AC 2012-4832: ASME'S VISION 2030'S IMPORT FOR MECHANICAL ENGINEERING TECHNOLOGY

Dr. Scott Danielson P.E., Arizona State University, Polytechnic

Scott Danielson is the Associate Dean for Academic Programs in the College of Technology and Innovation at Arizona State University. Before assuming that role, he had been the Interim Chair of the Engineering Department and the Chair of the Engineering Technology Department. He has been active in ASEE in the Mechanics Division and the Engineering Technology Division. He has also been active in ASME, being awarded the 2009 Ben C. Sparks Medal for excellence in mechanical engineering technology education, serving as a member of the Vision 2030 Task Force, serving as chair of the Committee on Engineering Technology Accreditation, serving on the Board of Directors of the ASME Center for Education, and serving as a member of the Mechanical Engineering Technology Department Head Committee. He has been a Program Evaluator for both the Society of Manufacturing Engineers (SME) and ASME, and he currently serves on the Technology Accreditation Council (TAC) of ABET, representing ASME. He also serves on the SME's Manufacturing Education and Research Community steering committee. Before joining ASU, he had been at North Dakota State University, where he was a faculty member in the Industrial and Manufacturing Engineering Department. His research interests include machining, effective teaching, and engineering mechanics. Before coming to academia, he was a Design Engineer, Maintenance Supervisor, and Plant Engineer. He is a registered Professional Engineer.

Mr. Thomas Perry P.E., American Society of Mechanical Engineers
Dr. Allan T. Kirkpatrick P.E., Colorado State University

ASME's Vision 2030's Import for Mechanical Engineering Technology

Abstract

In recent years, various professional societies or individuals have put forth statements outlining how engineering and engineering education could improve or adapt to better meet the needs of society. Typically, such studies do not specifically address engineering technology's role as a part of the educational spectrum. While building on these previous works, the ASME Vision 2030 efforts provide additional insights to both the value of mechanical engineering technology but also to how it should change to provide an even better education for its students. This paper presents suggestions towards such change. While focused on mechanical engineering technology, the suggestions and data in the paper can be extrapolated to engineering technology education in all its disciplines. The strengths of engineering technology graduates as engineering practitioners and as implementers of technology; job-ready and focused on applied engineering, are a partial answer to what industry has told academia about the current needs of industry.

Introduction

In July 2008, the ASME Center for Education formed an engineering education task force, Vision 2030, led by representatives from industry and education, including engineering and engineering technology educators. The ASME Vision 2030 Task Force pursued two primary objectives: help define the knowledge and skills that mechanical engineering or mechanical engineering technology graduates should have to be globally competitive, and, to provide, and advocate for their adoption, recommendations for mechanical engineering education curricula, with the goal of providing graduates with improved expertise for successful professional practice. The Task Force investigated the current state of mechanical engineering education and practice within industry through assessment of recent literature addressing the shape and content of engineering and engineering technology education and through conducting surveys and workshops with stakeholders. As an example, Vision 2030 workshops were held at the ASME International Mechanical Engineering Education Conference in 2009, 2010, 2011 and 2012.

Examples of recommendations from literature about engineering education include the National Academy of Engineers' (NAE) *Educating the Engineer of 2020*,[1] which suggests an earlier and stronger introduction to engineering practice within undergraduate programs, with the students experiencing an iterative process of design, analysis, building, and testing. Another NAE project, *Changing the Conversation*[2], recommended re-branding of engineering to improve its appeal to different groups, especially minorities and young females. A general case for change in mechanical engineering education based on the Vision 2030 work is contained in Kirkpatrick et al.[3]

To help develop Vision 2030 recommendations for academia, it was important to understand the current needs of industry. This is especially important for engineering technology education, as preparing students for industrial practice is often a point of pride for such programs. Thus, the Vision 2030 Task Force did pilot surveys of industry and academics to begin to identify key knowledge areas, skills and abilities needed for mechanical engineering (ME) and mechanical engineering technology (MET) graduates to be successful in a global economy, including small and large companies. Focusing on these key skills, extensive follow-on surveys were developed and conducted in 2009 and 2010 of three key stakeholder groups in ME and MET (department heads, industry supervisors, and early career engineers) to assess the strengths and weaknesses of mechanical engineering education graduates. Responses were received from academic leaders at more than 80 institutions, from more than 1,400 engineering managers, and more than 600 early career engineers (those with less than ten years of practice). The details of these data and additional information about the Vision 2030's work are available in its Phase I report[4] and other related publications.[5]

Survey Results

Curricular change occurs slowly and mechanical engineering education programs have had essentially the same structure and content since the 1960s, when science-based engineering education replaced the shop, or practice-based education developed in the first half of the 20th Century, with engineering technology programs developing as a result of this change in engineering education. In one of the early Vision 2030 academic surveys, when department leaders were asked how many times in the past 10 years had there been major curricular revisions, 79% of ME department heads indicated none, one or two changes, and 46% of MET department heads indicated one to three changes. Most respondents indicated that the extent and substance of their most recent curricular modifications represented "tinkering on the edges" of their educational program. The motivations for ME and MET curricula change were characterized as the following.

- Adaptation to the 128 credit hour model for the four-year baccalaureate degree.
- Implementation of new, and modified courses, or adaptation to new teaching technologies.
- Curricular change in preparation for the ABET-accreditation review.
- Response to a change in the academic calendar.
- Responding to industry input to improve employability of graduates.

With regard to the perceived strengths of their Bachelor of Science in Mechanical Engineering Technology (BSMET) programs, MET program leaders indicated the following three items: design skills, strong basic (core) courses using engineering texts and good facilities/equipment for hands-on student experiences. Perceived weaknesses of their BSMET programs were cited as in three areas: specific curricular weaknesses, e.g., thermal/fluids engineering or project management, use of too many part-time faculty members and lack of resources, especially for laboratories and maintaining laboratories with modern equipment.

To meet anticipated future changes in engineering and engineering technology practice, MET department heads predicted a variety of impacts on their BSMET degree programs. The following capture the themes of these responses.

- Greater use of, and training in, simulation and computer-aided "X"
- Greater emphasis on professional skills, especially communication
- Some understanding of global financing
- Greater emphasis on energy conversion processes and technologies

Initial pilot survey data were used by the Vision 2030 Task Force to develop 14 broad categories of skills to further probe towards gaining an understanding of the preparation of mechanical engineering and mechanical engineering technology graduates. Analysis of the resulting survey data from industry, focusing on the strengths and weaknesses of baccalaureate ME and BSMET graduates, provides an outcomes-based assessment of undergraduate education. With these 14 categories of response, or attributes, which were derived from the survey data via a cluster analysis; a simple difference – strength minus weakness – in response rate for a given attribute provided a picture of educational outcomes and the difference between viewpoints of academia and industry. Tables 1 and 2 below show the attribute profiles for newly hired BSMEs and BSMETs, as of spring 2009. While there is some overlap in the distribution of strengths and weaknesses, the overall pattern of differences provides an indication of the outcomes of the two educational experiences that is not unexpected.

Table 1 indicates that attributes rated as strong for the BSME hires were electronic communication/information processing/computing. Technical fundamentals, interpersonal skills and teamwork were noted as reasonably strong attributes. Weak attributes were problem solving, critical thinking, oral/written communication, and knowledge of how devices are made and work.

Table 1. Strengths and weaknesses of BSME hires.
(Spring 2009 industry survey, n = 381)

Category	**%Strength**	**%Weakness**	□
Information processing – electronic communication	27	1	+26
Technical fundamentals – traditional ME disciplines	22	13	+9
Interpersonal/teamwork	19	10	+9
Computer modeling and analysis – software tools	17	2	+15
Communication – oral, written	3	14	-11
Practical experience - how devices are made and work	2	24	-22
Problem solving & critical thinking - analysis	2	9	-7
Design – product creation	1	5	-4
Business processes - entrepreneurship	1	6	-5
Project management -	1	3	-2
Overall systems perspective	1	1	0
Technical fundamentals – new ME applications (bio, nano, info, multi...)	0	0	0
Leadership	0	0	0
Experiments - laboratory procedures	0	0	0

Table 2 indicates that strong attributes of BSMET graduates were computer modeling and knowledge of how devices are made and work. Major weaknesses were technical fundamentals and oral/written communication. Moderate weaknesses were noted as interpersonal skills, teamwork and a systems perspective.

Table 2. Strengths and weaknesses of BSMET hires.
(Spring 2009 industry survey)

Category	**%Strength**	**%Weakness**	□
Information processing – electronic communication	**4**	**0**	**+4**
Technical fundamentals – traditional ME disciplines	**2**	**14**	**-12**
Interpersonal/teamwork	**6**	**11**	**-5**
Computer modeling and analysis – software tools	**14**	**4**	**+10**
Communication – oral, written	**0**	**14**	**-14**
Practical experience - how devices are made and work	**31**	**9**	**+22**
Problem solving & critical thinking - analysis	**0**	**4**	**-4**
Design – product creation	**4**	**0**	**+4**
Business processes - entrepreneurship	**0**	**2**	**-2**
Project management -	**0**	**0**	**0**
Overall systems perspective	**0**	**7**	**-7**
Technical fundamentals – new ME applications (bio, nano, info, multi...)	**0**	**0**	**0**
Leadership	**0**	**2**	**-2**
Experiments - laboratory procedures	**0**	**0**	**0**

Pathways to new educational structures and practices are not clearly revealed in Vision 2030 surveys, and ME and MET department heads readily identify several barriers facing them in program reform: budget cuts, hiring freezes, faculty expertise, salary freezes, either difficulty in, or pressure to obtain funded research and reduced job opportunities and opportunities for internships in industry.

The survey for mechanical engineering technology department heads concluded with a series of questions relating to internal and external factors that might be considered an environmental scan for MET. Responses indicate the following factors were viewed as important.

- Primary sources of faculty for BSMET programs is industry (64%), followed by graduate ME/MET programs (14%) and recruitment from other institutions (21%).
- The perceived need for BSMETs about the same as in the recent past (57% of respondents). About 21% of respondents see some change (growth or reduction).
- Three quarters of MET departments do not offer graduate programs.
- Of those programs offering graduate degrees, the predominant terminal degree is the MSMET, with most degree seekers not writing a thesis.

Summer 2010 ASEE Distinguished Lecture Workshop

A survey was distributed to those at a Vision 2030-focused Distinguished Lecture at the Annual Conference of the American Society for Engineering Education (ASEE) in June 2010. The audience numbered 137 people, representing some 60 institutions and a mix of engineering and engineering technology faculty. Since not all questions in the survey were answered by everyone, the number of responses to questions, shown in parentheses following the response, do not total to 137. One question was worded as follows.

> Engineering technology and engineering programs have co-existed since the 1970s, although recent trends have seen some engineering technology programs convert to

engineering programs. Is there a place for engineering technology in the engineering education spectrum? If so, what should it look like as an educational experience?

Responses to these questions were as follows.

(a) Engineering technology's applied focus could serve as the first two years of a four-year engineering degree (e.g., two year ET plus two year Engineering program). (25)
(b) In a CDIO style implementation, e.g., Conceive-Design-Implement-Operate, engineering technology's role would be to place emphasis on Implement-Operate content (25)
(c) Four-year engineering technology programs should be ABET-accredited under the same criteria as engineering programs but retain the applied engineering learning focus (31)
(d) There is no need to change engineering technology programs (7)
(e) Only two year engineering technology programs should remain as engineering technology programs but all four-year technology programs would convert to practice based engineering programs. (36)

Recommendations for Mechanical Engineering Technology Education

The role and scope of the engineering practice is transforming rapidly. What mechanical engineering technology graduates do, and how they do it, are changing due to global challenges, expansion of the disciplinary boundaries, and rapid technological innovation. Dominant engineering organizations in 2030 will be those successful at working collaboratively and fostering global partnerships. Successful mechanical engineers or technicians in these organizations will be individuals who, in addition to technical knowledge, have skills in communication, management, global team collaboration, creativity, and problem-solving. In addition to being skilled in working collaboratively and in virtual design teams, mechanical engineering practitioners need innovation skills that encompass practical understanding of how things are designed, produced and supported in a global marketplace.

Aspects of such a skill set are reinforced via Vision 2030 data, from industry supervisors and early career engineers (those with less than 10 years experience), with regard to the weaknesses of the current mechanical engineering graduates. It is important for mechanical engineering technology educators, and their colleagues in other engineering technology programs, to know these data and use them to shape and express the strengths of their programs.

These data below, in Figure 1 and 2, both reinforce mechanical engineering technology traditional strengths as well as point to areas that need to be strengthened. In addition to technical knowledge, the role of the mechanical engineering technology graduate in addressing "grand challenges" of sustainable engineering, energy, and human health requires educational change to achieve new areas of impact. To develop and implement creative solutions, mechanical engineering technology graduates must possess leadership and innovation skills, in addition to their technical fundamentals.

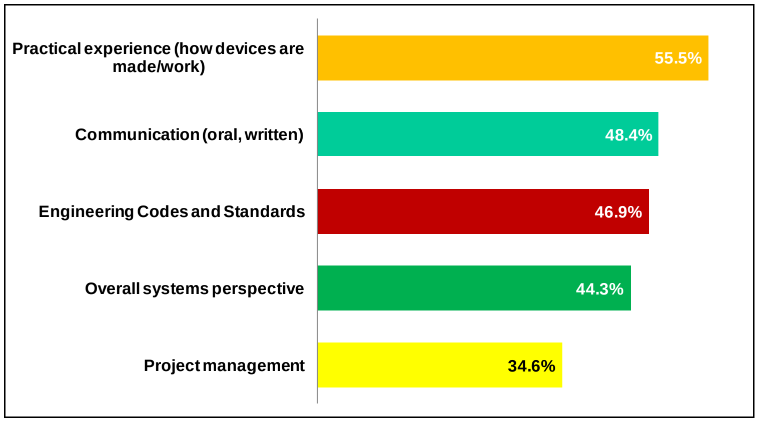

Figure 1. Industry Supervisor Perception of Weakness in Knowledge/expertise Areas of Recent Mechanical Engineering Graduates (n=1500)

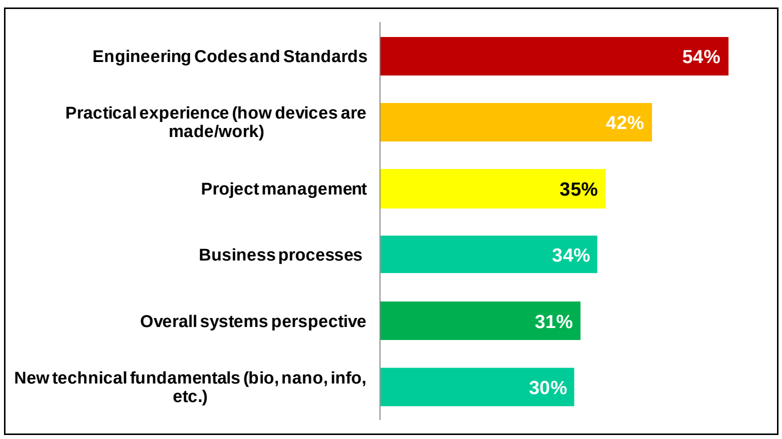

Figure 2. Early Career Engineers Perception of Weakness in Their Mechanical Engineering Academic Preparation (n=635)

The Vision 2030 Task Force recommends strengthening the following aspects of undergraduate mechanical engineering technology curricula, as appropriate for the level of program (e.g., two-year or four-year programs). Mechanical Engineering Technology programs should strive towards creating curricula that inspire innovation, creativity, entrepreneurship, increasing curricular flexibility, offering even more authentic practice-based engineering experiences, developing students' professional skills to a higher standard and, while a conclusion not directly a result of those data above, implementing effective strategies to attract a more diverse student body.

The chance to produce practical or technical innovations to solve real world problems and to help people is one of the most inspiring aspects of the profession to prospective or young engineers. Mechanical engineering technology programs typically have strength in embedding laboratory-based instruction teaching their students about product realization, e.g., manufacturing, and component design. Such strengths should be enhanced to further developing student creativity and innovation skills, through explicit curricular components that emphasize active, discovery-based learning (such as a design spine/portfolio or other intensive extracurricular engineering experiences). Such a design spine can also enhance motivation and retention. The ‘grand challenges’ can be incorporated as elements into early program courses to help provide an engineering context and background for students as they take their science and mathematics courses. Service-based projects needing innovative solutions should be made available for students ranging from the first-year to the senior-year. Mechanical engineering technology faculty members often have extensive industry experience and this expertise can be used to mentor and coach students through these experiences.

To provide more curricular flexibility and to incorporate such change, departments should designate a set of classes as their mechanical engineering technology core, which all students would be required to complete. This core would consist of the first course in the fundamental ME discipline areas. Once a student completes their core set of classes, they should be able to choose a concentration area, and complete additional courses in that concentration area to develop technical depth. The specialty concentration areas could fit the program’s region or faculty, e.g., provide exposure to areas of interest to students or the local industry.

The survey results above indicate that the greatest weaknesses noted by employers of current ME graduates, as well as by the early career engineers themselves, were a lack of practical experience in how devices are made or work, lack of familiarity with codes and standards, and a lack of a systems perspective. While Mechanical Engineering Technology programs often claim that their graduates have strength in “how things work and are made,” as validated by the pilot survey results above, issues remain around the use of codes and standards and a lack of systems perspective. These two areas should be strengthened in mechanical engineering technology programs. After all, reduction to practice of engineering theory has long been a strength of engineering technology programs.

A proven, successful approach, as discussed in Sheppard et al.[6], to do this uses a design/build/test spine in which a design course is present in the freshmen, sophomore, and junior years, where student teams tackle increasingly difficult design and build projects. Ideally, this design spine would be multidisciplinary in nature, providing the students with multiple experiences working with people from other majors as they progress through their curriculum. This sequence is completed with a yearlong senior capstone design course that has a focus on system design, building, testing, and operation.

It is recommended that the development of professional skills in the engineering technology graduate be strengthened to help produce the engineering leadership characteristics required for implementing engineering solutions to help solve the complex challenges facing companies, regions and planet. Professional skills such as a complex system-level perspective, inter-disciplinary teamwork, leadership, entrepreneurship, innovation, and project management should be central features of the design spine.

A systematic focus on integration of such skills into mechanical engineering technology curricula must approach the priority currently given to technical topics. Again, the strength of many MET programs is their faculty with experience in product realization and innovation, project management and business processes, use and understanding of codes and standards in different contexts. These faculty can lead the way for engineering technology programs and provide impressive examples for colleagues in mechanical engineering programs.

The mechanical engineering profession and its academic programs have one of the lowest percentage of women within the various engineering disciplines, and, similar to all engineering fields, a low percentage of underrepresented groups. To successfully attract underrepresented groups to the field of mechanical engineering, the message about the positive impact mechanical engineering profession has on improving the world should be communicated. Recruitment messages, mentorship, increasing faculty diversity, and emphasizing the idea that mechanical engineering is really about solving problems that impact people lives, are all important strategies. Utilizing the research portrayed in *Changing the Conversation*[7], which recommended re-branding of engineering to improve its appeal to different groups, especially minorities and young females, should be emphasized. Many of the curricular changes suggested above, especially those that reinforce connection of engineering study to contextual real-world solutions that help people and society, have been shown to increase student retention and diversity. This message should be infused into the first-year engineering technology courses to ensure higher retention of underrepresented groups. Service-based projects requiring innovative solutions should be made available for students ranging from the first-year to the senior-year.

Summary

These recommendations reflect findings of previous reports, such as the two NSF 5XME[8] workshops, and the Carnegie Foundation's reports (e.g., Sheppard et al.[6]). Some of these recommendations are not new, with some implemented and integrated into curricula by mechanical engineering or mechanical engineering technology programs and have been shown to have a positive impact on program outcomes. But, such changes and modifications have not been implemented in the pervasive manner necessary to impact the bulk of mechanical engineering education. Thus, it can be assumed that not all program leaders and faculty have been convinced that change is necessary. Hopefully, those data developed by ASME's Vision 2030 Task Force helps convince more of academia that change is necessary to lead to improved graduate skills and attributes. Mechanical engineering technology should lead mechanical engineering education in the quest to improve engineering education, building upon its strengths even as it improves in important ways to provide well-prepared graduates of the future for the engineering workforce.

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