRICS FOR ASSESSING PROGRAM OUTCOMES

Depending on the program outcome being assessed, a variety of performance criteria can be

Table 1. Program outcomes and assessment instruments for our electrical engineering program

Program outcomes	Benchmark courses *	Senior design course **	Comprehensive exam ***	Senior exit surveys	Alumni surveys
a. An ability to apply knowledge of mathematics, science, and engineering	EE 262 EE 301	×	×	×	×
b. An ability to design and conduct experiments, as well as to analyze and interpret data	EGR 360 EE 371	×		×	×
c. An ability to design a system, component, or process to meet desired needs	EE 371 EE 373	×		×	×
d. An ability to function on multi-disciplinary teams	EE 333	×		×	×
e. An ability to identify, formulate, and solve engineering problems	EE 332 EE 352	×	×	×	×
f. An understanding of professional and ethical responsibility	EGR 110	×		×	×
g. An ability to communicate effectively	EE 371	×		×	×
h. The broad education necessary to understand the impact of engineering solutions in a global and societal context	EGR 351	×		×	×
i. A recognition of the need for, and an ability to engage in life-long learning		×		×	×
j. A knowledge of contemporary issues	EGR 351	×		×	×
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	EE 231 CS 303	×	×	×	×
l. An ability to develop a sense of personal, social, and moral responsibility		×		×	×

* Data from assessment of these benchmark courses are used to assess the success of the associated program outcome.
** × indicates that the particular program outcome is addressed.
*** EE faculty administered comprehensive examination used to assess the outcome.

used to assess students' work For each program outcome a sample list of the rubrics is shown below:

a) An ability to apply knowledge of mathematics, science, and engineering

- Formulate and solve mathematical models describing the behavior and performance of physical, chemical, and biological processes and systems.
- Use basic scientific and engineering principles to analyze the performance of processes and systems.
- Derive an engineering formula from mathematical, scientific, or engineering science principles.
- Determine and apply the appropriate formula for a particular engineering problem.
- Manipulate formulas to find an appropriate answer.

b) An ability to design and conduct experiments, as well as to analyze and interpret data

- Conduct a laboratory procedure with minimal supervision.
- Design an experiment (i.e., set up experiment, determine the proper models to use, consider the variables and constraints, and consider ethical issues).
- Analyze laboratory data to determine specified quantities.
- Interpret the results for correctness and precision or apply results to a pre-assigned problem.

c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

- Identify an engineering problem.
- Apply established design criteria for an engineering system, component, or process within realistic constraints.
- Use appropriate design methods for an engineering system, component, or process.
- Evaluate alternative solutions to select an appropriate solution.

d) An ability to function on multi-disciplinary teams

- Collaborate on an assigned task.
- Understand the four dimensions of team work: collaboration, communication, conflict management, and self-management.
- Organize the delivery of products for an assigned task.
- Collaborate in applying the design process.

e) An ability to identify, formulate, and solve engineering problems

- Identify a problem by defining the problem expectations.
- Identify a problem by collecting information about the problem and determining which information is important and which information is not.

- Formulate a problem by selecting the appropriate formula and making appropriate assumptions that apply to the problem.
- Formulate a problem by sketching or other graphics, when appropriate.
- Solve a problem by applying appropriate principles, assumptions, and formulas.
- Understand that the problem solving process is never complete.

f) An understanding of professional and ethical responsibility
- Understand their respective professional society's code of conduct.
- Understand the variety of ethical theories (i.e., virtue ethics, right ethics, duty ethics, and utilitarian ethics).
- Make informed ethical choices.
- Evaluate the ethical dimensions of professional practice.

g) An ability to communicate effectively
- Organize a written work.
- Provide in writing the purpose of the work and suitable background information related to the work.
- Clearly present results, conclusions, and recommendations related to the work.
- Write clearly and concisely.
- Organize an oral presentation.
- Effectively use visual aids in an oral presentation.
- Deliver an oral presentation clearly and with minimal distractions.

h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- Understand environmental, political, economical, aesthetics, and social impacts of engineering work.
- Interpret solutions in both societal (a particular community, state or a country), and global (more than one community, nation, or country) contexts.

i) A recognition of the need for, and an ability to engage in life-long learning
- Articulate the need for continued education and participation in professional activities.
- Recognize problems that require learning beyond that attained in their curriculum.
- Engage in self-study to acquire learning beyond that attained in their curriculum.
- Research a topic and prepare an informed presentation.

j) A knowledge of contemporary issues
- Understand application of recent hardware and software in their discipline.
- Understand impact of a global engineering environment on their discipline.
- Understand and have in-depth knowledge of non-technical contemporary issues such as socio-economic, political, and environmental issues.

k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
- Use specific computer software and simulation packages specific to their discipline.
- Demonstrate the ability to use modern equipment in their discipline.
- Use technical library resources and literature search tools.

l) An ability to develop a sense of personal, social, and moral responsibility
- Develop the knowledge, skills, and commitments for acting ethically in everyday life.
- Examine faith, its place in one's own life, and the lives of others.
- Critically examine the ideas and traditions of western civilization.
- Value the importance of learning and reflection throughout one's life.
- Learn to live and contribute in a diverse society and an interdependent world.

COURSE EMBEDDED ASSESSMENT [14]

Course embedded assessment is one of the instruments that is used for measuring the degree to which students attain the program outcomes. Therefore, course embedded assessment has two primary roles: (1) to use student work to assess the achievement of each program outcome and the degree to which each outcome is achieved, and (2) to provide data for developing and improving the program. The course embedded assessment process should also provide a means of documenting the assessment results and the course and program changes that follow from these results.

Not all courses are involved in course embedded assessment. Each program outcome should be assessed with student work in preferably two courses, termed 'benchmark courses.' Only required courses in the program curriculum are selected as benchmark courses. Although a benchmark course will likely address multiple program outcomes, only one or two of its outcomes would be designated for course embedded assessment.

Course embedded assessment would be administered with the following factors in mind:

- Assessment of student work should resolve the degree to which program outcomes are being achieved and should provide useful information for making program improvements.
- Within a benchmark course, it is not necessary to use all student work to assess an outcome that has been designated for the course.
- Outcome assessment instruments should be designed so that they are focused and easy to administer and evaluate.

- Outcomes assessment should be based upon student work and can be guided by the grading of that work. However, student grades by themselves should not be instruments for assessing program outcomes.

Documentation of Course Embedded Assessment

At the end of a benchmark course, the instructor will assess the student work. The format for documenting the results would be as follows:

- A list of all outcomes addressed by the course. Designated outcome(s) for which the course is used as a benchmark are highlighted.
- A list of the course learning objectives. Those objectives that are directly related to the benchmark outcome are highlighted.
- An analysis of student performance using the rubrics for the designated program outcome. This would involve the following steps:
  - Identify the specific instruments of student work, such as homework, tests, and projects that will be used to measure achievement of a particular outcome.
  - Describe the methods that have been used to analyze student work and determine the degree to which the outcome's criteria have been achieved. Where appropriate, 'grade descriptors' and relative weights of the various types of student work should be provided.
  - Apply the analysis to student work and determine the degree to which the designated outcome is achieved. A mapping of course learning objectives to outcome(s) addressed should be provided, when applicable.
  - Summarize student comments from course evaluations as they pertain to meeting course learning objectives.
- Suggestions for changes/improvements for the course or the program. The faculty member would also discuss the effect of changes from previous annual assessments. Possible changes/improvements include, for example: curriculum changes, offering new courses, changing course sequencing and/or course content, removing courses from curriculum, adding/removing design or engineering science contents, modifying laboratory course content, and providing more exposure to professional practice for students.

ANNUAL DOCUMENTATION OF ASSESSMENT RESULTS

In its end of the year meeting, the faculty of the program will meet to assess the degree to which program outcomes have been achieved. The course embedded assessment of key required building-block courses as selected by the faculty would be considered. Data from assessment of these benchmark courses, along with other assessment processes as described earlier, are used to assess the success of the associated program outcome.

Using multiple assessment methods for each outcome, such as presented in Table 1 for our electrical engineering program, they will determine if the outcomes have been achieved, identify actions to be taken as a result of assessment to improve the program, and plan an implementation schedule, such as illustrated in Table 2 for one of the outcomes of our electrical engineering program. This documented assessment will serve as a comparative reference for the next annual outcomes assessment.

SUMMARY AND CONCLUSIVE REMARKS

The purpose of assessment is to: (1) document the success of an educational program in assisting students to achieve the desired outcomes, and (2) identify aspects of the program which may need improvement. The relationship between the assessment instruments and the program outcomes is determined by the faculty of each of the degree programs at our school. Many of the instruments used for assessment are designed to assess more than one program outcome.

Actions taken to improve the program are documented by each program faculty at the end of each academic year. As part of this annual report:

- The faculty summarizes the assessment processes used, their analysis, and conclusions reached.

Table 2. Sample of documentation for a program outcome—ability to identify, formulate, and solve engineering problems

Assessment method	Who conducted	Action taken by program faculty	Remarks
Course assessment with EE abc	Dr. Who 1	Accept recommendation. Change pre-requisite.	Change will appear in the next Catalog.
EE xyz	Dr. Who 2	The faculty believes there are already too many credit hours required. No new courses will be added.	Dr. Who 2 will look into revising course contents.
Comprehensive examination	Drs. Who 3 and Who 4	Agree with Drs. Who 3 and Who 4 recommendation.	No action. Students did extremely well on the topics related to this outcome.
Senior exit survey	Dr. Who 5	Accept recommendation. Students didn't suggest any changes, were confident.	No action.

- They document how the results from the assessment of outcomes will be used to modify their program.
- They describe in detail how this action is likely to improve their program.

Samples of changes based on assessment include:

- The freshman year curriculum was revised to better prepare students for their subsequent courses.
- The course evaluation instrument was revised to reflect the focus on outcomes assessment.
- Scholarship guidelines were revised to emphasize the role of faculty scholarship in the education of undergraduate students.
- Closer coordination of the subject matter of sophomore and junior lecture and laboratory courses was implemented to enhance learning the theoretical and practical aspects of circuits and electronics, and
- Integrated capstone design experience for electrical engineering and computer science students was instituted to enhance interdisciplinary learning.

Although it involved extensive discussions over extended periods of time to decide which direct and indirect assessment methods to apply, how to apply them, and to implement them on a trial basis, the time required to apply the assessments to our courses and programs is now manageable. Hence, we have concluded that the mix of direct and indirect assessment methods described in this paper are appropriate for us to apply and sustain 'over the long haul' to continually assess and improve student learning.

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He has authored and/or co-authored over 40 articles and a textbook which has been translated into Chinese, 22 technical reports, 12 summary papers, and seven discussions. His professional experience includes 25 years of university administration, teaching, consulting, and research, and five years of full-time work in the industry.

In the last decade, he has authored a number of articles and has given numerous presentations on outcomes-based engineering curriculum development and implementation of the ABET Engineering Criteria 2000. He also served as a consultant on preparing for ABET accreditation for two other institutions of higher learning. In the 1990s, he served as an ABET evaluator for the Engineering Accreditation Commission of ABET.

Robert J. Albright joined the electrical engineering faculty of the University of Portland in 1970, following doctoral studies at the University of Washington. Professor of electrical engineering since 1981, he has served as chair of the electrical engineering program for 28 years as well as chair of the computer science program for seven years, and one year as acting dean of engineering.

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During the past several years, he has collaborated with Dr. Zia A. Yamayee, Dean of the School of Engineering at the University of Portland, in developing program assessment methods and sharing the results with the accreditation community at numerous national workshops.