# CQI for Mechanical Engineering Education: A Two Year Experience

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## I. Introduction

For over two years the undergraduate program in mechanical engineering at Michigan State University has operated in a continuous quality improvement process mode. A CQI process known as ME 2000 has been developed for the undergraduate mechanical engineering degree program at Michigan State University in response to two primary motivations:

1) changes in the accreditation requirements for engineering programs
2) development of university/industry CQI partnerships.

The focus of this paper is to share the CQI process that has been developed and the results from this process following two years of implementation.

The paper begins with describing the rationale of implementing a CQI process for undergraduate education. Details of the development of the process are provided, including identification of constituent groups, governing principles of the process, and start-up of the process. Finally, the paper looks at the assessment data gathered over the first two years of the process and the program changes that have occurred due to this data and the review processes.

## II. Rationale and Motivation

The Accreditation Board for Engineering and Technology (ABET) has dramatically changed the criteria under which it will accredit engineering programs. Engineering programs seek accreditation to demonstrate to the public that they are graduating individuals with the skills and knowledge necessary to become engineers in a specific discipline, such as mechanical engineering. The ABET changes are to be implemented across the country during the next millennium, hence it has been dubbed Engineering Criteria (EC) 2000. Engineering Criteria 2000 requires engineering programs to have an assessment process with documented results (Accreditation Board for Engineering and Technology 1998). This assessment process includes setting educational program objectives and outcomes. Furthermore, these outcomes must be measured and the results used to improve the program. The overall concept of EC 2000 is to apply the principles of Continuous Quality Improvement to the development and improvement of the undergraduate program.

Another motivation for developing ME 2000 has come from industry, a customer of the products of engineering undergraduate programs. Within the last two decades increasing global competition has forced American manufacturing to adopt some form of continuous quality improvement, total quality management, reengineering, lean manufacturing, call it what you may. Many companies with active CQI programs have extended the CQI tools and concepts to their supplier base, often partnering with key suppliers to meet customers' needs. Michigan State University (MSU) and Ford Motor Company have established such a partnership. Ford has supplied the CQI knowledge and training to MSU faculty and staff who then developed a CQI process to improve the engineering education received by potential future industry engineers.

## III. Development and Description of the CQI Process

### *Overview of the ME 2000 Process*

The Department of Mechanical Engineering at Michigan State University is committed to the development and implementation of a CQI process for its undergraduate program that is consistent with Engineering Criteria 2000. This process includes:

- Setting Program Educational Objectives that include measurable outcomes
- Developing Course Learning Objectives that ensure delivery of topics
- Ensuring a curriculum that is consistent with the Program Educational Objectives
- Utilizing Assessment Tools to evaluate the program
- Involving Constituent Groups in the program evaluation
- Recommending changes to the program
- Implementing changes to the program
- Assessing changes to the program
- Iterating on the program

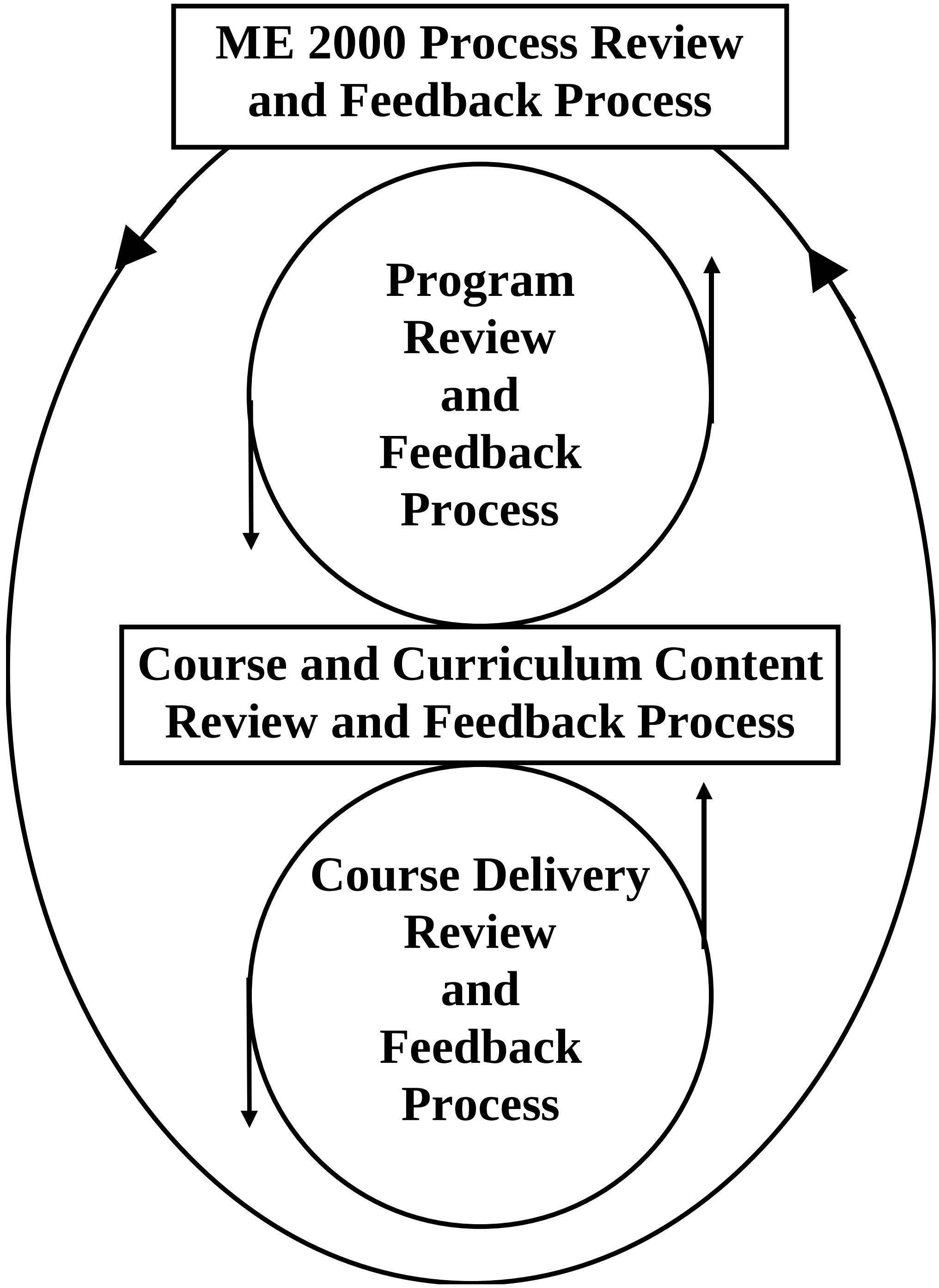
The goals of this CQI process are to graduate individuals with the strongest skills and backgrounds for the mechanical engineering profession and to have our graduates succeed at the highest levels in their careers. As shown in Figure 1, the ME 2000 program is composed of four review and feedback processes:

- **Program Review and Feedback Process:** Includes assessment of the achievement of the Program Educational Objectives and review of the Program Educational Objectives for appropriateness and relevancy.

- **Course Delivery Review and Feedback Process:** Includes an assessment as to whether the courses are delivering the specified Course Learning Objectives.

- **Course and Curriculum Content Review and Feedback Process:** Includes an assessment of the content of the curriculum and the courses that comprise the curriculum as to whether the Program Educational Objectives have sufficient coverage.

Figure 1. Graphical Representation of ME 2000 Process



- **ME 2000 Process Review and Feedback Process:** Includes an assessment of the assessment tools and procedures used in the ME 2000 process.

Each process has three components: review, feedback, and change. The review component specifies the focus and documentation, identifies the constituent groups involved, specifies the scope and timing of the process, identifies the assessment tools used, and compiles the assessment tool results. The feedback component of each process includes an evaluation of results, generation of recommendations, and a feedback of the results and recommendations. The change component involves consideration of recommendations and implementation of changes. Subsequent assessment of changes becomes part of the next review process. The foundation for all four of these processes is represented by the simple equation below:

**Review + Feedback + Change = CQI**

***Participants***

A key component to any CQI process is the inclusion of various stakeholders into the process. In developing ME 2000, it was recognized that there are many stakeholders associated with the educational process. Some stakeholder groups, such as parents of students and, in the case of public institutions, the state legislature and state taxpayers, are not going to be relevant sources of data for program assessment. ME 2000 has identified four stakeholder groups, called constituent groups, that need to participate in the program assessment:

- Faculty and Academic Staff
- Students
- Alumni
- Employers and Corporate Sponsors

In addition to soliciting assessment data directly from members of these constituent groups, three specific subgroups are used to develop decision-making input:

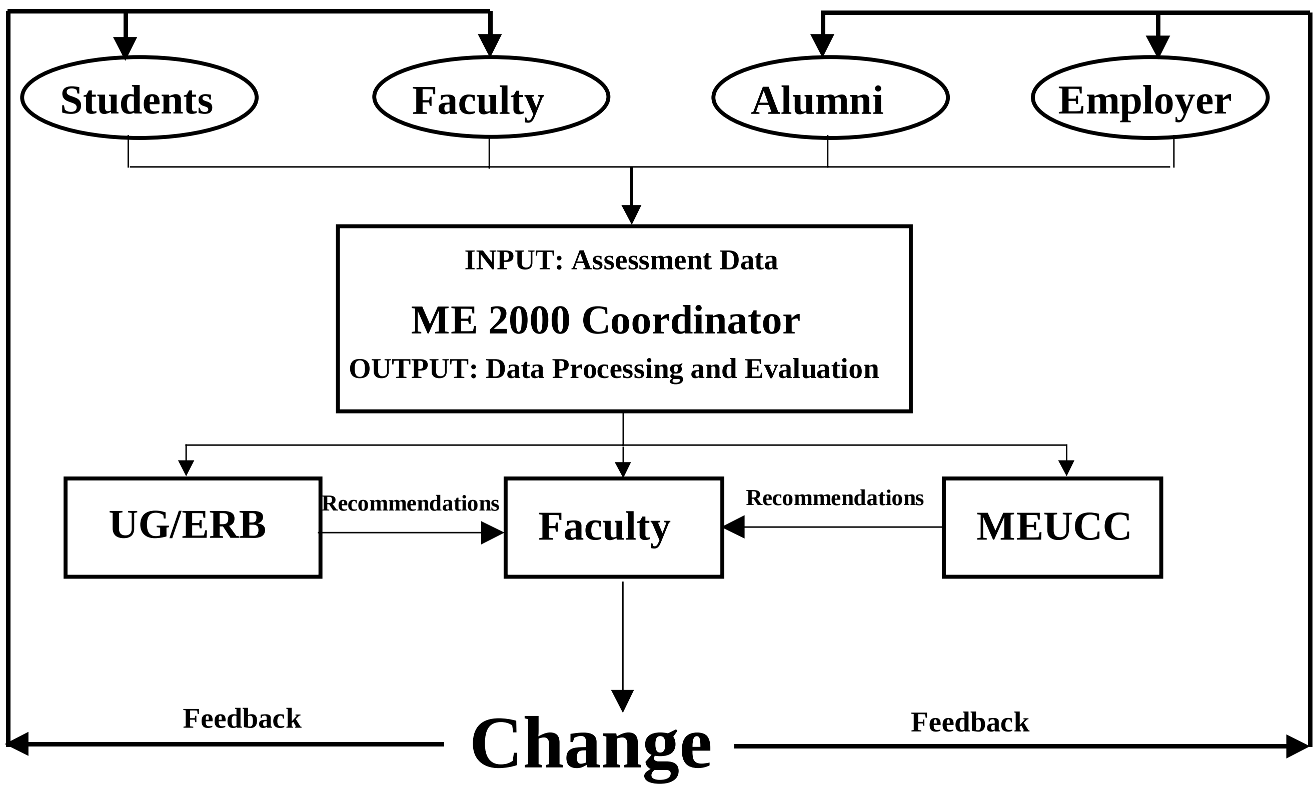
- Mechanical Engineering Undergraduate Curriculum Committee (MEUCC) which consists of members from the faculty and academic staff and student constituent groups

- Mechanical Engineering Undergraduate Continuous Quality Improvement Program External Review Board (UG/ERB) which consists of members from the alumni and employer constituencies

- Department Faculty Meetings which consist of the entire department faculty

The department chair appoints a faculty member to serve as the ME 2000 coordinator to champion the effort and to interact with the department chair and constituent groups. An indication as to how the stakeholder groups interact is shown in Fig. 2.

Figure 2. Stakeholder Group Interactions



*Program Review and Feedback Process*

The focus of this process is the achievement of the Program Educational Objectives, i.e., whether graduates of the program possess the knowledge and abilities required for success in the mechanical engineering profession. This process also includes a review as to the relevancy and appropriateness of the Program Educational Objectives. The documentation for this process is the Program Educational Objectives that have been set by the faculty with input from the student, alumni, and employer constituent groups. A task force of two faculty and two academic staff developed the first draft of the objectives using guidelines provided in EC 2000, data on the employment of program graduates, and anecdotal data from interaction with alumni and employers. This draft was then reviewed by the MEUCC (which allowed for direct input by students) and the UG/ERB (which allowed for input by alumni and employers), and revised according to input received. The draft program objectives were then distributed to the faculty, discussed at two separate faculty meetings, revised accordingly, and approved by the faculty. The current version of the Program Educational Objectives may be found in Figure 3.

To assess the achievement of these Program Educational Objectives several assessment tools had to be developed and instituted. Figure 4 presents the assessment tools used to evaluate the achievement of the fifteen different outcomes that are delineated in the Program Educational Objectives. The assessment tools fall into two categories: surveys administered to the constituent groups and portfolios reviewed by the constituent groups.

The faculty of the program develop three theme portfolios in the areas of design, communication and advanced mathematics. These portfolios include course materials and student work (in some cases including videotape evidence) from a number of different courses in which these areas are significantly emphasized. These portfolios undergo two separate reviews, one by the Mechanical Engineering Undergraduate Curriculum Committee (MEUCC) and one by the Undergraduate External Review Board (UG/ERB). The evaluation of the portfolios by the MEUCC and the UG/ERB is accomplished using a portfolio review tool developed by the ME 2000 coordinator.

*Course Delivery Review and Feedback Process*

The focus of this process is to assess the delivery of courses in the program, i.e. whether or not students are learning the knowledge and acquiring the abilities required in a given course. The documentation used in this process is a set of Course Learning Objectives that have been developed for each course by the faculty involved in teaching the course. Course Learning Objectives are a detailed list of the knowledge and abilities that students will learn in a specific course. Beginning with the major technical topics covered in the course, faculty list specific knowledge or abilities they believe students should have in these topics. The faculty also consider whether any nontechnical program objectives, such as communication or teaming skills, are components of the course and these are listed as well.

In the current development of ME 2000, two assessment tools are being used in the Course Delivery Review and Feedback Process. At the end of every course a survey is administered to the students in the course. The students are asked to evaluate their level of confidence in their abilities associated with the Course Learning Objectives. Hence each course will have its own individual

Figure 3. Program Educational Objectives

**Program Educational Objectives for the Undergraduate Program in Mechanical Engineering**
**Department of Mechanical Engineering**
**Michigan State University**

The undergraduate program in mechanical engineering must ensure that our graduates are very well prepared to enter into and continue progressing in the mechanical engineering profession. To achieve these goals, the program must provide a sufficiently broad and deep base of mathematics; physical science; engineering science; and computer, laboratory, design, and communication experience. The program must also provide breadth, depth, and a balanced view of the engineering principles in both the thermal/fluids area and the mechanical systems area, including the design and realization of such systems. In addition, the program must demonstrate the ability of graduates to apply multivariate calculus, statistics, differential equations, and linear algebra to the solution of mechanical engineering problems. Graduates must be prepared for entry into the engineering profession through a major design experience based on the knowledge and skills acquired in earlier coursework. This experience should incorporate engineering standards and realistic constraints that include most of the following considerations: economic, sustainability, manufacturability, health and safety, social, ethical, and environmental.

In summary the program must integrate knowledge and skills acquired in a diverse set of courses to achieve the following abilities in its graduates:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to function on multidisciplinary teams
(c) an ability to identify, formulate, and solve engineering problems
(d) an ability to communicate effectively
(e) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
(f) an ability to design a system, component, or process to meet desired needs
(g) an ability to design and conduct experiments, as well as to analyze and interpret data

Additionally, through the culture of the program and the attitude of the faculty the program must achieve the following abilities in its graduates:

(h) an understanding of professional and ethical responsibility
(i) a recognition of the need for and the ability to engage in life-long learning
(j) an understanding of the impact of engineering solutions in a global/societal context as provided by a broad education
(k) a knowledge of contemporary issues

Figure 4. Program Outcome Audit

| Outcome \ Assessment Tools | **Employer Survey** | **Senior Survey** | **Co-op Employer Survey** | **Co-op Student Survey** | **Alumni Survey** | **Theme Portfolio Review by MEUCC** | **Theme Portfolio Review by UG/ERB** |
|---|---|---|---|---|---|---|---|
| Apply knowledge of mathematics, science, and engineering | X | X | X | X | X | | |
| Function on multidisciplinary teams | X | X | X | X | X | | |
| Identify, formulate, and solve engineering problems | X | X | X | X | X | | |
| Communicate effectively | X | X | X | X | X | X | X |
| Use of techniques, skills, and modern engineering tools | X | X | X | X | X | | |
| Design a system, component, or process | X | X | X | X | X | | |
| Design and conduct experiments | X | X | X | X | X | | |
| Understand professional and ethical responsibility | X | X | X | X | X | | |
| Encouragement of life long learning | X | X | X | X | X | | |
| Awareness of global/societal impact on engineering | X | X | X | X | X | | |
| Knowledge of contemporary issues | X | X | X | X | X | | |
| Design, build, and test in mechanical systems area | | X | | | | X | X |
| Design, build, and test in thermal/fluids area | | X | | | | X | X |
| Application of advanced mathematics including multivariate calculus, differential equations, linear algebra, and statistics | | X | | | | X | X |
| Undertake a major design experience | | X | | | | X | X |

survey. Course evaluations by students have been shown to be valid indicators of the quality of instruction (Dooris 1997) and reasonable measures of the relationship between faculty effectiveness and student learning performance (Haug 1996). The second assessment tool is review of the course portfolio, which includes course materials, assignments, and student work, assembled by the instructor of the course and documented so as to show the achievement of the Course Learning Objectives.

***Course and Curriculum Content Review and Feedback Process***

Since the curriculum forms the foundation of the undergraduate educational program, a main step in achieving the Program Educational Objectives is to ensure appropriate coverage of the program objectives in the courses of the curriculum. The faculty responsible for each course in the curriculum were asked to assign a level of emphasis (major emphasis, some emphasis, little or no emphasis) for each program objective. The compilation of these emphasis levels has been developed into a mapping of the Program Educational Objectives into the curriculum (Figure 5). Two Program Educational Objectives appear in the curriculum map as not being a major emphasis in any required course, namely 1) having a knowledge of contemporary issues and 2) an awareness of the global and societal impact of engineering. This observation may lead to a change that would include these objectives as a major emphasis in a course. This might be accomplished by changing the content of a current course or by adding a new course. However, this action would only be undertaken if there was assessment data indicating a problem with these two outcomes.

***ME 2000 Process Review and Feedback Process***

The ME 2000 process is documented in a guidebook developed by the ME 2000 Coordinator. An annual ME 2000 report compiles the results of the other three review and feedback processes. The assessment of the ME 2000 process is accomplished through review of these two documents by MEUCC and UG/ERB. These two groups recommend changes to the process and/or the assessment tools based on their evaluation. These recommended changes are then presented to the faculty at a faculty meeting for review and approval.

IV. Two Year Assessment Data and Subsequent Program Changes

***Program Review and Feedback Process***

Some preliminary results from the surveys administered in the 1997-98 academic year are shown in Figure 6. Based on these results, there is some concern in the level of achievement for the Program Educational Objective dealing with the knowledge of contemporary issues. There also appears to be some weakness in achieving the objectives associated with understanding professional and ethical responsibility and developing an awareness of the global and societal impact of engineering. In Figure 7, a comparison is made of the alumni data for 1997-98 and for 1998-99. It is interesting to note that in all but two of the Program Objectives the arithmetic mean increased. It is also of great concern to see the large decrease in the score for the objective dealing with life long learning. Since these assessment results represent only the first and second attempts at gathering such data and the weaknesses identified appeared not to be overly negative, no recommendations for changes have been proposed at this time. However, discussion at the MEUCC indicated that part of the difficulty with the score for the objective involving contemporary issues may be with the wording rather than the achievement of the objective. At the suggestion of the MEUCC, questions were added to the Program Education Objectives survey to clarify this issue.

Figure 5. Mapping of Program Educational Objectives with Curriculum

**Mechanical Engineering Required Courses**

| **Program Educational Objectives** | **ME 201** | **ME 332** | **ME 371** | **ME 391** | **ME 410** | **ME 412** | **ME 451** | **ME 461** | **ME 471** | **ME 481** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Apply knowledge of mathematics, science, and engineering | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 29 |
| Function on multi-disciplinary teams | 1 | 3 | 3 | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 21 |
| Identify, formulate, and solve engineering problems | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 28 |
| Communicate effectively | 1 | 3 | 3 | 1 | 1 | 3 | 3 | 3 | 2 | 3 | 23 |
| Use of techniques, skills, and modern engineering tools | 2 | 3 | 2 | 2 | 3 | 1 | 3 | 3 | 2 | 2 | 23 |
| Design a system, component, or process | 1 | 1 | 3 | 1 | 2 | 3 | 2 | 2 | 3 | 3 | 21 |
| Design and conduct experiments | 1 | 2 | 1 | 1 | 1 | 3 | 3 | 2 | 1 | 3 | 18 |
| Professional and ethical responsibility | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 14 |
| Encouragement of life long learning | 1 | 1 | 2 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 15 |
| Global/societal engineering awareness | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 11 |
| Knowledge of contemporary issues | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 13 |
| Design, build, and test in mechanical systems area | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 16 |
| Design, build, and test in thermal/fluids area | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 3 | 14 |
| Application of advanced mathematics | 2 | 2 | 1 | 3 | 3 | 2 | 3 | 3 | 1 | 2 | 22 |
| Capstone design experience | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 14 |

**Key**

| | |
|---|---|
| 3 | Major Emphasis |
| 2 | Some Emphasis |
| 1 | Little or No Emphasis |

Figure 6. Assessment Results for 1997-98

Survey participants were asked to assess their abilities on a 5 to 1 scale as follows:
5 = Very Satisfied; 4 = Satisfied; 3 = Neutral; 2 = Dissatisfied; 1 = Very Dissatisfied

| **Outcome** | **Senior Survey**[1] | **Co-op Employer Survey**[1] | **Co-op Student Survey**[1] | **Alumni Survey**[1] |
|---|---|---|---|---|
| Apply knowledge of mathematics, science, and engineering | 4.32 | 4.07 | 3.70 | 4.04 |
| Function on multi-disciplinary teams | 4.41 | 4.50 | 4.10 | 3.71 |
| Identify, formulate, and solve engineering problems | 4.18 | 4.00 | 3.40 | 4.10 |
| Communicate effectively | 4.41 | 4.00 | 3.68 | 3.93 |
| Use of techniques, skills, and modern engineering tools | 3.95 | 4.29 | 3.44 | 3.72 |
| Design a system, component, or process | 4.05 | 3.71 | 3.50 | 3.72 |
| Design and conduct experiments | 4.09 | 4.15 | 3.70 | 3.84 |
| Understand professional and ethical responsibility | 4.18 | 4.29 | 3.80 | 3.38 |
| Encouragement of life long learning | 3.73 | 4.29 | 3.70 | 3.84 |
| Awareness of global/societal impact on engineering | 3.82 | 3.69 | 3.20 | 3.68 |
| Knowledge of contemporary issues | 3.64 | 3.92 | 3.56 | 3.35 |

**Notes:**
1: arithmetic mean of responses

Figure 7. Two Year Alumni Assessment Results

Survey participants were asked to assess their abilities on a 5 to 1 scale as follows:
5 = Very Satisfied; 4 = Satisfied; 3 = Neutral; 2 = Dissatisfied; 1 = Very Dissatisfied

| **Outcome** | **1997-98**[1] | **1998-99**[1] |
|---|---|---|
| Apply knowledge of mathematics, science, and engineering | 4.04 | 4.23 |
| Function on multi-disciplinary teams | 3.71 | 4.17 |
| Identify, formulate, and solve engineering problems | 4.10 | 4.11 |
| Communicate effectively | 3.93 | 4.05 |
| Use of techniques, skills, and modern engineering tools | 3.72 | 3.80 |
| Design a system, component, or process | 3.72 | 3.99 |
| Design and conduct experiments | 3.84 | 3.86 |
| Understand professional and ethical responsibility | 3.38 | 3.68 |
| Encouragement of life long learning | 3.84 | 3.17 |
| Awareness of global/societal impact on engineering | 3.68 | 3.56 |
| Knowledge of contemporary issues | 3.35 | 3.42 |

**Notes:**
1: arithmetic mean of responses

Figure 8. Student Evaluation of CLO's for ME 201 Thermodynamics

Survey participants were asked to evaluate their level of confidence with the following topics, using a 5-1 scale with 5 indicating complete confidence and 1 indicating no confidence.

| **Course Learning Objective (CLO)** | **Sec. 1[1]** | **Sec. 2[1]** | **Sec. 3[1]** | **Sec. 4[1]** |
|---|---|---|---|---|
| A. Ability to identify control volumes, closed systems, and transient systems | 4.03 | 4.26 | 4.67 | 3.69 |
| B. Ability to apply the state principle | 3.88 | 4.10 | 4.40 | 4.15 |
| C. Ability to recognize three types of substances: ideal gas, compressible substance, incompressible substance | 3.97 | 4.07 | 4.49 | 4.69 |
| D. Ability to use tables to evaluate the properties of compressible substances, including identifying the phase of the substance | 3.75 | 3.90 | 4.64 | 4.31 |
| E. Ability to use tables to evaluate the properties of ideal gases | 3.97 | 4.24 | 4.91 | 4.23 |
| F. Ability to use equations to evaluate the properties of incompressible substances | * | * | 4.22 | 3.85 |
| G. Ability to calculate boundary work for a system from $\int PdV$ | 3.75 | 3.93 | 4.49 | 3.46 |
| H. Ability to apply the first law to closed systems | 3.84 | 4.05 | 4.60 | 4.00 |
| I. Ability to apply the first law to control volume systems | 3.94 | 4.12 | 4.47 | 4.08 |
| J. Ability to apply the first law to transient systems | 3.34 | 3.57 | 4.18 | 2.69 |
| K. Ability to calculate the thermal efficiency for a heat engine and the coefficient of performance for a refrigerator and heat pump | 3.31 | 3.40 | 4.47 | 4.08 |
| L. Understanding the Clasius statement and the Kelvin-Planck statement of the second law | 2.75 | 2.83 | 3.56 | 3.31 |
| M. Understanding the concept of reversibility | 3.81 | 3.95 | 3.82 | 3.62 |
| N. Ability to understand the principle of the Carnot cycle and make calculations of Carnot thermal efficiency and Carnot coefficient of performance | 3.47 | 3.74 | 4.58 | 3.31 |
| O. Ability to understand the entropy property and can evaluate it for different types of substances | 3.53 | 3.83 | 4.11 | 3.23 |
| P. Ability to calculate and interpret the entropy change of the universe for a process | 3.28 | 3.60 | 3.87 | 3.31 |
| Q. Ability to use isentropic efficiencies for control volume work devices | * | * | 4.02 | 3.08 |
| R. Ability to solve and analyze engineering problems by applying appropriate combinations of thermodynamic principles and knowledge of fluid properties | 3.19 | 3.57 | 4.02 | 3.46 |

**Notes:**
1 arithmetic mean of responses
* Questions not included for these sections

### ***Course Delivery Review and Feedback Process***

During the first year of the CQI process, course surveys were done for only three courses. Figure 8 shows these results for four sections of the undergraduate thermodynamics course, ME 201. Some questions were not included for the surveys administered to sections 1 and 2 due to a misunderstanding among the faculty. This information has been provided to the instructors of the course and the appropriate technical group in the department for review and possible action. Course surveys were done for all undergraduate courses during the second year of the CQI process. Again this information was provided to the faculty, and has spawned some conversation, but no action. The second assessment tool, review of the course portfolios, has been very challenging to implement. Most faculty are unwilling to compile portfolios making the subsequent reviews impossible. It would seem that the culture of the department is not quite ready for such an undertaking.

### ***Course and Curriculum Content Review and Feedback Process***

Two of the three Program Educational Objectives that were identified as having weak levels of achievement though the Program Review and Feedback Process, namely 1) having a knowledge of contemporary issues and 2) an awareness of the global and societal impact of engineering, also appear in the curriculum map as not being a major emphasis in any required course. The questions faced by the MEUCC and UG/ERB was whether the weak level of achievement was due to the curriculum and could be improved by changes in the curriculum.

Based on the data collected, there are no recommended changes in the curriculum. However, from anecdotal data there appear to be concerns with two aspects of the curriculum. First, there seems to be a major logistic problem with the senior elective component of the curriculum and the required design content of this component. It is a constant challenge for students and the Undergraduate Academic Advisor to identify sufficient courses to satisfy this requirement. The faculty took this concern under advisement, and the senior elective requirements were modified to solve this problem. Second, there is a concern with the lack of design in the lower division. It has been proposed by the department Chairperson that ME 371 be converted over to a sophomore level course. A task force has been appointed by the department Chairperson to address this issue.

### ***ME 2000 Process Review and Feedback Process***

For the 1997-98 year, a number of issues were identified that need to be addressed. A current status of these issues is provided below.

<u>Incorporating ME 2000 and the coordinator position into the department bylaws:</u> If the department is serious in its implementation of ME 2000 and its continuing development, then the process and its coordinator should be formally established in the department's bylaws. Proposals on this issues are under consideration by the faculty. The issue was left unresolved at the last department faculty meeting of 1998-99.

<u>Ensuring that all changes in the undergraduate program pass through the ME 2000 system:</u> During the past two years, several initiatives involving the undergraduate program were introduced without passing through the ME 2000 process. These included the introduction of a new sophomore level design course, development of an honors program, development of an undergraduate recruiting program, changing the responsibility for the intermediate dynamics course, introducing a new senior elective in dynamic systems, collecting assessment data outside the process, and the restructuring of

the engineering graphics course. If the ME 2000 process is to be successful, key department personnel need to coordinate such changes using the ME 2000 process.

Changing the attitude of the faculty towards participation in ME 2000: It has been a challenge to get faculty buy in for the ME 2000 process as demonstrated by the difficulty in the development of course learning objectives and the compilation of course portfolios. Faculty who have participated in the MEUCC appear to have a much higher level of buy in.

Developing methods to identify opportunities for program improvement: The ME 2000 process initially collected quantitative data in the form of surveys, but quite often it is from anecdotal data that the real opportunities for improvement are identified. The process needs to explore avenues to obtain anecdotal data in an consistent fashion. To this end, all of the assessment surveys have been modified, so as to obtain not only the quantitative data, but qualitative comments.

Review of the usefulness of course portfolios as an assessment tool: Since the assembling of course portfolios has become a major problem (the faculty are very unwilling to participate), the MEUCC has recommended that these be dropped as assessment tools.

## V. Conclusions

A CQI process has been developed for an undergraduate mechanical engineering program. All four components of this process are well underway with most of the assessment tools implemented. It appears that useful information is being collected that can be used to improve the program. Lessons learned from this experience include:

- Early in the development process, it is important to identify the constituent groups that are to be involved in the decision making and develop mechanisms to facilitate this involvement.

- The implementation of such a program requires a faculty champion that is willing to share the administrative load with the department chairperson. In higher education CQI efforts where implementation resulted in tremendous and exciting results, the principal driving force was management's leadership (Cornesky 1994). Quality in education will come about only through the leadership of American universities, particularly through the personal leadership of university presidents, deans, and faculty (Feigenbaum 1993).

- Gaining the commitment from faculty/staff and facilitating teamwork is a critical and ongoing task. In similar efforts, resistance has been attributed to the reality that change is painful and threatening; the arrogance of senior faculty and administration; the time, energy, and work involved; the lack of a clear understanding about what CQI can and cannot accomplish; reluctance to empower subordinates; and the difficulty faculty have in accepting the concept that academic work can be measured and improved (Lamkin 1994).

- Difficultly in getting faculty to empower their peers as representatives on committees resulted in having to solicit input from the faculty at open faculty meetings and to make decisions based on voting by the entire faculty of the department.

- Survey results do provide important quantitative data on the achievement of program objectives that can be used to improve the program to better attain these objectives. However, assessment tools also require assessment and may require modification or clarification.

- Program Educational Objectives and Course Learning Objectives must be viewed as “living” documents that will need to be changed as part of the evolution of an educational process.

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