

Updating the Objectives of a Manufacturing Engineering Technology Program

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Abstract:

A key aspect of outcomes based assessment processes like those used in the TAC of ABET accreditation process is setting the objectives and outcomes for the activity under review. Assessments of the Manufacturing Engineering Technology Program at Rochester Institute of Technology (RIT) indicated that the needs of industry employers had shifted based on changes in product design, product development and manufacturing strategies. Globalized production, joint technology development ventures, interdisciplinary team based product/process design and other issues have changed the traditional roles and needs of the Manufacturing Engineer. This paper highlights a process of establishing and evaluating the program outcomes and program educational objectives for Manufacturing Engineering Technology at RIT by focusing on the changing role of the practicing manufacturing engineer. Findings include identification of new constituents, impacts on the traditional industrial advisory board, and updates to outcomes, objectives and curriculum.

Introduction:

The Manufacturing and Mechanical Engineering Technology and Packaging Science Department (MMET/PS) at the Rochester Institute of Technology (RIT) offers Bachelor of Science degrees in Manufacturing Engineering Technology, Mechanical Engineering Technology, Electrical/Mechanical Engineering Technology and Packaging Science as well as Master of Science Degrees in Computer Aided Manufacturing and Packaging Science. The department currently has 809 students and there are 51 in the Undergraduate Manufacturing Program. Students can complete the Manufacturing Engineering Technology program on a part-time or full time basis. Five quarters of cooperative education or equivalent full time experience is required. Transfer students are accepted from a variety of academic programs including internal transfers from other RIT programs and external transfers from two-year programs in engineering technology and similar areas. Full-time students entering as freshmen normally require 12 academic and 5 co-operative education (co-op) quarters to complete the program. As a result, the Manufacturing program typically requires 4 years and 9 months to complete.

Terms and Terminology:

Within the Manufacturing and Mechanical Engineering Technology/Packaging Science Department and all of Engineering Technology Programs at RIT the term Program Educational Objective (PEO) is used to indicate things our graduates should be able to do 3-5 years after their graduation. The term Program Outcome (PO) is used to describe things a students should be able to do upon graduation. Finally, the term Intended Learning Outcome (ILO) is used at the course level to describe things the student should be able to do when they have successfully completed that specific course. Obviously our ILO's must be linked to and support our PO's. How these are connected is at the core of the construction of our curriculum. Also obvious is that our PO's must support the PEO's of the program. Much of the work of the development of our latest continuous improvement system was in the creation, definition and linkage of these various items. The focus of this paper is on the evaluation and update of these items after they have been in place long enough for us to realize what we should have done in the first place. As is true in many projects you only discover how you should have approached the work when you are 90% complete and take a moment to step back and evaluate the results.

Developing the Original Program Educational Objectives:

The original educational objectives for the program were developed based on the long standing goals of the department and program and additional input from constituent groups. These initial Program Educational Objectives (PEO's) are shown below.

Graduates from the Manufacturing Engineering Technology Program will demonstrate:

- A professional work ethic, a commitment to lifelong learning, quality and continuous improvement through the clear ability to assume increasing levels of technical and/or management responsibility.
- Leadership and participation in teams that act as change agents and innovators in product design and manufacturing related organizations.
- The ability to drive the design of manufacturable products, design effective and efficient new production processes and improve the performance of existing operations.
- Effective communication with all levels of the organization.

Developing the Original Program Outcomes:

The original set of PO's for the manufacturing program were actually easier to create than the PEO's. The Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET) specifies a basic set of outcomes for all programs referred to as A through K. On top of that the Society of Manufacturing Engineers (SME) specifies the specific technical outcomes appropriate for manufacturing engineers. Add to that a few special topics specific to the requirements of our other constituents and you have our beginning set of outcomes shown below. A1 through A9 come from SME. A10 and A11 come from our constituents, B through K come from ABET and L through P are also based on specific constituent needs.

Graduates from the Manufacturing Engineering Technology Program will demonstrate:

- A The ability to apply the knowledge, techniques, skills and modern tools of manufacturing technology listed below to the solution of manufacturing problems.
 - A1 Materials
 - A2 Manufacturing Processes
 - A3 Quality
 - A4 Tooling
 - A5 Automation
 - A6 Production Operations
 - A7 Maintenance
 - A8 Industrial Organization and Management
 - A9 Statistics
 - A10 Financial Measures
 - A11 Systems Integration
- B The ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology.
- C The ability to formulate, conduct, analyze and interpret experiments and apply experimental results to improve processes.
- D The ability to apply creativity in the design of manufacturing systems, components and processes.
- E The ability to function effectively on teams.
- F The ability to identify, analyze and solve technical problems.
- G Effective communication.
- H Recognition of the need for, and the ability to engage in lifelong learning.
- I Knowledge of ethical and social responsibility expected of professionals working in the manufacturing engineering technology field.
- J Respect for diversity and a knowledge of contemporary professional, societal and global issues.
- K Commitment to quality, timeliness, and continuous improvement.
- L Competence in the use of the computer as a problem solving and communications tool.
- M The ability to apply project management techniques to the completion of lab assignments and projects.
- N Successful completion of a comprehensive design project that demonstrates the ability to improve the manufacturability of product designs and design effective new manufacturing/assembly processes and procedures.
- O Meaningful work experience in the manufacturing engineering technology field.
- P The ability to articulate the economic and organizational importance of manufacturing to companies, individuals and the community.

This initial set of program outcomes and objectives served the program well and was in place for our first accreditation under the new outcomes based criteria. The visit for this accreditation cycle happened in October of 2004 and the findings appear very positive. This detailed study and evaluation completed for this visit generated the findings and provided the impetus to update the objectives and outcomes of the program as they relate to specific new issues in manufacturing.

Program Objectives and Outcomes for a Large Multi-Program Department:

When developing and utilizing program outcomes and objectives in a large department like ours some consistency in the objectives must be present to make the instruction, measurement and evaluation procedures manageable. Therefore the PEO's for the Manufacturing, Electrical/Mechanical and Mechanical Engineering Technology Programs have only slight differences. For example only the middle two PEO's for Mechanical Engineering Technology differ from the Manufacturing program PEO's, and the difference is slight.

Graduates from the Mechanical Engineering Technology Program will demonstrate:

- A professional work ethic, a commitment to lifelong learning, quality and continuous improvement through the clear ability to assume increasing levels of technical and/or management responsibility.
- Participation and leadership while working on teams involved in the analysis, design, development, implementation, or oversight of mechanical and/or manufacturing systems and processes.
- An ability to design new and improved products, systems and processes that are appropriate for their use.
- Effective communication with all levels of the organization.

The Program Outcomes (PO's) for the Mechanical Engineering Technology Program (shown below) only differ in the specifics of technical mastery area described by A1-A10, slight differences in the way C, D and O are stated, a totally different statement in N, and no objective described by P.

Graduates from the Mechanical Engineering Technology Program will demonstrate:

- A The ability to apply technical expertise from the following areas to the analysis, design, development, implementation, or oversight of mechanical systems and processes:
- A1 Manufacturing processes
 - A2 Engineering materials
 - A3 Statics
 - A4 Strength of materials
 - A5 Dynamics
 - A6 Fluid mechanics
 - A7 Thermodynamics
 - A8 Computer aided engineering tools
 - A9 Mechanical design
 - A10 Electric, Hydraulic and Pneumatic Circuits
- B The ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology.
- C The ability to formulate, conduct, analyze and interpret experiments and apply experimental results to improve designs and processes.
- D The ability to apply creativity to the design of mechanical systems, components and processes.
- E The ability to function effectively on teams.
- F The ability to identify, analyze and solve technical problems.

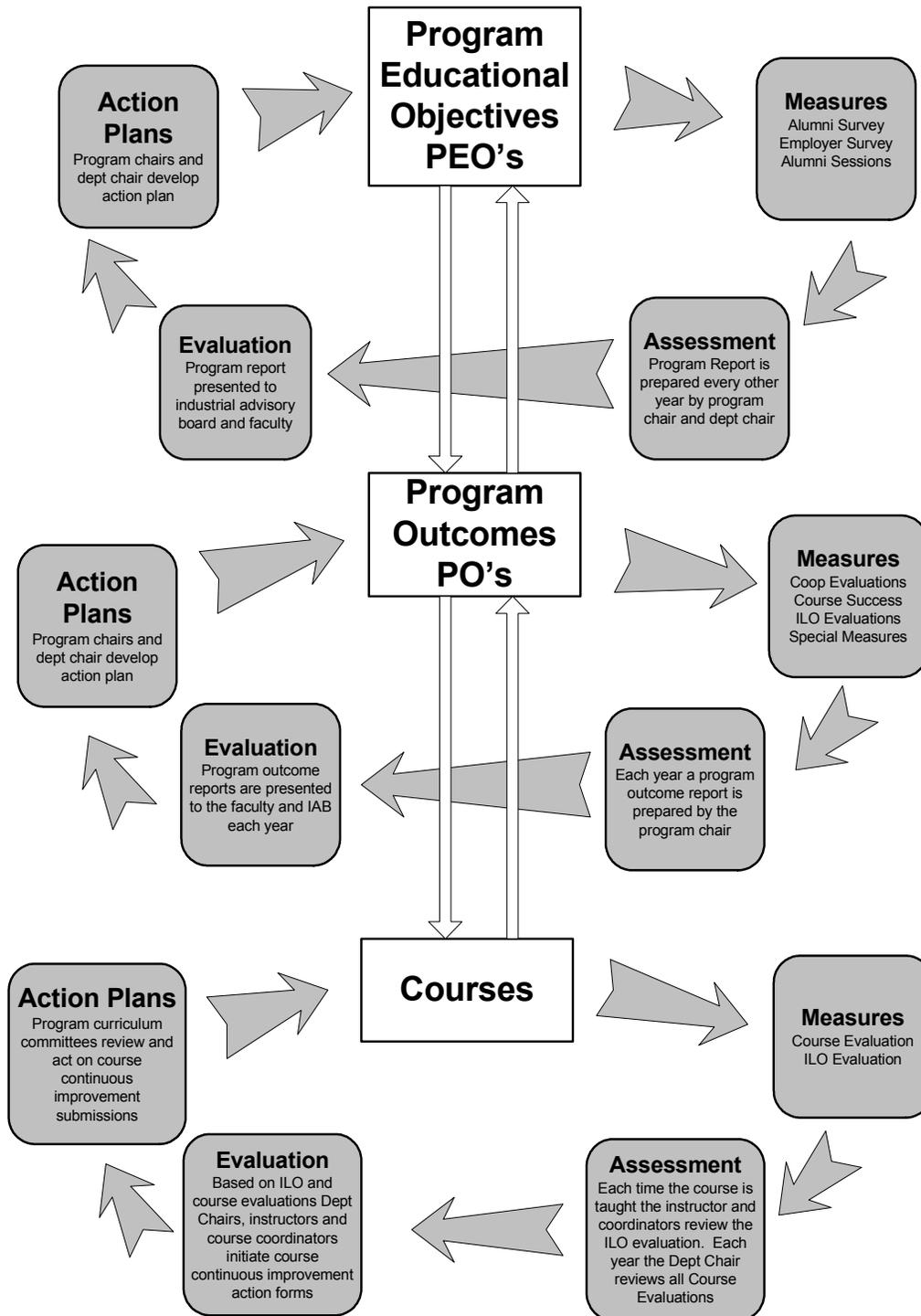
- G Effective communication
- H Recognition of the need for, and the ability to, engage in lifelong learning.
- I Knowledge of the ethical and social responsibilities of professionals working in the mechanical engineering technology field.
- J Respect for diversity and knowledge of contemporary professional, societal and global issues.
- K Commitment to quality, timeliness, and continuous improvement.
- L Competence in the use of the computer as a problem solving and communications tool.
- M The ability to apply project management techniques to the completion of laboratory and project assignments.
- N Knowledge of and the ability to apply codes and regulations, and produce proper documentation to comply with them.
- O Meaningful work experience in the mechanical engineering technology field.

While this paper focuses only on evaluating and updating the objectives and outcomes for the manufacturing program, we cannot ignore the organizational requirement to maintain the close coupling achieved in the original design. The department will need to address updating this linkage as a separate issue; however many of the external forces considered in this evaluation are the same for students graduating from the mechanical and electrical/mechanical programs so the findings should be adaptable to updating the requirements of these programs in a similar fashion.

The Opportunity for Improvement, AKA the Problem:

When developing what would be our first set of official PO's and PEO's the focus was on getting the right things included based on the need of our various constituents. Of the constituents the ones with the primary impact on this list of needs were; RIT, ABET, SME and the companies that typically hire our graduates. RIT of course has a set of minimum requirements for a bachelor's degree, some of which are specified by the State of New York. ABET presents us with A-K, SME with the specifics of the technical specialty and industry input restates much of what ABET and SME prescribe and add additional specifics primarily in the technical and soft skills area. Describing all of these requirements in our PO's and PEO's gave us a great starting set of objectives and outcomes. However, the first cycles of our continuous improvement system indicated some opportunities for improvement of this list. A diagram of our departmental continuous improvement system is shown in Figure 1. The first area of improvement is simply the opportunity to rearrange, combine and separate some of the outcomes and objectives purely to simplify measurement and assessment. The second area of opportunity (and the area discussed in this paper) came from the realization that many companies have changed the way that they design, develop and produce products. These changes should be reflected in the needs which we collected and identified as a part of our original process. However, what we collected were skills and behaviors that industry has already identified as necessary based on their current experience with these processes. We had not yet looked specifically at these new technologies and procedures and considered skills and behaviors that could allow industry to better utilize these technologies and techniques. This issue was of particular concern to us in Manufacturing because of the notion that many companies 'don't do manufacturing anymore'. This while a frequently stated opinion is in fact misleading because any company with a tangible product still has to make it, and is still ultimately responsible for its

design and quality regardless of where or how it is manufactured. This shift does not eliminate the need for manufacturing professionals, but it does change their role in the organization.



MMET Continuous Improvement – Overall Process

Figure 1 – MMET/PS Department Continuous Improvement Process Flow

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The Specific Issue for Manufacturing Engineering Technology:

The problem/opportunity described above could present itself within any sort of technical academic program. However there is a unique challenge for manufacturing programs because the area of production and manufacturing has changed so dramatically in recent times in that operations have been shifted, redefined, subcontracted and outsourced to an expanding global supply base. This shift has been so dramatic that in fact many have questioned the need for programs of study in manufacturing engineering. This opinion fails to consider that even if production itself as been distributed to a global network the work of manufacturing engineers often remains with the company that is ultimately responsible for the product. If the manufacturing engineering activities are also subcontracted it is completed as a service provided to the ultimate customer and is still done by graduates of our program. This situation highlights the critical importance for programs in manufacturing not to just react to the needs of current employers but to consider the new roles, challenges and opportunities that technical and business changes will create for graduating manufacturing engineers.

Selecting the Factors Considered:

In undertaking this assessment we did not try to predict future trends or investigate emerging technologies. Although using technology forecasting and similar techniques to predict the issues we will soon be facing would certainly be possible and valid, we decided to first focus on current but still new issues facing the world of design, development and production. First we considered the shift to global supplier networks and global production, most often described by companies outsourcing all or part of production to countries such as China and Mexico as a cost saving measure. Second we considered the use of concurrent engineering techniques in product development. This is most often described by cross functional product development teams that include representation from functional areas from across the enterprise, including manufacturing engineering. Also considered within this subject was the issue of involving suppliers and joint venture partners in the product design and development process. These two general topics were seen as the most pressing by the industrial advisory board, and each has an underlying subset of subject matter that required our consideration.

Converting General Subjects to Objectives and Outcomes:

In order to find outcomes and objectives related to the general areas of globally distributed production and team based product development, lists of issues and subjects were generated based on researching these areas. General lists were also developed by members of the industrial advisory board. Subjects related specifically to the work of manufacturing professionals, and seen as underrepresented in our current objectives were of specific interest. In each case we tried to break down general subjects into it underlying components and then narrow down into specific skills. In most cases the subject was then broken down into several specific skills that could be defined as outcomes for the program.

Underlying Issues and Subjects for Concurrent Engineering:

The area of concurrent engineering and team based product design received a lot of consideration in the development of our initial program outcomes. Two primary areas however did not appear to have been given significant consideration. First was product design and development efforts that evaluate life cycle costs. While design for manufacturing is specifically covered, we felt that objectives should be included that specifically identify the area of evaluating product concepts not just on their initial production cost, but also on the overall cost and impacts of the design during the useful life and disposition of the product. Second, was the issue of cross-corporation product design and development. As companies draw their supplier network into the product design process our student's traditional role of evaluating designs for manufacturability expands. This can now include evaluating the capability of an outside supplier to produce the design, pursuing cost saving ideas and projects in conjunction with the supplier, and using target costing and other techniques to negotiate price reductions. Students may also take on the role of the technical expert for a supplier, so the skills then shift to helping customer companies tweak designs to take best advantage of manufacturing processes. In many cases this area involves using the same set of skills a manufacturing professional already has only in a different way.

Underlying Issues and Subjects for Globalized Production:

The primary areas that needed attention when the subject of global supplier networks was considered were the issues of logistics and system level process design. Traditionally, manufacturing engineering activities have been locally focused on the processes immediately at hand. Within a global network of suppliers the problems and cost reduction opportunities may lie in other companies, in other countries and in potentially unfamiliar processes such as customs inspections, ocean going cargo shipment and supplier certifications. Certainly undergraduate students in manufacturing can't be experts across these wide ranging fields, however expanding the scope of typical process design, evaluation and improvement activities seems appropriate. In most cases awareness level knowledge and a few specific tools are required so that our students are prepared to participate as problem solving team members in projects that have global production considerations.

The Base Set of Skills:

Based on the evaluation of the subjects discussed above a base set of missing skills was developed. This set cuts across several of the subjects discussed above and is focused specifically on areas that needed enhancement in our PEO's, PO's or ILO's. The skills are listed below and each is discussed in the following sections.

New Skills:

- Assessing Capabilities
- Evaluating System Designs
- System Level Process Improvement
- Capitalizing on Innovation
- Consulting and Negotiation

Assessing Capabilities:

This issue is greater than just the ability to perform quality system assessments. Often, manufacturing professionals can be called upon to assess not only the quality of a suppliers output, but the ability of the supplier in general to meet the needs of their enterprise. Obviously, this skill will be beyond the capability of most recent graduates, however the understanding of the need for this sort of endeavor and the ability to act as part of a team that performs assessment tasks was found to be a worthwhile objective for the program.

Evaluating System Designs:

Building the ability to improve the manufacturability of product designs has long been an objective of our program. However life cycle cost impacts must be considered as well as the cost impacts of complex logistics. This can expand opportunities to improve designs beyond individual parts and processes. Expanding the evaluation of the impacts of design decisions to include life cycle issues, logistics, supplier capabilities and overall production systems was found to be a worthwhile objective to be added to the program.

System Level Process Improvement:

With production activity underway at a global level a manufacturing professional needs to have the ability not to evaluate and improve just the activities that are immediately at hand. Often, the greatest opportunities to solve problems, reduce cost, and speed product flow lie in long, complex supply chains of interdependent suppliers, transportation systems and supporting procedures. The awareness that any product is simply a wasteful pile of work in process until all of its parts are in place and functioning is critical. While understanding the deep complexities of all of the logistics of large multinational corporations is probably too ambitious a goal for a recent manufacturing graduate, the top level understanding of the issues at work, and the ability to be part of a team that studies these issues is indicated as a valid objective for our program.

Capitalizing on Innovation:

The struggle to consistently create and capitalize on new, innovative and profitable products and services is clearly critical to the success of companies. Manufacturing professionals play a critical role in this process in the development and support of the processes and procedures that create these products. Manufacturing Engineers are frequently part of product development teams and often the intellectual property contained in the process design of a product is as valuable as the intellectual property represented by the product design alone. Companies that outsource production operations run the risk of creating their own competition by sharing product and process technology with suppliers. Additionally, many companies create products in joint venture formats where the knowledge, ideas and capabilities of several companies are shared to create new products and product categories. The impact on the needs of graduates falls then in two areas, first in fostering the ability to be innovative and support the realization of innovative ideas, and second in having a basic understanding of the legal issues involved in the creation, development and use of intellectual property.

Consulting and Negotiation:

Many talented Manufacturing professionals are quite comfortable in the roles of supervisor, manager, analyst and general internal problem solver. However, in a globally distributed production system the root cause of problems frequently falls outside the authority of these confident professionals. Helping a supplier or customer to solve their problems puts this person in the role of consultant or coach. The key difference being the lack of direct authority or responsibility for the people and equipment involved in the situation. The manufacturing engineer may also become the technical representative in a customer supplier relationship. While often supported by purchasing or sales people this role requires basic skills in building relationships, negotiation and generally the basics of sales and purchasing.

Blending the New into the Old:

Based on the above findings an updated set of Intended Learning Outcomes (ILO's) Program Outcomes (PO's) and Program Educational Objectives (PEO's) was developed. Table 1 below shows each item and highlights what was changed.

Table 1:

Item	New Statement	Change
Graduates from the Manufacturing Engineering Technology Program will demonstrate:		
PEO-A	A professional work ethic, a commitment to lifelong learning, quality and continuous improvement through the clear ability to assume increasing levels of technical and/or management responsibility.	No Change
PEO-B	Leadership and participation in teams that act as change agents and innovators in product design and manufacturing related organizations.	No Change
PEO-C	The ability to drive the design of manufacturable products, design effective and efficient new production systems and improve the performance of supply chains.	Expanded to indicate systems and supply chains
PEO-D	Effective communication	Eliminated within the organization focus
PO-A	The ability to apply the knowledge, techniques, skills and modern tools of manufacturing technology listed below to the solution of manufacturing problems. A1 Materials A2 Manufacturing Processes A3 Quality A4 Tooling A5 Automation A6 Production and Supply Chain Operations A7 Maintenance A8 Industrial Organization and Management A9 Statistics	Added supply chain to A6

	A10 Financial Measures A11 Systems Integration	
PO-B	The ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology.	No Change
PO-C	The ability to formulate, conduct, analyze and interpret experiments and apply experimental results to improve processes.	No Change
PO-D	The ability to apply creativity in the design of manufacturing systems, components, processes and supply chains	Added supply chains
PO-E	The ability to function effectively on teams.	No Change
PO-F	The ability to identify, analyze and solve technical problems.	No Change
PO-G	Effective communication.	No Change
PO-H	Recognition of the need for, and the ability to engage in lifelong learning.	No Change
PO-I	Knowledge of ethical and social responsibility expected of professionals working in the manufacturing engineering technology field.	No Change
PO-J	Respect for diversity and a knowledge of contemporary professional, societal and global issues.	No Change
PO-K	Commitment to quality, timeliness, and continuous improvement.	No Change
PO-L	Competence in the use of the computer as a problem solving and communications tool.	No Change
PO-M	The ability to apply project management techniques to the completion of lab assignments and projects.	No Change
PO-N	Successful completion of a comprehensive design project that demonstrates the ability to improve the manufacturability of product designs and design effective new manufacturing/assembly processes and procedures.	No Change
PO-O	Meaningful work experience in the manufacturing engineering technology field.	No Change
PO-P	The ability to articulate the economic and organizational importance of manufacturing to companies, individuals and the community.	No Change
At the end of the course students will be able to...		
ILO	Describe the process of assessing the production capability of a supplier.	New
ILO	Describe the process of assessing the quality system of a supplier.	New
ILO	Describe a basic supplier development and certification program.	New
ILO	Make product design decisions using life cycle cost analysis.	New
ILO	Make product design decisions based on logistical cost analysis.	New
ILO	Create process maps that include transportation and logistical systems.	New

ILO	Apply the concepts of lean manufacturing and the theory of constraints to the improvement of production systems that include complex logistics.	New
ILO	Describe the innovation process and how companies can capitalize on innovation.	New
ILO	Describe the basic terms and issues involved with the protection of intellectual property.	New
ILO	Demonstrate basic skills in negotiation.	New
ILO	Describe key problems and techniques when working in a consulting or coaching role.	New
ILO	Describe basic issues and activities involved in technical sales.	New
ILO	Describe basic issues and activities involved in corporate purchasing.	New

Conclusion:

The basic outcome of this analysis is an updated set of outcomes and objectives for our program which consider issues that may have been underrepresented in our initial design. There are however other things we have discovered as a part of this process. First is that our industrial advisory board may need to be expanded to specifically include professionals with responsibilities in the areas of global sourcing/global production and product design and development. Our current committee has some of this experience but we may need to recruit specifically in this area and even consider representatives from companies that do not even do manufacturing. It is strange to consider but if our graduates can indeed meet the outcomes described here their skills would be in great demand at companies that outsource manufacturing and even product design. Along the same lines as the advisory board these findings indicate we need to expand the base of constituents we need to consider to include product design and logistics professionals. A second finding is that we need to be sure that our continuous improvement process continues to look for shifts in technology and business processes that can impact our students. If we sit back and wait for external constituents to tell us what is required it will typically be too late for us to react and change to meet the challenge. As engineers we are comfortable with reacting to changes in technology; however the issues we face are just as likely to be in the soft skill areas. Therefore we need a process that not only considers new technology but new skills, behaviors and business practices that will impact our students.

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