Conforming a New Manufacturing Engineering Curriculum to the SME Four Pillars

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Abstract

This paper will highlight the challenges in developing a manufacturing engineering curriculum that conforms to the SME four pillars based on the experiences of the Engineering and Design (ENGD) department at Western Washington University (WWU). These experiences are unique in a number of ways. Foremost, this program was created by transitioning an existing Manufacturing Engineering Technology (MET) program that included an option in CAD/CAM. As a result, the new program was designed to incorporate the strengths of this long established technology program. One of these is hands-on intensive lab experiences within courses that require students to utilize state-of-the-art CAD/CAM technology in support of fabrication activities. Examples of these include classes in Computer-Numerical Control and Mold Making. It was decided in consultation with local industry, that the preservation of these experiences within the new engineering curriculum was to remain a key part of the program’s and ENGD department’s mission. It was also viewed as a way of customizing the new engineering program to the needs of local and regional industry. This presented significant logistical challenges as the new programs also needed to be configured to satisfy ABET’s EAC criteria and program objectives, where design experiences are highly valued. The efforts and results of doing this will be described in this paper.

Other unique aspects of these experiences that will be discussed in this paper include the impact of integration with other programs in the ENGD department, in particular a new program in Plastics and Composites Engineering, the influence of the regional aerospace industry in shaping the curriculum particularly in the area of composites manufacturing, and the benefits and challenges of the liberal arts environment at WWU in broadening the experience of students. In addition to the ABET mandated one-year foundation in math and basic science, the new MFGE program has greater depth and breadth when compared to the MET program it has replaced. From the standpoint of the SME four pillars, most of the additional depth is in the areas of Materials and Manufacturing Processes and Product Tooling and Assembly Engineering, and there is a much stronger emphasis on composites manufacturing. Though these experiences are unique, they will be shown to add support to the recommendation made by Curriculum 2015 that the SME four pillars be followed in developing manufacturing engineering curricula.
Introduction

The decline of manufacturing in the United States towards the end of the millennium was of historic proportions, with an estimated trade deficit of around $7 trillion dollars between 2000 and 2010. Evidence suggests that a turnaround is underway as manufacturing growth has stood out as one of the bright spots in the current economic recovery. The question of why manufacturing is important to an economy cannot be overstated. Foremost amongst these is that manufacturing creates jobs. Estimates vary, but each manufacturing job supports almost three other jobs in other sectors of the economy. It should be noted that the US lags behind other industrial powers in the percentage of its work force dedicated to manufacturing. Achieving levels similar to Japan and Germany for example translates to between 7 and 8 million new jobs.

At the top of this job creation pyramid are engineers that develop the goods, equipment, tooling and facilities that are produced. The downturn at the end of the 20th century precipitated a loss of highly skilled engineering expertise across a broad swath of American manufacturing industries including the machine tool and auto industries. Many of those that remained are reaching the age of retirement and will take valuable expertise with them when they leave their companies. For this reason the education of new engineers remains a critical need for many states across the US. As important as this need is, budgetary constraints occurring simultaneously with the economic downturn, have resulted in challenges to four-year schools graduating engineers in sufficient numbers. In particular manufacturing engineers, whose expertise is best matched to the production of goods, only graduate from fewer than 20 programs here in the United States.

Part of the need for manufacturing engineers is undoubtedly being filled by graduates from Mechanical Engineering programs. There are efforts under way to infuse these curriculums with more manufacturing content. However, this is a difficult strategy to follow. The advances in manufacturing technology particularly those driven by new materials and processes, computerization, the Internet, wireless and portable computing, and globalization are transforming in ever more fast-paced ways, how goods are manufactured. Keeping up with these changes requires not only a dedicated manufacturing curriculum, but ones that are customizable to local and regional manufacturing influences.

To address this need in Washington State, a new manufacturing engineering program has been created at Western Washington University. This new program resulted from transitioning an existing program in Manufacturing Engineering Technology along with its option in CAD/CAM. This new program accepted its first class of students in 2014 and plans to graduate 24 engineers per year starting in 2017. As part of the development of the curriculum for this new program, faculty in the department focused heavily on the recommendations from the Curriculum 2015 initiative conducted by the Society of Manufacturing Engineers (SME). Its primary goal was to examine the state of manufacturing education in the US and to develop a plan for revising and improving it. Included in the sixteen recommendations were two that encouraged the further development of SME’s Four Pillars of Manufacturing, and its use for curriculum design. The Four Pillars identify the areas of 1) Materials and Manufacturing Processes, 2) Product Tooling and Assembly Engineering, 3) Manufacturing Systems and Operations, and 4) Manufacturing Competitiveness as critical to the knowledge base of a practicing manufacturing engineer. It is
unclear at this time to what extent manufacturing engineering and technology programs have embraced this template for curriculum development, though there is evidence that some have.\textsuperscript{6-7}

**Creating manufacturing engineers from Mechanical Engineering programs**

One strategy for creating manufacturing engineers is to do so through specialization within a Mechanical Engineering degree. However, significant challenges exist in doing this. The needs of an ABET accredited Mechanical Engineering degree leave little room for the type of in-depth treatment of manufacturing engineering relevant subjects. As indicated in the SME Manufacturing Education Plan (MEP) this includes competencies in areas such as Materials, Manufacturing Processes, Product and Process Design, Manufacturing Process Control, Quality, Manufacturing Systems and Supply Chain Management. Mechanical Engineering programs typically include a course on manufacturing processes. In addition students through electives may be able to specialize in manufacturing during related areas such as CAD/CAM, CNC, robotics, automation and manufacturing systems engineering.

Another strategy as described by Waldrop et al.\textsuperscript{2} is to sprinkle manufacturing related topics and methods throughout traditional mechanical engineering classes. One example used by these authors is the integration of Design for Manufacture and Assembly (DFMA) principles in an engineering design class. While both these approaches have merit, it is unlikely that either will close the skill gap given the range of topics and the depth needed to produce a manufacturing engineering graduate with the competencies identified by SME. Waldrop et al. also point towards certification as a means for graduates to develop resumes that are commensurate with its employer’s expectations. Examples of this include the Society of Manufacturing Engineers certified manufacturing technologist and engineer examinations. He also however admits that larger companies typically offer academic courses to cover educational gaps in their new employees.

One of the deficiencies of all these approaches is that they neglect to give a student a true capstone experience in manufacturing that empowers them to utilize the design process as it pertains to products processes and systems, and pursuing it within the context of a manufacturing related problem.

**Benefits and challenges of creating dedicated Manufacturing Engineering programs**

A program dedicated specifically to creating a manufacturing engineer can avoid the problems identified above. The curriculum can be designed to ensure adequate treatment of the desired competencies for this type of engineering, and can ensure that the design experiences are rich enough in the appropriate areas. However, there are several challenges that programs face that must be overcome if they wish to become more established. One of these challenges is a perception that manufacturing does not carry the same significance as other engineering degrees such as mechanical and electrical. The perception of students and their parents that manufacturing is about using one’s hands to build or make things as opposed to other engineering degrees which are more analytically driven needs to be addressed. This is largely about addressing the image of manufacturing and making it clear that while at the end of the day...
something does get made, there are exciting and elegant methodologies and technologies that must be applied by these engineers to get to a final result.

Another challenge facing the creation of Manufacturing Engineering programs is the lack of a framework for developing robust curriculum. SMEs 4-Pillars provides an answer to this. Manufacturing by definition is a very broad discipline that includes products on a scale that ranges from creating nano-sized products all the way up to commercial airliners. Technology and methods applied at these different scales can be significantly different. For this reason, for manufacturing to be relevant, education of engineers needs to be customized to a given need that should be driven by regional manufacturing preferences. A generic manufacturing engineer is harder to educate and to fit into the workforce generic mechanical engineer. These regional preferences are best identified through the inclusion of a vibrant Industrial Advisory Committee that collaborates with the faculty and helps to guide their decisions on curriculum.

Finally, a third major challenge to creating a Manufacturing Engineering program is establishing working laboratory and fabrication spaces and facilities to support the curriculum. Since by definition manufacturing requires the fabrication of a product, tool or system, by definition there needs to be equipment and technical staff to support fabrication activities.

**Overview of the programs at Western Washington University and rationale for the transition to engineering**

The new Department of Engineering and Design created at WWU has three engineering programs in Manufacturing, Plastics and Composites, and Electrical Engineering. These programs were created from their technology equivalents as part of the decision package approved by the Washington State legislature in 2013. In addition to these, the department has a program in Industrial Design and another in Industrial Technology-Vehicle Design. The rationale for this transition was to create a new source of engineers for the state to take advantage of expanding opportunities in the aerospace industry. The curriculums of the technology programs were both highly “hands on” with sufficient rigor in mathematics, science and engineering sciences to place them closer to the engineering side of the spectrum. As a consequence, the creation of the engineering programs could be accomplished through additional classes in mathematics, expansion of use of this new material in existing classes, increase in design experiences in the curriculum, and the expansion of the capstone project experience. The need to add significant additional new content as new classes was limited to the areas of Design for Manufacture and Assembly and Machine Design. Table 1 summarizes the courses offered in the new program. More details on the challenges of creating a program by transition will be discussed in a later section of this paper.
The role of the SME Four Pillars of Manufacturing in developing the new curriculum

In creating the new curriculum, the SME 4-pillars were used in the following two ways. First, they were used to help assess the strengths of the proposed curriculum in each of the four areas for development. Second, they were used to better understand how to interpret and apply ABET’s EAC criteria for Manufacturing Engineering programs. To accomplish the former, each course in the curriculum was broken down according to its content based upon content relevant to each of the four areas. The result highlighted the relative strengths of the four pillars, and was informative in identifying within the program, pillars with the greater strength and others where weaknesses were apparent. Details of this analysis will be discussed in a later section. For accreditation, competencies in the four pillars were aligned to the new program’s version of the ABET specified program outcomes.

Review of existing Manufacturing Engineering programs’ stated outcomes

In addition to the standard ABET a-k outcomes, there are five proficiency criteria specified by ABET for manufacturing engineering programs. Table 2 lists the five proficiency criteria. Included is the alignment with the appropriate pillar from SME’s 4-pillar model.

This table shows that except for the last program criteria, the 4-Pillars are in one-to-one alignment. Our interpretation of criteria “e” is that a laboratory environment where students can get manufacturing relevant, hands-on experience across all four areas is an indispensable part of the educational experience.
Table 2. Alignment between ABET Manufacturing Engineering Proficiencies and the 4-Pillars

<table>
<thead>
<tr>
<th>ABET Proficiency Criteria</th>
<th>SME 4-Pillar Equivalent</th>
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<tbody>
<tr>
<td>1. materials and manufacturing processes: ability to <strong>design manufacturing processes</strong> that result in products that meet specific material and other requirements.</td>
<td>Materials and Manufacturing Processes</td>
</tr>
<tr>
<td>2. process, assembly and product engineering: ability to <strong>design products and the equipment, tooling, and environment</strong> necessary for their manufacture.</td>
<td>Product, Tooling and Assembly Engineering</td>
</tr>
<tr>
<td>3. manufacturing competitiveness: ability to <strong>create competitive advantage</strong> through manufacturing planning, strategy, quality, and control.</td>
<td>Manufacturing Competitiveness</td>
</tr>
<tr>
<td>4. manufacturing systems design: ability to <strong>analyze, synthesize, and control manufacturing operations using statistical methods</strong>.</td>
<td>Manufacturing Systems and Operations</td>
</tr>
<tr>
<td>5. manufacturing laboratory or facility experience: ability to <strong>measure manufacturing process variables</strong> and develop technical inferences about the process.</td>
<td>Intersects all 4-Pillars</td>
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</table>

Review of the online documentation available for the Manufacturing Engineering programs that are ABET accredited in the United States was conducted. It was discovered that there are a number of different strategies adopted in defining program outcomes that to lesser or greater extents emphasize manufacturing. These can be loosely grouped as follows:

- Unedited use of the ABET a-k outcomes – 3 programs
- Modified outcomes with generic wording, that is no mention of manufacturing – 3 programs
- Edited and/or expanded use of the ABET a-k outcomes to include phrases and terminology related to manufacturing – 6 programs
- Appended (added to a-k outcomes) manufacturing related program outcomes – 3 programs
- Others – 2 programs

This review shows that the favorite approach for defining outcomes for Manufacturing Engineering programs is to modify the generic ABET a-k outcomes to include wording that introduces manufacturing related terminology. This is the approach taken in defining the outcomes for the new Manufacturing Engineering program at WWU. Table 3 lists the MFGE program outcomes as well as the mapping to the manufacturing specific criteria listed in Table 2.

In addition to emphasizing manufacturing, the following changes have been made to the generic criteria in creating these:

- Outcome “b” is tailored to focus on the ability to measure process variables, and to interpret data and results from design of experiments to control manufacturing operations.
- The design activities for outcome “c” are explicitly defined as pertaining to products, processes, equipment, tooling, and manufacturing systems. This facilitates better alignment with the ABET proficiency criteria for manufacturing engineering programs, and the SME 4-pillars.
- Outcome “l” has been added to better harmonize the outcomes with the ABET proficiency criteria for manufacturing engineering.
### Table 3. WWU MFGE Program Outcomes and Criteria Mapping

<table>
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<tr>
<th>Program Outcome</th>
<th>Criteria</th>
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<tr>
<td>a an ability to apply knowledge of mathematics, science, and engineering to solving problems in <strong>manufacturing</strong> engineering.</td>
<td></td>
</tr>
<tr>
<td>b an ability to measure process variables, to design and conduct experiments, to analyze and interpret data, and to control <strong>manufacturing</strong> operations using appropriate methods.</td>
<td>4, 5</td>
</tr>
<tr>
<td>c an ability to design products, and to design or select the processes, equipment, tooling, and systems necessary for their <strong>manufacture</strong> to desired specifications.</td>
<td>1, 2, 4</td>
</tr>
<tr>
<td>d an ability to function on multidisciplinary teams.</td>
<td></td>
</tr>
<tr>
<td>e an ability to identify, formulate, and solve engineering problems.</td>
<td></td>
</tr>
<tr>
<td>f an understanding of the professional and ethical responsibilities of an engineer.</td>
<td></td>
</tr>
<tr>
<td>g an ability to communicate effectively.</td>
<td></td>
</tr>
<tr>
<td>h the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.</td>
<td></td>
</tr>
<tr>
<td>i a recognition of the need for, and an ability to engage in life-long learning.</td>
<td></td>
</tr>
<tr>
<td>j a knowledge of contemporary issues.</td>
<td></td>
</tr>
<tr>
<td>k an ability to use and practical experience with the techniques, skills, and modern engineering technologies necessary for <strong>manufacturing</strong> engineering practice.</td>
<td>1, 2, 3, 4, 5</td>
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<tr>
<td>l an ability to create competitive advantage through manufacturing planning, strategy, quality, and control.</td>
<td>3</td>
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It was felt that while the remaining outcomes (a, d-j) would all be addressed within a manufacturing context, meeting these develops the “engineer” more than the “manufacturing engineer”. There was no advantage in clarity to be gained by tailoring these to be more specific to manufacturing. Together, Tables 2 and 3 provide a link between outcomes and the SME 4-Pillars.

### Content of the WWU MFGE program using the SME 4-Pillars

![Figure 1. Distribution of MFGE Curriculum Content](image)

Figure 1. illustrates the breakdown of content in the WWU MFGE program according to the SME 4-Pillars. The pie chart on the left includes the foundational Math and Sciences, and General University Requirement (GUR) content. The foundational component is designed to support ABET’s 1-year rule. GUR classes help to broaden a student’s background typically in non-technical areas such as in the social sciences and humanities. As will be discussed in a later section, potential exists to utilize GURs in meeting a couple of the program’s student outcomes, in particular outcome h.
The pie chart on the right shows the relative distribution of the core content of the program between the SME 4-Pillars. Integration and Specialization include the capstone Senior Project experience and technical electives. As each student’s experience will vary in these areas depending on the project and electives taken, the contribution of this 20% of the core to any of the 4-Pillars is unknown. It is fair to say that some portion of this piece supports each pillar. The pie chart clearly shows that there is a strong emphasis in the WWU MFGP program in the areas of Materials and Manufacturing Processes (36%) and in Product Tooling and Assembly Engineering (24%). The reasons for this are as follows:

- A high level of interaction with the Plastics and Composites Engineering program. MFGP students take two junior level courses accounting for 10 credits from this program, one in plastics materials and processes and the other in composites. This exposure is driven by the regional needs of the aerospace industry where manufacturing engineers are increasingly involved in activities associated with composites product design and fabrication. 75% of these credits are in the Materials and Manufacturing Processes pillar. The remainder is in Tooling.

- The influence of CAD/CAM and CNC. The old technology programs included an option in CAD/CAM. So historically graduates of the programs in plastics and manufacturing technology have benefited from significant exposure to the use of CAD/CAM systems in the design and fabrication of products and tooling. This has helped to support a high level of sophistication in lab and project activities that rely on a hands-on approach. So as to not lose this characteristic in the new MFGP program, a significant amount of CAD/CAM content has been deliberately maintained in the curriculum. Classes with this type of content include (see Table 1) ENGR 104, MFGP 261, 332, 333, 381, 362, 434, 463, 465 and PCE 372. The consequence of this is a greater emphasis in the Product Tooling and Assembly Engineering pillar (23%).

**Experiences creating a Manufacturing Engineering program by transition**

What factors need to be considered when making a decision to transition a Manufacturing Engineering Technology program to a Manufacturing Engineering program? The experience at WWU can be viewed as the natural consequence of the growth of the technology programs over a period of 10 to 15 years. An evolution in the curriculum occurred over this period that enhanced math/science and design content while still maintaining a focus on the application of technology. At the same time graduates from the program developed the reputation in local regional industries of being highly capable upon graduation and would find themselves in positions equivalent to those of engineers. This reputation in turn slowly altered the demographic of students entering the program. The proportion of students with stronger academic credentials entering the major increased. This became a self-reinforcing cycle which pushed the program towards the engineering side of the ET curriculum spectrum. The following summarize some of the favorable factors that assisted the transition:

- **Strength of the curriculum:** It’s important to have a strong math and science base to the technology program, with a good proportion of high performing students in these
fundamentals. This makes the inclusion of additional courses to meet the ABET 1 year rule for an engineering program feasible. Across the ET majors, many students were already taking these additional classes as technical electives or in pursuit of minors to broaden their employment prospects, or suitability for graduate studies. So the addition of multivariable calculus, linear algebra and differential equations was not a shock to the system. In addition, students were familiar with the engineering design process (introduced in their freshman year) and applying it throughout the curriculum in the design of products, processes and tools.

- **Quality of students:** Though the transition to engineering had been in the works for several years, its approval and implementation coincided with the economic downturn following 2007. A consequence of this was a shift at WWU within applications to majors towards the sciences and technology, away from the arts and the humanities. This trend can be clearly seen from Figure 2. The plot for the College of Sciences and Engineering (CSE) shows a change in majors of almost 700 students over the seven year period starting in 2007. The perception amongst students and their parents was that a degree in sciences or engineering was a more certain route to a secure high paying job. This shift ended up overwhelming the resources of most of the science departments including the Engineering Technology department. As a consequence pre-major systems were implemented across the college of science and engineering that limit enrollment in majors to match available capacity. For the Manufacturing Engineering Technology (and now the Manufacturing Engineering) major this meant a 3 to 1 ratio between applicants and available spots. While most reputable engineering programs experience this type of excessive demand, this was new for the WWU programs. Its immediate effect was to filter out lower performing students who in the past would have had unrestricted access to the major.

![Change in Declared Majors since 2007](image)

**Figure 2.** Declaration of majors at across colleges at WWU
**Demand for Engineering Graduates:** Washington state’s aerospace industry continues to experience strong growth. Orders to Boeing for commercial aircraft remain at historical highs. Yet, even with additional investment by the state to its flagship institutes (University of Washington and Washington State University) to graduate more engineers, the aerospace industry faces an increasing deficit in the engineering workforce. In addition to growth, this negative trend is also driven by engineering retirements amongst baby boomers. The transition to the new engineering programs at WWU has benefited from this state of affairs. In addition, the focus on manufacturing and plastics and composites engineering, make these programs unique in the state and almost so in the Pacific Northwest (a MFGE program exists at Oregon State University).

**Faculty and Staff Support:** A shift from technology to engineering must be supported by the entire faculty. Prior to the most recent faculty hires funded by the transition, the makeup of the faculty flipped from being predominantly professionally and MSc qualified to one that was equally split with those having a PhD. The decision to proceed with the transition was a consensus decision that was supported by the entire faculty. At the center of this was agreement on the part of the all that the core values and mission of the department needed to continue to emphasize a hands-on and applied approach to education. This required a continued commitment to teaching that included an emphasis on laboratory experiences, and a willingness to engage undergraduates in scholarship activities. Recent hires (8 in total) have shifted the faculty mix to one that is now predominantly Ph.D. qualified. However, most have some industrial experience, and all have backgrounds that will help in promoting these core values and mission of the department.

The old technology programs were effective in their hands-on approach in large part because of a collegial and collaborative environment that existed between faculty and the department’s highly trained technical staff. This was to be maintained in the new programs. The concerns of staff and their role in supporting the new programs was thus a major consideration. A heavy emphasis on laboratory experiences meant limits on class sizes to prevent overloading of the technical staff and to mitigate concerns regarding the safety of students working on industrial scale equipment. The staff’s input and oversight of departmental safety and operational procedures have given them a pivotal role in the development of laboratory experiences for the new programs.

**The University Environment:** Strong support of the university administration was critical to successful lobbying for the transition. At both the college and university levels creating engineering programs at WWU was viewed as one of the top legislative priorities for the 2013-15 biennial budget. It was broadly perceived within the university community that this move would support an important educational need of the state, and that it would more clearly establish these engineering programs as worthy of state support. The old engineering technology programs, despite their strong reputation amongst local companies for creating industry-ready graduates, were often overlooked in state university funding initiatives for engineering. It is a testament to the vision of WWU’s leadership that at a time of reduced state contributions to higher education, it was able to win support from the state for the creation of these engineering programs.
Industry Participation: One hallmark of the old technology programs at Western was the strong involvement of industry in supporting student development and in advising on curriculum development. All programs had assembled, and strongly relied upon Industrial Advisory Committees for this input. In each case, the plan to transition to engineering was strongly supported by the respective IAC, with the proviso that the core values of the department that emphasizes graduates with industry-ready abilities not be lost as new content is added. The IACs were also engaged in a letter writing campaign to the state legislature to provide clarity on the impact of the proposed transition on job creation and to underscore support for this decision package. The new engineering programs continue to utilize a continuous improvement mechanism that includes feedback from the IAC on matters related to the curriculum. This is to ensure that industry acts as a check on changes that might impact industry-readiness, and to assist in tailoring the curriculum to the needs of the local industry which is strongly aerospace influenced.

Lab Spaces with Industry Scale Equipment: The requirements of the engineering technology programs through the evolution of the department meant an emphasis on teaching labs and equipment over research oriented facilities. The focus has always been on the use of industry scale equipment to give students a near equivalent experience that cannot be fully simulated using educational trainers. Faculty conduct research using the same equipment and resources that are used for teaching. This has proven to be fruitful in attracting industry sponsorship for projects. The use of industry scale equipment makes the results of this research more relevant to the goals of the sponsor. Thus, the need for new equipment to support the transition was minimal.

Despite these favorable factors and the success thus far of the transition, there is a period of time ahead where challenges and risks remain. The most important of these include:

Successful completion of the ABET accreditation process. This is scheduled to be completed by the summer of 2017 and will be retroactive to cover graduates from the first class. While confidence is high that this will happen as planned, the uncertainty is difficult for faculty and students. The faculty have had to deal with the “bird in the hand” syndrome of swapping the certainty of accredited technology programs for this uncertain future. There have been instances of students transferring to other schools because of their need of a guarantee of an accredited degree.

Maintaining and building diversity. While a higher quality student is desirable to meet the rigors of an engineering program, the filtering described early due to increased demand for science and engineering degrees has the potential to also filter out women and minorities. This has been a long standing challenge for high demand engineering programs. Though WWU provides a more affordable degree than the other state funded universities, this advantage may not translate into a meaningful opportunity in a highly competitive environment. With demographic shifts in the state towards the growing Hispanic population, special attention will need to be made to recruiting and retaining qualified students from this group.
• **Shifting faculty priorities.** One of the biggest risks to the core teaching mission of the department is a shift in faculty priorities towards more research. This is desirable to some extent as vibrant scholarship and teaching go hand-in-hand. It is also expected and encouraged as an engineering faculty, particularly the one assembled at WWU has the credentials to do this. Finding a proper mix that does not undercut the primary teaching mission of the department, requires a discernment process that the faculty will need to be committed to for the foreseeable future.

• **Changing industry perceptions, priorities and fortune.** The ability of the MFGE program to continue producing industry ready graduates will not be immediately known. Feedback from industry in time will show how well this part of the department’s mission has been maintained. The likely scenario is that there will be some change in perception of this ability, but that this will be balanced by enhancements in a graduate’s analytical and problem solving skills. On the whole it will be viewed as a positive evolution in the program. Perception is also likely to change as a result of a broader interest in hiring of engineering graduates. This is not only with new companies, but also with new groups or divisions in a company that already hire these graduates. Though unlikely in the short term, the “boom and bust” nature of the aerospace industry could lead to reduced demand for engineers. The current strength of the industry makes it likely that the MFGE program will be well established before the next downturn.

• **Aging facilities and space constraints.** The use of industrial scale equipment has the downside of expense of maintenance and replacement. The department estimates that the cost to replace equipment to be around $3M over the next 10 years. While a portion, roughly one third will come from student lab fees, significant fund raising is necessary to find the remainder. In addition, space constraints make expansion of the curriculum to incorporate new technologies impossible. This also limits future increases in class size to at most 50% with additional faculty lines.

**Regional aerospace influence on curriculum**

As mentioned previously, all of the programs utilize IACs to ensure that changes to the curriculum hone graduates who are well adapted to the regional manufacturing preferences. The old MET program and now the new MFGE program hold meetings with the IAC twice per year, in the Fall and Spring term prior to the summer recess. This is a step in the program’s continuous improvement process. Membership of the IAC is strongly, though not exclusively companies that support the aerospace industry.

Undoubtedly, one of the key influences of the regional industry has been the promotion of a strong program in Plastics Engineering Technology, now transitioned to Plastics and Composites Engineering. Within the past five years, this has become even more important with the expansion of composites as a material in the manufacture of commercial aircraft. The new PCE program is well positioned to support the need for engineers in this area. However, this also impacts greatly the MFGE program as the curricula of the two are closely intertwined.
PCE and MFGE majors take 38 credits in common or which 30 are upper division (see Table 1, MFGE 261, 231, 332, 362 341, 342, PCE 371, 372 and MFGE/PCE 491). In addition, industry sponsored, team-based senior projects (MFGE/PCE 491, 492, 493) on plastics and composites can mix majors based on the needs of the project. Of these 38 credits, 10 (PCE 371, 372) are related to polymers, half of which are composites focused. In addition, with the encouragement of the IAC, curricular content on composites product design has been introduced into the MFGE 362 course. The CATIA Composites Design workbench provides majors with an experience using a CAD tool to design the structure of a composite part and to perform analysis using FEA. With this background, MFGE majors are also able to take elective classes in advanced polymer processing, tooling, and composites. Thus, it is possible for a manufacturing engineering graduate to emerge from the program with a broad background in manufacturing (spread over the 4-pillars) but with a strong emphasis in composites engineering. Though not as versed on the materials aspects of composites as their PCE peers, these graduates are well suited to support manufacturing with a composites focus.

**The role of GURs in creating a well-rounded MFGE**

As a liberal arts university, WWU prides itself in providing students with a well-rounded education. This mission aligns well with a consistent theme heard from the various IACs of the departmental programs. They stress time and time again the importance of the non-technical abilities of graduates to their long term employment success and upward mobility. This of course is the motivation behind criterion “h” in ABET EAC’s program outcomes set. Students in the MFGE program must complete at least 36 credits in General University Requirements (GURs) that span areas that include communication, the humanities, social sciences, and comparative gender and multi-cultural studies. These themes resonate with the demands on MFGEs who must increasingly demonstrate abilities to negotiate the challenges of a globalized workplace that has both gender and cultural diversity. This is particularly true of the aerospace industry where outsourcing has resulted in global demand for products, geo-dispersed manufacturing and supply chains. It is the goal of the faculty to leverage this GUR experience over time as a way to meet outcome “h”. This would involve prescribing a set of GUR courses for MFGEs to take (currently majors have broad discretion in their choice), and working with the respective instructors and departments to facilitate the integration of an engineering perspective into the assignments and projects that students must complete.

**Conclusion**

This paper has summarized the efforts at creating a new manufacturing engineering program at Western Washington University in conformance with SME 4-pillars of manufacturing. The use of SME’s framework was helpful in finalizing the program outcomes and in evaluating the composition of the content of the program across the four areas. It was found that in keeping with the strengths of the prior technology program, the new MFGE program had greater emphasis in the areas of Materials and Manufacturing Processes (36%) and Product Tooling and Assembly Engineering (24%). To assist other technology programs planning a transition, the experiences of the program that have favorable influenced the transition have been discussed, and some of the challenges and risks that remain to be addressed highlighted. Both the regional
aerospace influence and WWU’s strong liberal arts tradition have, and will continue to influence the program’s curriculum.

The real measures of the success of this approach to creating an MFGGE program will with the first program graduates in spring 2016. The first measures of success will be industrial sponsor satisfaction with students’ work on their senior projects and the program outcomes assessment of those first graduates. Even more telling measures will be those graduates’ ability to get jobs as manufacturing engineers and the initial ABET accreditation review in 2016-17. We are confident that these measures will show that the use of the SME 4-pillars as a guiding framework for MFGGE program development is a good approach that other programs could replicate.

References


