AC 2008-2236: OUTCOME ASSESSMENT PROCESS IN A MANUFACTURING ENGINEERING PROGRAM

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Outcome Assessment Process in a Manufacturing Engineering Program

Abstract

To achieve the goals and objectives of program educational objectives, our Manufacturing Engineering (MANE) program at Virginia State University developed a curriculum that provides students with balanced coverage of ABET and the University core requirements. The program outcomes have been adopted considering the University and school mission, program objectives, (a) through (k) defined by Accreditation Board for Engineering and Technology (ABET), and specific outcomes for manufacturing engineering as defined by the Society of Manufacturing Engineering (SME).

Our MANE program focuses on the areas of automation, quality, manufacturing process, engineering analysis and manufacturing design to prepare students for successful careers in manufacturing engineering and allied professions. This paper presents a brief description of the major components of our assessment that fulfill the ABET criteria for continuous improvement requirements. The assessment process and evaluation of the program outcomes are discussed along with the results as well.

Introduction

Although there are several papers published in the field of engineering program outcome assessment [1, 2, 3], there are very few that discuss assessment process of manufacturing engineering programs. Most of these assessment plans revolve around certain aspects of the program such as courses, capstone courses, or engineering labs. This paper presents an assessment procedure which considers all program outcomes assessment processes.

The Manufacturing Engineering (MANE) program at Virginia State University developed a curriculum that provides students with balanced coverage of ABET and the University core requirements. The outcomes have been adopted considering the University and school mission, program objectives, (a) through (k) defined by Accreditation Board for Engineering and Technology (ABET) [4], and specific outcomes for manufacturing engineering as defined by the Society of Manufacturing Engineering (SME). The program provides students with extensive experience in basic science and mathematics, engineering science, laboratories, computers, design, communication and teamwork, along with humanities and social science.
To achieve the goals and objectives of the program educational objectives, we have developed an innovative model for assessing our program. The model uses both indirect measure and direct measure and is based on multiple indicators such as presentations, student portfolio, and report writing evaluated by different focused groups. The results mapped to the program objectives and course outcomes using a matrix. That matrix brings a strong alignment and a common frame of reference (the criteria), used for evaluation or the interpretation of results which identifies the areas for improvement and improvement plan.

Program Educational Objectives

Consistent with the University's mission and in accordance with the ABET accreditation criteria, the Manufacturing Engineering Program, in concert with our Industrial Advisor Committee (IAC), developed five program educational objectives to prepare graduates who

1. Understand and apply math and engineering principles to the manufacturing engineering profession.
2. Understand and apply problem solving and analysis skills to meet the challenging demands and responsibilities of a successful career.
3. Demonstrate continuous learning and growth in their profession using both oral and written communication skills to contribute as a team member or leader in solving problems for their employer and society.
4. Demonstrate high standards of professionalism and ethics in fulfilling their responsibilities to both employer and society.
5. Demonstrate the ability to pursue a variety of career paths with many finding employment in industry or government but some will pursue graduate studies in other fields.

Program Requirements

The Manufacturing Engineering program focuses on the areas of automation, quality, manufacturing process, engineering analysis and design to prepare students for successful careers in manufacturing engineering and allied professions. The manufacturing engineering program outcomes are achieved through a balanced 127-hour curriculum including both labs and lecture courses. As shown in the Table 1, the curriculum consists of 63 credit hours of engineering fundamental and manufacturing core, 33 credit hours of mathematics and science and 31 credit hours of general education courses to prepare students for engineering practice as required by ABET Criterion 4 and to meet the University's general education requirements.

Table 1- Categories of Manufacturing Engineering Curriculum

Manufacturing and Engineering (63 hrs)		**Math and Science (33 hrs)**	
MANE 205 Manufacturing Process I	3	MATH 200 Calculus I	3
MANE 210 Manufacturing Process II	3	MATH 201 Calculus II	3
MANE 310 CAD/CAM with Lab	3	MATH 300 Calculus III	3
MANE 315 Mfrg Automation with Lab	3	MATH 350 Differential Equations	3
MANE 400 Senior Seminar	1	MATH 392 Linear Programming	3
MANE 410 Prod. Plan. and Inventory Ctrl.	3	MATH/SCIENCE Elective	3
MANE 415 Project Eng. and Management	2	PHYS 112 Physics I with Lab	4
MANE 420 Simulation	3	PHYS 113 Physics II with Lab	4
MANE 450 Mfrg Design Implement. with lab	3	CHEM 101 General Chemistry (with Lab)	4
ENGR 101 Intro to Engineering I	2	ENGR 301 Engineering Statistics	3
ENGR 102 Intro Engineering II	2	**General Education (31)**	
ENGR 200 Engineering Graphics	2	ENGL 110 Composition I	3

ENGR 201 Electronic Circuits	3	FRST 101 Freshman Studies	2
ENGR 203 Intro to Programming	3	Wellness/Health Elective	1
ENGR 210 Statics and Strength of Mat.	3	ENGL 111 Composition II	3
ENGR 305 Materials Engineering	3	History Elective	3
ENGR 313 Thermal Engineering	3	Wellness/Health Elective	1
ENGR 315 Dynamics	3	Social Science Elective	3
ENGR 430 Quality Control with Lab	3	Literature Elective	3
ENGR 310 Engineering Economics	3	Global Studies Elective	3
ENGR/MANE Elective	3	Elective	3
ENGR/MANE Elective	3	PHIL 275/ 450 Ethics/Applied Ethics	3
ENGR/MANE Elective	3	ENGL 342 Technical Communication	3

The program provides students with extensive experience in basic science and mathematics, engineering science, laboratories, computers, design, communication and teamwork, along with humanities and social science. These experiences are carefully mixed through the entire curriculum to help students assimilate systematically the knowledge of scientific and technical principles to develop skills to compete in a global marketplace for engineering services. The distribution of the courses for the professional components of the program is summarized in Table 2.

Table 2 - Course Distribution by Professional Components of the Curriculum.

Category	**Courses**
Freshmen Engineering Experience	ENGR 101, ENGR 102
Engineering Science Experience	ENGR 201, ENGR 210, ENGR 305, ENGR 313, ENGR 315
Engineering Design Experience	ENGR 200, MANE 310, MANE 450, MANE 315, ENGR 430, MANE 420
Laboratory Experience	ENGR 101, ENGR 102, ENGR 200, MANE 310, MANE 315, ENGR 430, MANE 450
Communication and Teaming Experience	
Writing and Oral Presentation Skills	MANE 310, MANE 450, MANE 315, MANE 400, ENGL 110, ENGL 111, ENGL 342
Teamwork in Courses and Projects	MANE 450, MANE 415
Graphical Communication Skills	ENGR 200, MANE 310
Computer Experience	ENGR 101, ENGR 102, ENGR 203, ENGR 200, MANE 310, MANE 315, MANE 420
Senior Capstone Experience	MANE 450
General Education	
Basic Science and Mathematics	MATH 201, MATH 200, MATH 300, MATH350, MATH 392, PHYS 112, PHYS 113, CHEM 101, ENGR 301
Professional Experience Through Internships	

Process to Develop Outcomes and Relationship to Objectives

The MANE program outcomes have been adopted considering the University and school missions, program objectives, and to fulfill both ABET (a) through (k) as well as specific required outcomes for manufacturing engineering defined by the Society of Manufacturing Engineering (SME).

These program outcomes will be reevaluated for relevance every three years or as soon as a change appears in the University or school mission, program objectives, ABET requirements or SME requirements, or Industrial Advisory Committee (IAC).

Program Outcomes

The following are the fourteen program outcomes for the Bachelor of Science of Manufacturing Engineering degree. Outcomes 1 through 11 are ABET (a) through (k) criteria and 12 through 14 are SME criteria. By the time of graduation, students in the Manufacturing Engineering program must attain the:

1. Ability to apply comprehensive knowledge in mathematics, science and engineering science to manufacturing engineering.
2. Ability to perform engineering analysis by designing and conducting appropriate experiments and analyzing and interpreting results.
3. Ability to design products, equipment, tooling and environment for manufacturing systems.
4. Ability to function effectively in team or group setting.
5. Ability to identify, formulate, and solve engineering problems.
6. Ability to practice engineering profession at highest ethical standards.
7. Ability to communicate effectively.
8. Ability to implement technology with an awareness of important social issues and understand the impact of engineering solution in a global and societal context.
9. Recognition of the need to engage in lifelong learning.
10. Knowledge of contemporary issues such as understanding the creation of competitive advantage through manufacturing planning, strategy, and control.
11. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
12. Understanding of the behavior and properties of materials as they are altered and influenced by manufacturing processes.
13. Ability to use statistical and calculus based methods to analyze and control manufacturing operations.
14. Ability to measure manufacturing process variables in a manufacturing laboratory and make technical inference about the process.

The courses in the manufacturing engineering core curriculum were developed from the program outcomes with input from the IAC. The core courses were developed with strong hands-on focus to integrate groups of students with diverse learning styles and a broad array of backgrounds and preparations. The relationship of these courses with the program outcomes is shown in Table 3.

Table 3 - Core Courses mapped to Program Outcomes

Course Number	Course Title	1. knowledge of	2. Design System	3. Design product,	4. teamwork	5. Solving Engr …	6. Ethics	7. Communicate …	8. Social issues	9. Lifelong learning	10. Contemporary	11. Engineering	12. Materials	13. Statistical	14. Manufacturing
ENGR 101	Intro to Eng I	x	x			x		x				x			
ENGR 102	Intro to Eng II	x	x			x		x				x		x	
ENGR 200	Eng. Graphics			x				x				x			
ENGR 201	Circuits					x									
ENGR 203	Programming					x						x			
ENGR 210	Statics & Str.	x				x									
ENGR 301	Statistics		x			x								x	
ENGR 305	Materials	x				x							x		
ENGR 313	Thermal	x				x									
ENGR 315	Dynamics	x				x									
ENGR 430	Quality								x		x			x	x
MANE 205	Process I	x			x	x		x					x		
MANE 210	Process II	x		x	x	x		x	x				x		
MANE 310	CAD/CAM			x				x				x			
MANE 315	Automation	x	x			x		x				x			
MANE 400	Seminar	x				x	x	x		x					
MANE 410	Planning								x		x				
MANE 415	Management				x						x				
MANE 420	Simulation		x			x					x	x		x	
MANE 450	Implementation		x	x	x	x		x				x			

Assessment Tools and Metric Goals for Program Outcomes

The program uses direct and indirect measures to assess and evaluate the program outcomes. The direct measure involves looking at students' works produced in certain courses in the program. Student performance in selected ENGR and MANE courses is used to measure achievement of the program outcomes. Depending on the nature of each course, various methods such as course-embedded questions, analyses of course projects, capstone course evaluations, and administrating FE type exams are used to assess how successful each course was in achieving associated program outcomes.

Direct Method: The primary instruments for direct measures are student performance in courses using Faculty Course Assessment Reports (FCAR). The FCAR is a methodology for the reporting of course assessment results that facilitate the assessment process. Although, the FCAR is used to report both indirect and direct measures for the purpose of course improvement, only the direct measure is used to assess the program outcomes. Several tools such as embedded

questions, project report, and project presentation have been used to assess how successful each course was in achieving its own outcomes as well as the program outcomes related to that course. The performance criteria employed for all outcomes is based on the percentage of students who score at or above a 60% grade for a question or project criteria. If 75% of students score above 60%, performance is considered acceptable. If between 65% and 75% of students score above 60% it is considered a concern. If less than 65% of students score above 60%, it is considered a weakness.

Indirect Method: The indirect measure involves gathering information through means other than looking at actual samples of student work, such as surveys, exit interviews, and focus groups. In our program we used surveys after completion of each course as well as at the time of graduation to assess success reaching our outcomes. The main instrument that we use is an exit survey, which shows students' perceptions of how well they have achieved each outcome by the time of graduation. The exit survey is administrated through Educational Benchmarking Institution (EBI). EBI exit survey includes questions related to the program outcomes and graduates may express their satisfaction in their ability in each outcome. This survey uses a scale of 1 to 7 with 1 indicating "not at all", 4 indicating "moderately" and 7 indicating "extremely well". The percentage of graduates that answered a question with a rating of 5, 6 or 7 has been calculated. The target level is 75%, so if less than 75% of graduating seniors answer more than 5 then there will be a concern to investigate. The indirect measure just signal if there is a problem and needs to be used with direct measure to support the achievement level indicated.

Assessment Process for Program Outcomes

To design a sustainable assessment process in line with our resources and our program size, we first map all of the MANE and ENGR required courses offered to the program outcomes. Then for each outcome we selected a maximum of four courses (possibly one from each freshman, sophomore, junior and senior levels) to include in a folder designed for each outcome.

Although a program outcome folder gives us a more detail explanation of how well a specific outcome matures over the four year period, only one course was chosen as a main indicator course to be look at first as an indication of how well the program achieved its outcomes. If the assessment results from this course is more than 75% then the outcome is assumed to be achieved at the current target level and at this point is not a concern for continues improvement. If the assessment result from this course is between 65% and 75% then there is concern with this outcome and as a result we will need to carefully look at all select course related to this outcome and come up with suggestions to improve the level of achievement for this outcome. If the assessment result from this course is less than 65% then there is a major problem with this outcome and as a results all "supporting courses" for this outcome must be considered and evaluated for the propose of continues improvement. The support, select and Main indicator courses related to outcomes are shown in Table 4.

Table 4 - Support, Select, and main Indicator Courses

Program Outcomes	Support Course	Select Course	Main Indicator Course
Outcome 1	ENGR 101, ENGR 102, ENGR 305, ENGR 313, ENGR 315, ENGR 430, MANE 205, MANE 210, MANE 315, MANE 400	ENGR 101, MANE 205, ENGR 313, MANE 400	MANE 400
Outcome 2	ENGR 101, ENGR 102, ENGR 301, ENGR 430, MANE 315, MANE 420	ENGR 102, ENGR 301, MANE 420	MANE 420
Outcome 3	ENGR 200, MANE 210, MANE 310, MANE 450	ENGR 200, MANE 310, MANE 450	MANE 450
Outcome 4	MANE 205, MANE 210, MANE 415, MANE 450	MANE 205, MANE 415, MANE 450	MANE 450
Outcome 5	ENGR 101, ENGR 102, ENGR 210, ENGR 301, ENGR 305, ENGR 313, ENGR 315, MANE 205, MANE 210, MANE 315, MANE 400, MANE 420, MANE 450	ENGR 102, MANE 205, ENGR 313, MANE 400	MANE 400
Outcome 6	PHIL 450, MANE 400	PHIL 450, MANE 400	MANE 400
Outcome 7	ENGR 101, ENGR 102, ENGR 200, MANE 205, MANE 210, MANE 310, MANE 400, MANE 450	ENGR 101, ENGR 200, MANE 310, MANE 450	MANE 450
Outcome 8	ENGR 430, MANE 210, MANE 410	ENGR 430, MANE 410	MANE 410
Outcome 9	MANE 400	MANE 400	MANE 400
Outcome 10	ENGR 430, MANE 410, MANE 415, MANE 420	ENGR 430, MANE 410, MANE 415	MANE 410
Outcome 11	ENGR 101, ENGR 102, ENGR 200, MANE 315, MANE 420, MANE 450	ENGR 102, ENGR 200, MANE 310, MANE 450	MANE 450
Outcome 12	MANE 205, MANE 210, ENGR 305	MANE 205, MANE 210, ENGR 305	ENGR 305
Outcome 13	ENGR 102, ENGR 301, ENGR 430, MANE 420	ENGR 301, ENGR 430, MANE 420	MANE 420
Outcome 14	ENGR 430	ENGR 430	ENGR 430

In summary there are six main indicator courses used for the final assessment of all program outcomes which are as follow:

- MANE 400 (Senior Seminar) used to assess program outcomes 1, 5, 6 and 9 by using an FE type exam and research project report.

- MANE 450 (Manufacturing Design Implementation) used to assess outcomes 3, 4, 7, and 11. In MANE 450, students are required to work on a capstone project and present the result as well as submit a comprehensive report at the end of semester. Both presentation and report are carefully evaluated by all faculty members of manufacturing engineering as well as invited faculty from the department and a member of industrial advisory committee.
- MANE 420 (Simulation) was used to assess outcomes 2 and 13. The assessment is based on an analysis of two class projects assigned and evaluated by an outside evaluator in consultation with the faculty.
- MANE 410 (Production Planning and Inventory Control) used to assess outcomes 8 and 10 using embedded questions.
- ENGR 430 (Quality Engineering) used to assess outcome 14 using embedded questions.
- ENGR 305 (Materials Engineering) used to assess outcome 12 using embedded questions. Figure 1 illustrates the flow chart of the assessment process of an outcome.

The assessment process flow chart is illustrated in figure 1.

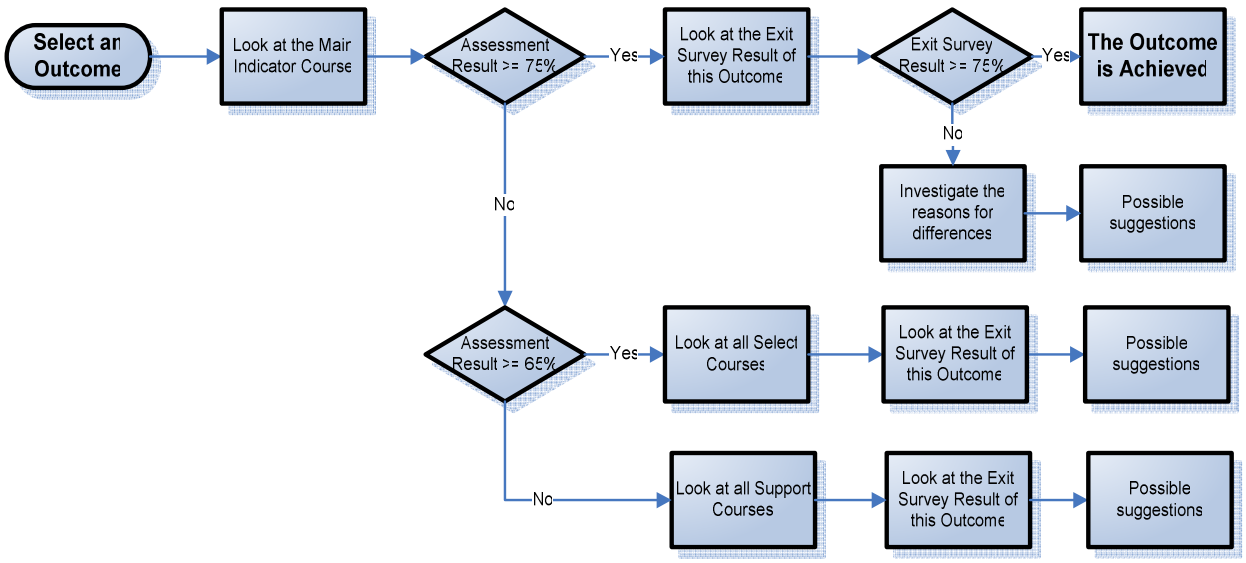

Figure 1- Assessment and Evaluation Process Flow Chart

Analysis of Assessment Results and Strategies for Continuous Improvement

The direct and indirect measures for all program outcomes are summarized in Table 5. Although all fourteen program outcomes have been assessed and evaluated, the goal is to evaluate all odd outcomes in odd years and all even outcomes in even years. This procedure has been developed to keep our assessment process manageable based on the number of the Manufacturing Engineering faculty. Each Manufacturing Engineering faculty is assigned primary responsibility monitoring four outcome folders.

Table 5 - Summary of the Results of Direct and Indirect Measures

Program Outcomes	Assessment Method & Performance Criteria			Actions for Continuous Improvement
	Indirect	Direct	Decision	
Outcome 1	85% - 100%	67%	Concern	Include at least 3 hours for review of math required in each related courses. Encourage students to use math help center. Explore developing an integrated math/science/engineering math course to improve the application of math to engineering problems.
Outcome 2	72% - 86%	89%	Achieved	No action is needed to be taken for this outcome.
Outcome 3	86%	100%	Achieved	No action is needed to be taken for this outcome.
Outcome 4	57%	83%	Achieved	Recommend to add Manufacturing Automation (MANE 315) to supporting courses of this outcome. Emphasize multidisciplinary activities in support courses of this outcome.
Outcome 5	72% - 86%	67%	Concern	Review the level of difficulty of the embedded questions used in the assessment in MANE 400. Review the list of select courses for this outcome. Avoid the same professor teaching all the select courses for this program outcome. After reviewing the course folders for the select courses it was clear that students' not doing homework remains an issue. In an attempt to improve this, require a standard format for homework to be used in all courses beginning with the first year. Encourage faculty to schedule a weekly problem solving session in addition to regular class time.
Outcome 6	72%-100%	100%	Achieved	While the limited data indicate this outcome was met, more extensive overage of this outcome is needed. Recommend an increase in ethical awareness in the engineering field at all levels.
Outcome 7	86%	100%	Achieved	No action is needed to be taken for this outcome.
Outcome 8	57% - 72%	100%	Achieved	The results of exit survey made us to realize that there are few places in our curriculum that we touch this outcome so program faculty decided to include some materials related to this outcome in Manufacturing Process I (MANE 205) and Materials Engineering (ENGR 305). Recommend to support this outcome in more courses.
Outcome 9	57% - 86%	83%	Achieved	No action is needed to be taken for this outcome.
Outcome 10	72%	92%	Achieved	While based on the direct measure results at the current target level, no action is needed to be taken for this outcome. However, the EBI questions used to assess this outcome needs to be improved. Adding detailed, clear and focused questions to EBI survey is recommended.
Outcome 11	72% - 86%	100%	Achieved	No action is needed to be taken for this outcome.
Outcome 12	100%	62%	Problem	Recommended to add Manufacturing Process II (MANE 210) to the list of support courses for this outcome. Reviewing the FCAR for ENGR 305 indicates that some of the topics in this course must be transferred to lower courses such as MANE 205 and MANE 210. It also recommended adding laboratory experience encourage students to have more profound look to topics.
Outcome 13	72%	78%	Achieved	Based on the results and at the current target level, no action is needed to be taken for this outcome. However, more emphasize on interpretation of data is recommended in Engineering Statistics (ENGR 301) and Quality Control (ENGR 430).
Outcome 14	72% - 86%	100%	Achieved	Based on the results and at the current target level, no action is needed to be taken for this outcome. However, there is just one course addressing this outcome. Recommend to support this outcome in more courses such as Manufacturing Process I (MANE 205), Manufacturing Automation (MANE 315) and Materials Engineering (ENGR 305).

Conclusion

The process of fourteen outcomes developed for the MANE program at Virginia State University along with the methodology of assessment was described. Eleven of these outcomes were completely achieved. There were some concerns in outcomes 1 and 5 and problems in outcome 12 were identified. Discussion on the outcome assessment indicated changes that were needed and improvement of the supporting courses. In summary, to achieve these outcomes the following recommendations have been made:

For Outcome 1:

- Include at least 3 hours for review of math required in each related courses.
- Encourage students to use the math help center.
- Explore developing a math course to improve the application of math to engineering problems.

For Outcome 5:

- Review the level of difficulty of the embedded questions used in the assessment in MANE 400.
- Review the list of select courses for this outcome.
- Avoid the same instructor teaching all the select courses related to this outcome.
- After reviewing the course folders for the select courses it was clear that students' not doing homework remains an issue.
- Encourage faculty to schedule a weekly problem solving session in addition to regular class time.

For Outcome 12:

- Recommended to add Manufacturing Process II (MANE 210) to the list of support courses for this outcome.
- Some topics in ENGR 305 are transferred to lower courses such as MANE 205 and MANE 210.
- Adding laboratory experience helps students to better understand topics related to materials and processes.

References

1. Paul Biney, "ASSESSING ABET OUTCOMES USING CAPSTONE DESIGN COURSES ", *Proceedings of the 2007 ASEE Annual Conference and Exposition*, ASEE, 2007.
2. Owe Petersen, Stephen Williams, Eric Durant, "UNDERSTANDING ABET OBJECTIVES AND OUTCOMES", *Proceedings of the 2007 ASEE Annual Conference and Exposition*, ASEE, 2007.
3. Kathryn Abel, "FINDING APPROPRIATE DATA FOR ABET SELF-STUDY SECTIONS B2 AND B3 FOR ENGINEERING PROGRAMS", *Proceedings of the 2007 ASEE Annual Conference and Exposition*, ASEE, 2007.
4. "ABET Criteria for Accrediting Engineering Programs", Effective for Evaluations During the 2007-2008 Accreditation Cycle. WWW.ABET.org