The Development, Implementation and Revision of a Departmental Assessment Plan

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Abstract. In the late 1990s, the Colorado School of Mines began to prepare for a visit by the Accreditation Board for Engineering and Technology. As a support department to eight accredited engineering departments, the Mathematical and Computer Sciences Department had a responsibility to assist in the accreditation process. The approaching visit motivated the creation of a departmental assessment plan. This paper traces the development and implementation of the original departmental assessment plan and the events that stimulated the revision of that plan. An emphasis will be placed throughout this paper upon what the Mathematical and Computer Sciences department has learned.

Background

In the late 1990s, the Colorado School of Mines (CSM) began to prepare for a visit by the Accreditation Board for Engineering and Technology (ABET) that was to take place in the academic year 2000–2001. Eight CSM engineering departments were to be reviewed using ABET's newly revised engineering criteria [1]. A major difference between the old and the new criteria was that the new criteria required that accredited departments directly demonstrate what students know and can do. In other words, the new criteria emphasized the direct assessment of student outcomes.

All of the engineering departments and the departments that support core-engineering courses worked to develop and implement an assessment system that measured student outcomes. As a department that provides many of the core engineering courses, the Mathematical and Computer Sciences Department (MCS) began to develop an assessment plan in the fall of 1997. The first step in this process was to establish departmental goals and objectives. This was completed by the end of the 1997–98 academic year. The next two years were dedicated to developing and implementing a departmental assessment plan that would support the student attainment of the departmental goals and objectives. Much of the original assessment plan focused upon how the information that was currently being collected could be better used for assessment purposes. A number of survey instruments were also introduced with the purpose of acquiring data in a fast and efficient manner. In summary, much of the early work with respect to assessment process was focused upon ensuring a successful ABET visit.

The ABET visit in 2000–2001 resulted in all eight accredited departments receiving full accreditation. The success of this visit immediately reduced the administrative pressure to produce quick assessment results. The MCS department now had the time and opportunity to review and revise the department's assessment plan. The review process began in the fall of 2001. By the end of the academic year, the department's Undergraduate Curriculum Committee had approved a revised set of goals and objectives and a revised departmental assessment plan. The MCS department is currently in the process of implementing the revised plan.

This paper traces the development and implementation of the original MCS departmental assessment plan and the events that stimulated the need to revise that plan. An emphasis will be placed throughout this paper upon what the MCS department has learned.

Conceptual framework

According to the Mathematical Association of America's (MAA) Committee on the Undergraduate Program in Mathematics (CUPM) in collaboration with the MAA's Assessment Subcommittee, assessment is a cycle that consists of the following five phases [2]: 1) articulating goals and objectives, 2) developing strategies for reaching goals and objectives, 3) selecting instruments to evaluate the attainment of goals and objectives, 4) gathering, analyzing and interpreting data to determine the extent to which goals and objectives have been reached, and 5) using the results of assessment for program improvement. When the final phase is reached, the assessment cycle begins again. This conceptualization of the assessment process is consistent with other literature on assessment [3, 4, 5]. The phases within this cycle provide a framework for developing a departmental assessment plan. Each phase can be moved through sequentially, supporting the emergence of a departmental assessment plan. Once the initial cycle has been completed, the knowledge and information that has been gained through the implementation process can be used to improve the assessment plan prior to the next cycle.

Development and revision of goals and objectives

As was discussed earlier, the first step in the development of a departmental assessment plan is the establishment of goals and objectives. Goals are broad statements of expected student outcomes and "objectives" divide a goal into circumstances that suggest whether a given goal has been reached [6]. Careful thought should be given to the University Mission Statement [2, 7] and to the requirements of any appropriate accreditation board when developing departmental goals and objectives [7]. Attention should also be given to faculty buy-in. Faculty will not work to assist students in reaching goals and objectives that they do not believe are important. Departmental goals and objectives

Original Statement*	Revised Statement*
G1: Develop technical expertise within mathematics/computer science O1: Design and implement solutions to practical problems in science and engineering O2: Use appropriate technology as a tool to solve problems in mathematics/computer science O3: Create efficient algorithms and well structured programs	G1: Students will demonstrate technical expertise within mathematics/computer science by: O1: Designing and implementing solutions to practical problems in science and engineering, O2: Using appropriate technology as a tool to solve problems in mathematics/computer science, and O3: Creating efficient algorithms and well structured computer programs.
G2: Develop breadth and depth of knowledge within mathematics/computer science O4: Extend course material to solve original problems O5: Apply knowledge of mathematics/computer science O6: Identify, formulate and solve mathematics/computer science problems O7: Analyze and interpret data	G2: Students will demonstrate a breadth and depth of knowledge within mathematics/computer science by: O4: Extending course material to solve original problems, O5: Applying knowledge of mathematics/computer science to the solution of problems, O6: Identifying, formulating and solving mathematics/computer science problems, and O7: Analyzing and interpreting statistical data.
G3: Develop an understanding and appreciation for the relationship of mathematics/computer science to other fields O8: Apply mathematics/computer science to solve problems in other fields O9: Work cooperatively in multi-disciplinary teams O10: Choose appropriate technology to solve problems in other disciplines	G3: Students will demonstrate an understanding and appreciation for the relationship of mathematics/computer science to other fields by: O8: Applying mathematics/computer science to solve problems in other fields, O9: Working in cooperative multi-disciplinary teams, and O10: Choosing appropriate technology to solve problems in other disciplines.
G4: Communicate mathematics/computer science effectively O11: Communicate orally O12: Communicate in writing O13: Work cooperatively in teams O14: Create well documented programs O15: Understand and interpret written material in mathematics/computer science **G: Goals, O: Objectives*	G4: Students will demonstrate an ability to communicate mathematics/computer science effectively by: O11: Giving oral presentations, O12: Completing written explanations, O13: Interacting effectively in cooperative teams, O14: Creating well documented programs, and O15: Understanding and interpreting written material in mathematics/computer science.

Table 1. General Statement of Student Goals and Objectives.

should reflect the collective understanding of the faculty members of what students should know and be able to do, rather than the ideas of a single individual.

Departments may be tempted to use the current curriculum to motivate the development of student goals and objectives. Although this method will result in the perfect alignment of the goals and objectives with the curriculum, it will also result in a missed opportunity for improving the curriculum. In other words, the process of determining what is important should not be artificially constrained by what currently exists.

In order to support the development of a set of goals and objectives and to acquire faculty support for the goals and objectives, each member of the full-time MCS faculty was interviewed in the fall of 1997. They were asked:

1. What competencies do you think students should have after completing the mathematics core courses?,
2. What competencies do you think students should have after completing their major courses in mathematics?, and
3. What competencies do you think students should have after completing their major courses in computer science?

The reader will notice that each of these questions refers to student competencies rather than student goals and objectives. This phrasing stimulated the faculty to identify specific knowledge and skills. A feature of the interview process was that the faculty were not directed to consider the current curriculum, but rather they were asked to indicate the competencies that students should have upon completion of their course work.

Using the specific information that the faculty provided, the departmental assessment specialist created broader statements of goals that captured these competencies. Next, a departmental sub-committee was formed that consisted of the head of the department, a mathematician, a computer scientist, a mathematics education expert and an assessment specialist. Based on the faculty responses to the interview process, the requirements of ABET and the University Mission Statement, the sub-committee drafted four sets of departmental goals and objectives: 1) a general statement for all students of mathematics and computer science, 2) a statement for the core mathematics courses, 3) a statement for the major mathematics courses, and 4) a statement for the computer science major courses. The fulltime faculty approved a version of these goals and objectives later that academic year.

Periodically, the established departmental goals and objectives should be reviewed to determine whether they continue to be consistent with departmental needs. In the academic year 2001–2002, the department's Undergraduate Curriculum Committee reviewed the student goals and objectives. Although the committee felt that this list continued to capture the desired student outcomes, questions were raised with respect to the phrasing of the goals and objectives. The original list consisted of short phrases that implied the desired student outcome. The revised list directly indicated what the students needed to demonstrate in order to suggest that a given goal had been reached. Both the original and the revised list of student goals and objectives are displayed in Table 1.

A critical question was raised during the final review of the revised student goals and objectives, "What is the faculty's responsibility in assisting students in reaching these goals and objectives?" This question resulted in the development of the faculty goals and objectives that are shown in Table 2.

G1: Faculty will demonstrate technical expertise within mathematics/computer science by:
- O1: Providing clear, technical explanations of mathematics/computer science concepts to students,
- O2: Using appropriate technology as a tool to illustrate to students how to solve mathematics/computer science problems, and
- O3: Providing examples of how mathematics/computer science can be applied to the solution of problems in other fields.

G2: Faculty will support the students attainment of the goals and objectives outlined above by providing the students the opportunity to:
- O4: Solve original problems, some of which are drawn from other fields,
- O5: Use technology as a tool in solution of mathematics/computer science problems,
- O6: Design algorithms and structured programs,
- O7: Identify, formulate and solve mathematics/computer science problems,
- O8: Interact in cooperative teams,
- O9: Give oral presentations,
- O10: Communicate in writing, and
- O11: Interpret written material in mathematics/computer science.

G3: Faculty will evaluate the students attainment of the above goals and objectives outlined above by creating assessments for the evaluations of students ability to:
- O12: Solve original problems, some of which are drawn from other fields,
- O13: Use technology as a tool in solution of mathematics/computer science problems,
- O14: Design algorithms and well structured programs,
- O15: Identify, formulate and solve mathematics/computer science problems,
- O16: Interact in cooperative teams,
- O17: Give oral presentations,
- O18: Communicate in writing, and
- O19: Interpret written material in mathematics/computer science.

G: Goals, O: Objectives

Table 2. Faculty Goals and Objectives

The faculty goals and objectives were designed to parallel the student goals and objectives, indicating the faculty's responsibility in supporting the desired student outcomes.

Using goals and objectives to develop, implement and revise an assessment plan

Once a program has a set of goals and objectives, the next step is the creation of a plan that will support the attainment of those goals and objectives. In order to facilitate the creation of this plan, the MCS department used the Olds and Miller Assessment Matrix [8, 9]. This matrix, which is available electronically,[1] provides a framework for planning and recording the phases of the assessment cycle. An example of a portion of the current student assessment plan is shown in Table 3. In the academic year 2001–2002, this plan was extended to include a faculty assessment plan. Both components of the larger assessment plan, student and faculty, are also available on-line.[2]

The first column, "Performance Criteria (PC)", is a statement of an observable performance that is used to determine whether a given objective has been reached. The statements within this column describe the strategies that will be used to interpret the collected data. Stating performance criteria is a first step in the development of strategies for reaching and evaluating the attainment of goals and objectives (phase 2 of the assessment process). The reader will notice that many of the established performance criteria in the MCS assessment plan reference a specific course. For example, PC1 states, "Students in Calculus for Scientists and Engineers (CSE) I, II and III will complete common exams that assess this objective. All students will pass the calculus sequence prior to graduation." The calculus sequence consists of three courses, all of which are coordinated. Coordinated courses have multiple sections, which are taught by different instructors. A lead faculty member coordinates these sections and holds regular meetings at which instructors have the opportunity to share instructional strategies and to create common assignments and/or exams. The lead faculty member for coordinated courses also ensures that the designated program objectives are assessed through common assignments and/or exams.

The MAA [2] has criticized the practice of many mathematics departments of restricting the assessment process to traditional testing techniques, which are characterized by examining individual student responses to written evaluations. Instead, the MAA has recommended that departments supplement information acquired through traditional methods with additional information that has been acquired through team assignments and presentations. One aspect of the MCS Performance Criteria is that it does not rely solely upon traditional testing methods. Several of the performance criteria within the MCS plan refer to common student assignments that require group work and/or oral presentations. For example, PC24 states, "All students are required to pass Engineering Practices Introductory Course Sequence prior to graduation. Successful completion of this course requires that students work in multidisciplinary teams for a semester on the solution of a problem that was solicited from a local business." Other papers have addressed how these team activities are evaluated [10, 11]. Performance Criteria has also been established for the evaluation of oral presentations, "PC27: Students complete team oral presentations in Field Session. All MCS majors are required to pass this course prior to graduation". Field Session is an intensive six week summer course that is completed immediately following the students' junior year. Students and their teams dedicate at least eight hours each day to solving a problem that has been solicited from a local business. At the conclusion of the course, the students are required to present their solution to the participating company and to their instructors in both written and oral form. These activities are then evaluated using a common scoring rubric or scoring scheme. Although PC27 is specific to team oral presentations, other criteria have been established that address individual oral presentations.

The second column in the assessment matrix is "Implementation Strategy." This refers to the student or faculty activities that support the attainment of given performance criteria. Stating which activities will support the attainment of the goals and objectives is the second step in developing strategies for reaching the goals and objectives (phase 2 of the assessment cycle). For the majority of the student goals and objectives in the MCS assessment plan, the implementation strategy is the students' coursework. This includes core courses (courses that are required of all CSM graduates), major courses (courses that are required of all MCS majors) and Field Session (a design course that is required of all MCS majors after their junior year).

As was discussed earlier, core courses are coordinated. A lead faculty member schedules regular meetings throughout the semester among the course instructors. During these meetings, instructors have the opportunity to share the activities that they have developed to support the attainment of the appropriate goals and objectives. In the major courses, it is the responsibility of the individual faculty member to ensure that the goals and objectives are being reached

[1] www.mines.edu/fs_home/rlmiller/matrix.htm

[2] www.mines.edu/Academic/assess/Plan.html

G1: Students will demonstrate technical expertise within mathematics/computer science by:					
Objectives (O)	**(1) Performance Criteria (PC)**	**(2) Implementation Strategy**	**(3) Evaluation Method (EM)**	**(4) Timeline (TL)**	**(5) Feedback (FB)**
O1: Designing and implementing solutions to practical problems in science and engineering.	PC1: Students in Calculus for Scientists and Engineers (CSE) I, II and III will complete common exams that assess this objective. All students will pass the calculus sequence prior to graduation. PC2: Students in Programming Concepts and Data Structures will learn to use computer programs to solve problems. All majors in MCS will pass these courses prior to graduation. PC3: All MCS majors will pass field session prior to graduation. Field session requires that the student apply mathematics/computer science to the solution of original complex problems in the field. PC4: At least 80% of graduating seniors will agree with the statement, "My MCS degree prepared me well to solve problems that I am likely to encounter at work".	Core Coursework Major Coursework Field Session	EM1: PC1 will be evaluated by instructors of the calculus sequence. EM2: PC2 will be evaluated by instructors of Programming Concepts and Data Structures. EM3: PC3 will be evaluated by the Field Session instructors. EM4: PC4 will be evaluated through the senior survey.	TL1: EM1 implemented in F'97. TL 2: EM2 implemented in F'97 TL3: EM3 implemented in F'97 TL4: EM4 implemented in S'99	FB1: Verbal reports will be given to the undergraduate committee and the department head concerning student achievements within the respective courses at the end of each semester. FB2: Degree audit completed prior to graduation to ensure that all students completed requirements of degree. FB3: A written summary of the results of the senior survey will be given to the department head.

Table 3. Portion of the Mathematical and Computer Sciences Department's Student Assessment Plan[3]

within a given course. The importance of reaching the stated goals and objectives through these courses is further reinforced in the faculty assessment plan in that faculty are expected to provide students with the opportunity to attain each of the student goals and objectives.

The third column in the assessment matrix, "Evaluation Methods," specifies the measurement instrument that will be used to collect the evidence as to whether the performance criteria have been reached. This column describes phase three of the assessment cycle (i.e., selecting assessment instruments). Two types of evaluations are mentioned in the student assessment plan: 1) common assignments and/or exams in coordinated courses and 2) the student senior survey. Three methods are referenced in the faculty assessment plan: 1) student evaluations of faculty instructional efforts, 2) voluntary observations completed during classroom instruction, and 3) a review of course materials by the course coordinator.

The majority of the evaluation methods that were used in the original student assessment plan were dependent upon surveying the faculty and students. Although survey instruments provide an easy manner in which to acquire information, it is not necessarily the most reliable method of data collection. When the plan was reviewed and revised in 2001–2002, the decision was made to shift the focus to measurement techniques that directly assess student performances. This resulted in the current student assessment plan, which is dependent upon student performances on assignments, exams, oral presentations and team activities that are completed in classes. Surveys have not been completely eliminated from the revised plan. Students, upon graduation, are still asked to complete a survey and this information is used to supplement the direct measurement

3 The complete plan is online at www.mines.edu/Academic/assess/ Plan.html.

Semester	Source	Concern	Response	Follow-up
Spring '00	Course evaluations	A set of open-ended questions were added to the course evaluations in 1997. The average faculty rating on each question in 1997 was compared to the average faculty rating in 2000. The faculty ratings have increased since the changes have been implemented.	Current faculty evaluation system will be maintained.	Open-ended questions continue to be used as part of the faculty evaluation.
Spring '00	Senior Survey	The senior survey indicated that many of the graduating seniors felt that the had inadequate skills in written communication.	Acting Department Head and Coordinator for Probability and Statistics course attended a summer workshop on how to introduce writing in summer workshops.	Writing assignments have been added to the Probability and Statistics course.
Fall '00	Course evaluations	Concern was raised that faculty do not use the information that is provided by students in response to the faculty evaluations.	A set of questions was developed that asks faculty to examine the student evaluations and to write a response as to how they would use the information to improve the course.	Faculty continue to respond in writing to the student evaluations each semester. Department head reviews the response.
Spring '01	Course evaluations Feedback from Engineering Division	Concern was raised about the content of the Probability and Statistics for Engineers Course.	A new book was selected that better meets the needs of engineers. Additionally, new labs were created with the same purpose in mind.	A mini-grant was sought and acquired to support the improvement of this course in an appropriate manner. As part of this effort, a survey has been developed and is administered each year concerning students' experiences in the course.
Fall '01	General Review of Assessment System	A general review of our assessment system indicated that a number of our instruments and methods are out of date.	An effort was begun to revise the goals, objectives and overall system in a manner that is appropriate to our current needs.	The revised goals, objectives and overall system were reviewed and approved by the Undergraduate Committee in the Spring '02.

Table 4. A Portion of the MCS Feedback Matrix[4]

of the student outcomes. Given that this is the first year of implementation for the revised plan, the new methodology has not yet been fully tested.

"Timeline" refers to when each evaluation method will be implemented. This column contains information on when the data will be gathered, analyzed and interpreted (phase four of the assessment cycle). Examination of the presented timeline suggests that the new assessment techniques have been introduced slowly during the five years in which the plan has existed. Spacing the introduction of new techniques has allowed the department to focus upon the implementation of specific methodology within a given year or semester. Had the department introduced all of the new measurements in the first year, the department would have been overwhelmed and the assessment plan would have failed.

The final column of the assessment matrix is "Feedback." This column indicates how the acquired information will be disseminated and used and is directly linked to the fifth phase of the assessment process (using results). A primary concern that has been expressed by the MAA [2] and others [1, 3, 4] with regard to assessment is ensuring that the information acquired through assessment is used for program improvement. At the end of each semester, the department's assessment specialist summarizes the results of all survey instruments and compares these outcomes to the stated performance criteria. She also meets with the coordinators of the core courses and discusses how the goals and objectives were supported and assessed. Based on this information, she then writes and submits a report to the head of the department. This report contains recommendations on how the department may improve its programs and its assessment system.

[4] Complete matrix online at: www.mines.edu/Academic/assess/Feedback.html

To assist the MCS department in documenting how the information that is acquired through assessment is used, a feedback matrix was developed [12]. A portion of this matrix is shown in Table 4; the complete feedback matrix can be found on line.[5] This matrix indicates in which semester the information was collected, the source of the information, the concern that the information raised, the department's response to that concern and the efforts to follow-up on whether the response was successful in addressing the concern. For example in the spring of 2001, the students in Probability and Statistics for Engineers indicated on the student evaluation that the content covered during the semester was not consistent with the statistics that they used in their engineering courses. Based on this, the MCS department asked the engineering division to review and provide feedback on the curriculum for the Probability and Statistics for Engineers course. The Engineering division made a number of suggestions, including the recommendation that error analysis become part of the curriculum. In the fall of 2001, a new textbook and lab manual was selected that was consistent with the Engineering divisions recommendations. This process is documented in the feedback matrix.

Conclusions

A great deal of time and effort has been dedicated to the development and implementation of the MCS departmental assessment plan. Revision of this plan is ongoing. As was discussed earlier, continual improvement of an assessment plan is a natural part of the assessment process. Many of the techniques that have been used here can be easily transported to the needs of other departments and disciplines. In fact, the Olds and Miller assessment matrix is already used across the CSM campus [12]. Further information concerning the MCS department's assessment efforts can be found at the department's assessment webpage,[6] together with additional information concerning the broader CSM assessment effort.[7]

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[5] www.mines.edu/Academic/assess/Feedback.html
[6] www.mines.edu/Academic/assess/
[7] www.mines.edu/Academic/assess/Resource.htm