# AC 2011-27: CHALLENGES IN ASSESSING INTERDISCIPLINARY ENGINEERING PROGRAMS

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# Challenges in Assessing Multidisciplinary Programs between Engineering and Non-Engineering Schools


## Abstract

Program accreditation by ABET requires that faculty assess and evaluate student performance to demonstrate that a program achieves its outcomes. For a conventional single-disciplinary program, these assessments are challenging to conduct because they require a substantial level of effort on the part of faculty to strategize and collect a reasonable amount of high quality and complete data documenting student performance. The assessment of student performance in multidisciplinary programs between engineering and non-engineering is even more challenging for several reasons: these programs may use existing engineering courses from other programs to fulfill coursework requirements, which are not under the control of the program, and the faculty that participate in the multidisciplinary program may be spread across schools and disciplines and have differing opinions on the importance of accreditation, their responsibilities to the assessment process, or the approaches that should be used to assess the students. All of these factors can ultimately affect the amount of data that can be used in the assessment of a multidisciplinary program, or the quality of the data in terms of its completeness or consistency. This paper presents and discusses some of the challenges associated with accreditation of multidisciplinary programs in general and gives examples for two specific programs: an undergraduate program between science and engineering and a masters program between science, engineering, and architecture. Based on these challenges and our experiences leading to a successful accreditation of an undergraduate multidisciplinary program between engineering and science, a set of guidelines is proposed. These guidelines include: the targeted assessment of high-level, non-elective courses that emphasize student outcomes pertinent to the appropriate accreditation commission, assessment of courses administered and controlled by the multidisciplinary program, the use of consistent direct and indirect approaches to assess student learning in the selected courses, and the filtering of results to only include students in the program.


## Introduction

There are four commissions by which multidisciplinary programs between engineering and non-engineering may be accredited: Engineering Accreditation Commission (EAC), Applied Science Accreditation Commission (ASAC), Computing Accreditation Commission (CAC), and Technology Accreditation Commission (TAC). These commissions have similar criteria that the programs must meet to become accredited, but they emphasize different subject areas within the criteria. Accreditation is ultimately determined by an external review of a program's self-study of their students, program educational objectives, student outcomes (SOs), continuous improvement practices, curriculum, faculty, facilities, and support, and other criteria specific to the program of study. This paper focuses on one of these aspects: SOs, or the skills, knowledge, and behaviors students acquire in their matriculation through the program[1].

The goal of SO assessment is to provide evidence and documentation, which shows the extent to which students achieving the SOs. This information informs the program's continuous improvement practices. Progress towards meeting SOs is typically assessed by having faculty strategize, collect and evaluate data that document student performance. While there are no particular requirements regarding data quality, the data should be of high enough quality (i.e., consistent, complete, statistically significant) to demonstrate achievement of SOs and the development of continuous improvement plans. Generally, directly acquired data are more common[2] than indirectly acquired data, and are also considered to be better indicators of performance.

Progress towards meeting SOs is generally assessed through several steps. First, direct and indirect evidence of student performance is identified, usually by mapping courses and student activities to student outcomes[3] and then selecting examples of student work in these courses or activities. Direct evidence includes student work such as homework, laboratory reports, examinations, quizzes, and projects. These are graded, and in some cases evaluated using rubrics, which define and describe the important components of the work and provide a more detailed way to measure student outcomes[4]. Indirect evidence includes students' self-assessment of their learning using instruments such as survey. The scores students receive on their work or self-report on surveys are then related to a single numerical range with a threshold value that is considered to demonstrate achievement of the SO. Finally, the average cohort score and the percent of students that achieved each SO is determined and evaluated to assess whether the program as a whole met its SOs. In this last step, the scores from various classes and surveys may be combined using weighting schemes since each course may not contribute equally to a particular performance criterion[5].

In a single-discipline engineering program, the acquisition of the high quality data used in SO assessment can be a challenging task. For a multidisciplinary program between engineering and a non-engineering field such as science or architecture, the challenge is even greater and has the potential to result in smaller data sets or data of lower quality. For example, these programs have substantial coursework in the non-engineering disciplines, resulting in fewer courses to assess than in conventional single-discipline engineering programs. Additionally, many multidisciplinary programs use existing courses offered and managed by other departments to fulfill coursework requirements. Even though these other departments may periodically assess student outcomes to support their own accreditation, their assessment approaches and frequency may vary from those of the multidisciplinary program and their assessment results may not be reported by major. Finally, the faculty in multidisciplinary programs are spread across disciplines and possibly schools, and as a result, may have differing opinions on the importance of accreditation or their responsibilities to the assessment process.

The engineering education literature offers little guidance on how to overcome the challenges associated with multidisciplinary program assessment. While multidisciplinary programs have been successfully accredited using extensive and intensive assessments of every individual student in a program [6], such assessment plans can be very consuming in terms of faculty time and effort. A set of helpful guidelines for assessing SOs has been proposed based on one program's experiences [7]. These guidelines include: assessing each outcome in several courses to ensure that students acquire an appropriate level of breadth and depth in the skill of the outcome;

assessing low number of courses for each outcome to minimize faculty workload; assessing non-elective courses; and excluding freshman and sophomore courses because of potential issues with transfer students.

This paper discusses the challenges to assessing student outcomes in multidisciplinary programs between engineering and non-engineering schools and provides guidelines for the collection of a reasonable amount of high quality data. It uses as examples,two multidisciplinary programs at the City University of New York's City College of New York (CCNY) for which accreditation, and specifically SO assessment, poses substantial challenges: the undergraduate program in Earth System Science and Environmental Engineering (ESE) and a master's program in Sustainability in the Urban Environment (SUS). Both programs have substantial coursework in sciences and engineering: science in the case of the ESE program, and science and architecture in the case of the SUS program. Both programs have common introductory courses that all students take, a culminating design course designed specifically for the program, and selected coursework from other programs to complete the remaining coursework requirements. In addition, the faculty in both programs are housed in multiple schools and disciplines within the schools.

**Multidisciplinary Program Assessment – Undergraduate Programs**

The ESE program is a multidisciplinary undergraduate program designed to prepare students to be professionals able to understand and effectively address major emerging environmental issues and implement scientific and engineering solutions to these issues. The program was accredited under the Engineering Accreditation Commission (EAC) as an "environmental, sanitary, or similarly named engineering program", consistent with ABET's requirement that the program name determine the commission and the criteria by which a program is reviewed [8]. The program is housed in the school of engineering although the curriculum includes introductory and advanced science courses housed in the College of Arts and Sciences. The curriculum is designed around existing academic programs and courses at the host university and provides students with a rigorous yet flexible program of study, which includes coursework in civil, electrical, mechanical, and chemical engineering, computer science, mathematics, and earth and atmospheric sciences, chemistry, physics, and biology. This flexibility allows students to design personalized curricula that support their individual career plans or interests.

An engineering student completing the ESE program is required to take 127 credits total, with representation in these curricular areas: 38% engineering (with 6/18 of the courses with substantial design content), 31% math and basic science, and 31% other. At a minimum, 46 of the credit hours are dedicated to environmental topics. Since this is a multidisciplinary program between science and engineering, students are able to select courses from a list of science and engineering technical electives in remote sensing, energy, water resources, earth systems, environment, other engineering and science, and analysis and computation. The "culminating" design experience required by the EAC is met through a 5 credit-hour, two-semester senior course sequence.

In preparation for the 2010 accreditation visit, the ESE program used all available indirect and direct data, regardless of method or frequency of assessment. This decision was made to ensure adequate coverage of all SOs and to have a larger dataset upon which to draw conclusions and improve the program.

One source of information used by the program but gathered by other departments was assessments of SOs in required ESE courses. These assessments posed three challenges to the assessment of SO achievement by ESE students. First, the assessments grouped ESE students in with the other students who took the course and therefore did not result in an evaluation of ESE student performance specifically. Second, assessments were not available for all of the courses that ESE students take because each department within the School of Engineering assessed only a limited number of their courses. Third, each department interpreted ABET's policies and procedures for demonstrating achievement of SOs differently, and so their assessments resulted in data that were inconsistent across the various courses that ESE students took. These differences are illustrated in Figure 1.

| | **Measurement Methods and Desirable Achievement Goals** | |
|---|---|---|
| **Home Dept.** | **Indirect Assessment of an Outcome Through Student Self Assessment** | **Direct Assessment of an Outcome Through Exams, Problems, and Projects** |
| **ESE** | 5-point scale<br>0 (None) – 4 (Excellent)<br>Target Goal: Class average ≥ 2.5 | 3-point scale<br>1 (Below Expectations) – 3 (Exceeds Expectations)<br>Target goal: ≥ 70% of students with scores ≥ 2 |
| **EE** | 5-point scale<br>0 (None) – 4 (Excellent)<br>Target Goal: Class average ≥ 2.5 | 3-point scale<br>1 (Below Expectations) – 3 (Above Expectations)<br>Target goal: ≥ 80% of students with scores ≥ 2 |
| **ME** | 5-point scale<br>1 (Very Poor) – 5 (Very Good)<br>Target goal: Class average ≥ 3.0 | 5-point scale<br>1 (Very Poor) – 5 (Very Good)<br>Target goal: Class average ≥ 3 |
| **CE** | 5-point scale<br>1 (Not at all) – 5 (A Lot)<br>Target Goal: Class average ≥ 3.0 | 3-point scale<br>1 (Below Expectations) – 3 (Above Expectations)<br>Target goal: ≥ 70% of students with scores ≥ 2 |
| **ChE** | 7-point Likert Scale<br>-3 (Strongly Disagree) – +3 (Strongly Agree)<br>Target goal: Class average ≥ 1.5 | 4-point scale<br>1 (Unsatisfactory) – 4 (Exemplary)<br>Target goal: ≥ 80% of students with scores ≥ 3 |
| **CSc** | 5-point scale<br>0 (Not at all) – 4 (Excellent)<br>Target goal: Class average ≥ 2.0 | 3-point scale<br>1 (Below Expectations) – 3 (Exceeds Expectations)<br>Target goal: ≥ 70% of students with scores ≥ 2 |

**Figure 1.** Assessment methods and achievement goals for departments within the School of Engineering

Most programs used a 5-point scale to assess their courses indirectly and a 3-point scale for direct assessments, and their achievement goals varied considerably. Performance criteria and rubrics were used to assess outcomes in some of the programs, but not every program defined their rubrics the same way. Whereas some used program-wide rubrics to determine whether student work met, exceeded, or fell below expectations, others allowed individual instructors to define student performance. Also, the level of detail regarding the measuring instruments or how they were expected to address a particular student outcome was not consistently provided. Finally, in some cases, entire courses or specific SOs in a course were not assessed on the planned schedule resulting in gaps in the data sets. As a result of the non-uniform way the various programs assessed achievement of student outcomes, it was unclear whether differences in performance were real or were actually due to differences in assessment method.

As a result of these challenges encountered while preparing its self-study and the feedback obtained during the most recent and successful accreditation of the ESE program, the ESE program revised its assessment plan to include specific standards for the quantity, quality and completeness of the assessment data. While a large amount of data might appear preferable from a statistical standpoint, not all of these data are likely to be of high enough quality. Therefore, a new goal was set to obtain a reasonable amount of high quality and complete data. Data are considered to be of high quality when they result from adherence to agreed upon assessment plans, including uniform assessment scales and performance goals. Data are complete when all SOs are adequately covered by suitable courses and assessments of a single course include all of the planned SOs and are conducted on all of the planned semesters.

Based on the recommendations from prior studies and the challenges experienced during the accreditation of the ESE program, the following eight guidelines were developed to guide multidisciplinary programs between engineering and non-engineering disciplines to acquire a reasonable amount of data of high quality and completeness:

**1. Assessment of high-level courses only**
Only sophomore, junior and senior level courses should be included in the assessment process. This ensures that the program is evaluating students who have had a chance to develop ability and knowledge over several previous courses and have committed to being multidisciplinary program majors.

**2. Assessment of non-elective courses only**
To ensure uniform assessment and representation of all students in a specific multidisciplinary program, and to be able to compare assessment results over time, assessments should include only non-elective or core courses. Due to the flexibility of the ESE program, students can choose from a wide range of science and engineering electives, most of which are taken by other students. Avoiding assessment of elective courses ensures that only ESE students are evaluated.

**3. Assessment of courses that cover a broad range of SOs appropriate to the accreditation commission**
From the high-level required courses, the selection of specific courses for assessment now should be refined based on the accreditation commission, since each commission emphasizes different subject areas. For example, the ESE program was accredited under EAC, therefore only courses which emphasize engineering knowledge are included in the assessment. Assessing a course such as “Environmental Engineering” streamlines the assessment process

because this course covers most EAC SOs, whereas other required courses such as "Fundamentals of Biology" may only adequately cover few of the EAC SOs.

**4. Assessment of courses administered by the multidisciplinary program**
To assure that the most complete and high quality assessment data are available, only those courses administered and controlled by the multidisciplinary program faculty should be assessed. In the ESE program, faculty who administer ESE courses are similarly committed to the success of the program, as they collaborated on its development, they regularly involve ESE students in their research programs, and they mentor and academically advise ESE students.

**5. Assessment of multiple courses across the program**
To evaluate student achievement of SOs as they matriculate through the program and to avoid basing all decisions on data collected from a single course, such as the "culminating" design course, assessment should be conducted on multiple courses across the program.

**6. Uniform assessment and evaluation plan**
To overcome the challenge of interpreting non-uniform indirect and direct assessment methods and performance standards, all courses are assessed based on a single set of methods and plans. This ensures that results are easy to compare and interpret. Using this guideline, and given the involvement of CE faculty in the ESE program, the CE program methods and plans can be used as a template.

**7. Collection of assessment data for multidisciplinary program students only**
Courses required for graduation from a multidisciplinary program can also be taken by other students across the various disciplines; therefore, only data from students in the multidisciplinary program should be used in the assessment of SO achievement to ensure that only the program under review is assessed. Courses taken by ESE students may be required or elective courses taken by other majors in the School of Engineering. If assessment data are collected for all students, results should be separated by major to ensure that only results from ESE student achievement are used in program evaluation.

**8. Use of both indirect and indirect assessment results**
The above guidelines necessarily restrict the number of courses (and therefore amount of student work) that can be assessed. Therefore, while direct assessments of student work are preferred, it may be necessary to also consider indirect assessments to obtain a statistically significant dataset upon which to base continuous improvement decisions. However, direct assessment results can be given a weighting factor of 2, while indirect assessment results can be assigned a weighting factor of 1. The weighting method allows for an effective way of evaluating student performance because it stresses the direct observation of specific student knowledge, while still measuring SOs indirectly.

Based on these guidelines, 5 core courses in the ESE program were chosen for the direct and indirect assessment of student work. The guidelines ensure adequate coverage of all SOs while producing high quality and complete data and minimizing the burden on faculty. The guidelines also result in assessment data that can be used to develop corrective action.

**Multidisciplinary Program Assessment – Graduate Programs**

The SUS program is a multidisciplinary masters program housed in the schools of architecture, engineering and science, and designed to prepare students to adapt old and advance new generations of infrastructure given modern constraints. Graduates develop leadership and teamwork skills giving them an advantage in diverse professional settings that demand interaction and collaboration among teams of scientists, engineers, architects and others. The program involves 30 credits with representation in these curricular areas: 30-60% engineering (with 2 or more courses with substantial design content), 40-10% math and basic science, and 30% other (i.e., architecture and economics).

The curriculum includes five required courses, which lay a foundation in sustainability values, strategies and metrics through coursework in urban and natural systems, environmental economics and industrial ecology. Students take four elective courses: three in engineering or science, and one in architecture. The two-semester, six-credit "culminating" multidisciplinary project challenges teams of students with different backgrounds to tackle a single broad "sustainability" problem that requires multiple perspectives and abilities.

Accreditation of masters level programs requires fulfillment of the baccalaureate level general criteria, fulfillment of the program criteria appropriate to the master level specialization area, and one academic year of study beyond the baccalaureate level. The various commissions also require other criteria of masters level programs: EAC requires programs to demonstrate that graduates have the ability to apply masters level knowledge in a specialized area of engineering related to the program area, and ASAC requires a project or research activity resulting in a report that demonstrates both the master of the subject matter and a high level of communication skills. The SUS program plans to apply for accreditation under ASAC in the next two years. In this section, we investigate the degree to which the eight major guidelines developed from the ESE program assessment plan can be applied to multidisciplinary masters programs between engineering and non-engineering disciplines in general, and the SUS masters program specifically.

**1. Assessment of high-level courses only**
By definition, a masters level course is at a high level. However, in multidisciplinary programs, masters level courses not in the student's baccalaureate discipline or school may be taught at a lower level. As a result, only courses within the student's baccalaureate discipline or school should be considered in the assessment, since only these courses are expected to be taught at a true masters level. Using this guideline, the CCNY SUS program could consider any of its courses in an assessment.

**2. Assessment of non-elective courses only**
To ensure uniform assessment and representation of all SUS students, and to be able to compare assessment results over time, assessments should include only non-elective or core courses. Using this guideline, the SUS program could consider 6 of the 10 courses in an assessment: 3 in engineering, 1 in science, 1 in architecture and 1 in economics. However, it is not clear whether these courses provide adequate coverage of all student outcomes.

**3. Assessment of courses that cover a broad range of SOs appropriate to the accreditation commission**

From the high-level required courses, the selection of specific courses for assessment now should be refined based on the accreditation commission, since each commission emphasizes different subject areas. The SUS program will be accredited under ASAC, therefore courses which emphasize applied science knowledge are most appropriate. This reduces the number of courses to be assessed to 4: 3 engineering courses and 1 science course. Only if reasonable coverage of a particular SO is not met by these 4 courses, will the other 2 required courses be considered in an assessment.

**4. Assessment of courses administered by the multidisciplinary program**

To assure that the most complete and high quality assessment data are available, only those courses administered and controlled by the SUS program faculty should be assessed. These faculty are similarly committed to the success of the SUS program. Using this guideline, the SUS program could assess all of the 4 courses already identified since they are all developed and conducted by SUS faculty.

**5. Assessment of multiple courses across the program**

To evaluate student achievement of SOs as they matriculate through the program and to avoid basing all decisions on data collected from a single course, such as the “culminating” experience or project, assessment should be conducted on multiple courses across the program

**6. Uniform assessment and evaluation plan**

To overcome the challenge of interpreting non-uniform indirect and direct assessment methods and performance standards, all courses are assessed based on a single set of methods and plans. Using this guideline, the SUS program will have to develop a set of methods and plans. Given the involvement of CE faculty in the SUS program, it is likely that the CE program methods and plans will be used as a starting point.

**7. Collection of assessment data for SUS students only**

The required SUS courses are electives to other engineering, science and architecture students. Therefore, only data from the SUS students in these courses should be used in the assessment of SO achievement to ensure that only the program under review is assessed.

**8. Use of both indirect and indirect assessment results**

The above guidelines necessarily restrict the number of courses (and therefore amount of student work) that can be assessed. Therefore, while direct assessments of student work is preferred, it may be necessary to also consider indirect assessments to obtain a statistically significant dataset upon which to base continuous improvement decisions. Like the ESE program, indirect assessment results are assigned lower weighting factors than direct assessment results.

While the recommendations developed by the baccalaureate ESE program are applicable to the masters SUS program, their application highlights several challenges that any multidisciplinary graduate program will face. First, there are far fewer courses that are reasonable candidates for SO assessment because masters level programs are typically 30 credits total, or about 25% of the credits that a baccalaureate program requires. Second, only a fraction of the courses offered are required of all students in the program. Third, only a fraction of these may have substantial coverage of appropriate SOs at the masters level.

## Conclusions

Demonstrating achievement of student outcomes is a critical part of the development of sound educational programs and the ultimate accreditation of the programs. Programs that are multidisciplinary face some additional challenges. This paper discussed some of these challenges and proposed a set of guidelines that could be used to develop robust program outcome assessments of baccalaureate or masters level multidisciplinary programs. These guidelines include the targeted selection of higher-level courses that are required of all students and that are under the control of active program faculty, the use of consistent direct and indirect assessment approaches across the selected courses, and the filtering of results to only include students in the program.

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