AC 2012-4805: ASME VISION 2030'S RECOMMENDATIONS FOR MECHANICAL ENGINEERING EDUCATION

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ASME Vision 2030 -- Recommendations for Mechanical Engineering Education

Abstract

The role and scope of the engineering practice is transforming rapidly and academia should change to better prepare graduates. The ASME Vision 2030 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, through conducting workshops among stakeholders at key conferences and gatherings, and by extensive surveys of industry supervisors and early career engineers. As a result, the Task Force has formally recommended, and begun to advocate for, specific actions to strengthen the following seven aspects of undergraduate mechanical engineering education curricula: creating curricula that inspire innovation and creativity, increasing curricular flexibility, offering more authentic practice-based engineering experiences, developing students' professional skills to a higher standard, attracting a more diverse student body, increased faculty expertise in professional practice, and adapting post-graduate education to support specialization for practicing engineers. Partnership between industry, professional societies, government, and academia is needed to successfully implement these recommendations and help develop the full potential of mechanical engineering graduates. Initial actions have been taken towards implementing several of these recommendations.

Introduction

The role and scope of the engineering practice is transforming rapidly. What mechanical engineers do, and how they do it, is changing due to meeting 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 in these organizations will be individuals who, in addition to technical knowledge, have depth and skill 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.

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. Three years of sustained effort by the ASME Vision 2030 Task Force and ASME staff, with significant input from the mechanical engineering community, have been made to provide a roadmap for the future of mechanical engineering education. The ASME Foundation provided critical support enabling the work of the Task Force.

The constituents of mechanical engineering education were viewed as mechanical engineering and mechanical engineering technology academic department chairs/heads, faculty in these programs, their academic deans, industry practitioners (including engineering management), and government agencies. These groups helped frame the significant questions to be addressed, participated in information gathering, and reviewed the committee's work as it progressed. As used in the committee's work and reports, the term "mechanical engineering profession" includes the endeavors of both mechanical engineering and the mechanical engineering technology graduates.

The project 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 workshops among stakeholders at key conferences and gatherings. The National Academy of Engineers' (NAE) *Educating the Engineer of 2020*[1] 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 and a description of 'grand challenge' areas for mechanical engineers is contained in Kirkpatrick et al.[3]

Vision 2030 workshops included the ASME International Mechanical Engineering Education Conference (2009, 2010, 2011), the ASME International Mechanical Engineering Conference and Exposition (2009, 2010, 2011), the University of Houston's Engineering Technology Summit (2010), the annual meeting of the American Society for Engineering Education (2010), and the 5XME workshop sponsored by the US National Science Foundation (2009).

Curricular Assessment

An assessment of recent engineering education literature, multiple surveys of stakeholder groups, including mechanical engineering department heads, industrial supervisors, and early career engineers, was completed and involved over 3000 respondents. Using these data and formative assessment by the Vision 2030 Task Force members, numerous open-forum and panel discussions sessions at major education conferences and ASME meetings, including interaction with the ASME Industrial Advisory Board, provided additional input to the Task Force. These efforts enabled the identification and validation of overarching issues facing the mechanical engineering profession, as well as the development and refinement of a vision of the future of mechanical engineering education. These perspectives from industrial and academic stakeholders and constituencies were critical to the formation of recommendations.

To develop its recommendations, the Task Force identified key areas of knowledge, skills and abilities needed for mechanical engineering and mechanical engineering technology graduates to be successful in a global economy, whether working in small companies or large. Focusing on these key skills, the project developed and conducted extensive surveys 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 with less than ten years of practice. Complete data sets are given in the Vision 2030 report[4], and an overall summary is given in Danielson et al.[5]

Strengths

Figure 1 shows a comparison of how the industry supervisors (n=647), the educators (n=42), and the early career mechanical engineers (those that answered the strengths question, n~590) rated the 15 areas as a strength (e.g., "strong" on the scale above) of the graduates. Note the wide disparity of opinion between the industry supervisors and the academic leaders in many of these areas. This should serve a reality check for many academic programs. For example, problem solving and critical thinking were rated as a strength by 48% of department heads but only 14% of industry supervisors. Interpersonal teamwork was rated as strength by 51% and 43% of early career engineers and academic department heads, respectively; but by only 20% of the industry supervisors.

There was agreement about graduate capabilities in some areas, with computer modeling/analysis and new technical fundamentals showing reasonable agreement (albeit low as a strength in the later case). More often, the early career engineers and the academic leaders showed a relative level of agreement, with the industry supervisors showing less agreement.

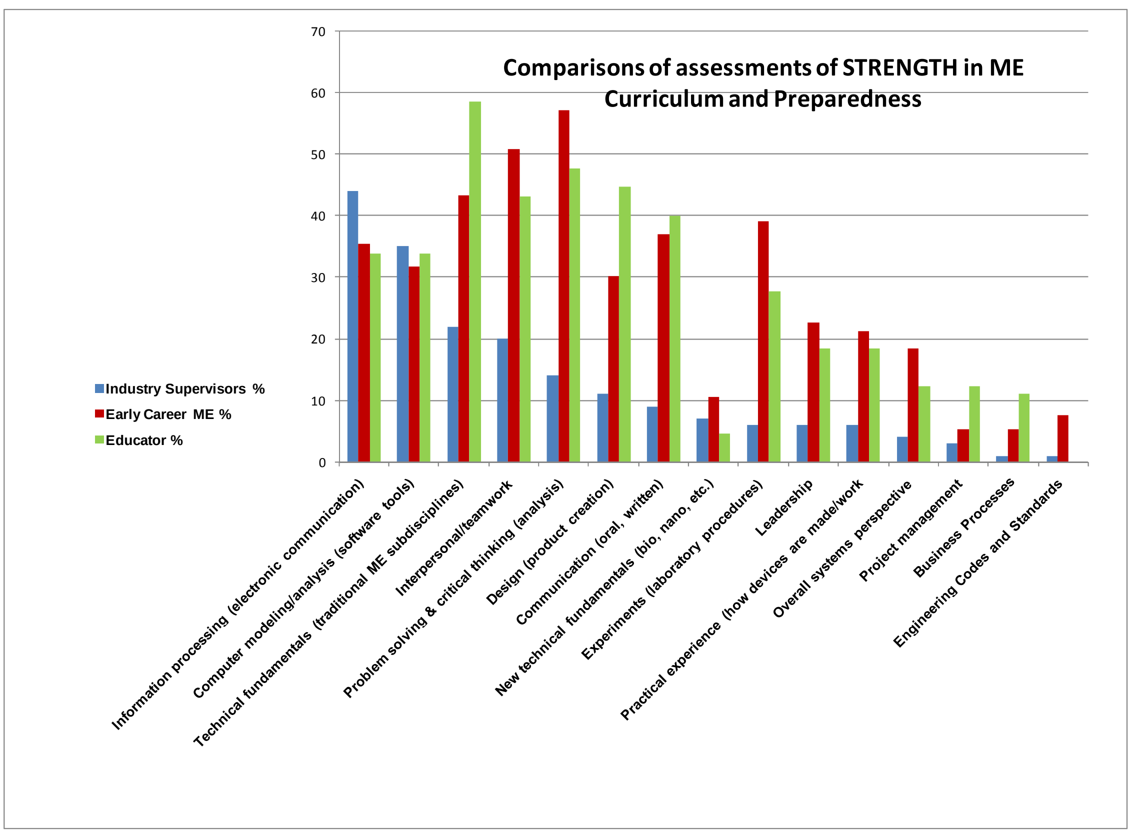

Figure 1
Comparison of Strengths

Weaknesses

Figure 2 shows a comparison of those industry supervisors rating the 15 areas as a weakness (e.g., "weak—needs strengthening" on the scale above) of the recent graduates. Again, note the disparity of opinion between the industry supervisors and the academic leaders in some of these areas. There was general agreement about lack of capability of graduates in some areas, with project management and business processes showing perception of weakness in reasonable agreement at the 30% level. The industry supervisors' four strongest (highest percentage) perceptions of weakness were practical experience—how devices are made or work (59%), communication (oral and written—52%), engineering codes and standards (47%) and having a systems perspective (45%).

These were matched by early career engineers' perception of their greatest weakness in two areas: practical experience (42%) and engineering codes and standards (54%). The other two high percentage weaknesses as rated by early career engineers were project management (35%) and business processes (34%). (In addition, their data portrays a sense that overall systems perspective education was weak, echoing their supervisor's impression, with 31% indicating this rating level.) The engineering educators had one of their four strongest perceptions of weakness aligned with the industry supervisors and the early career engineers (engineering codes and standards at 37%). Only one other area aligned with industrial supervisors (overall systems perspective at 46%). In addition, academia and early career engineers agreed on another common weakness, business processes (37%). The fourth top academic perceived weakness was new technical fundamentals/new mechanical engineering applications (40%), a perspective not shared by industry supervisor.

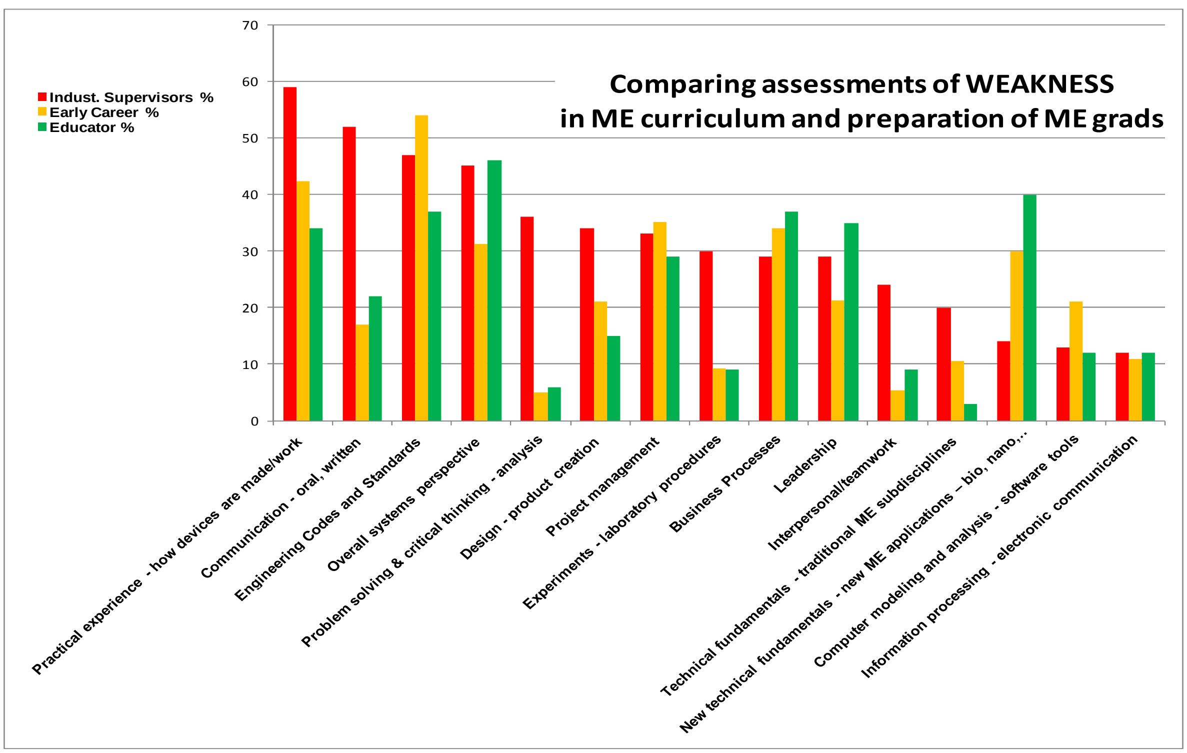

Figure 2
Comparison of Weaknesses

Recommendations

Seven aspects of the educational landscape have emerged as target areas for change. They encompass a wide range, spanning the educational pathways of mechanical engineering and mechanical engineering technology to increasingly diverse practice of mechanical engineering. The task force recommends strengthening the following aspects of undergraduate mechanical engineering education curricula: creating curricula that inspire innovation and creativity, increasing curricular flexibility, offering more authentic practice-based engineering experiences, developing students' professional skills to a higher standard, implementing effective strategies to attract a more diverse student body, increased faculty expertise in professional practice, and using post-graduate education as a mechanism to support engineering practitioners who desire to develop additional specialization. Specific comments on each of these recommendations follow.

Innovation and Creativity -- 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. 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) can also enhance motivation and retention. The 'grand challenges' can be incorporated as elements into early design 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. Faculty members who can mentor and coach students through these experiences are also needed.

Curricular Flexibility -- To provide more curricular flexibility and to incorporate new applications and emerging technologies, departments should designate a set of classes as their mechanical engineering 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 regional industry base or faculty expertise, e.g., provide exposure to research areas (nanoscience, etc.) in mechanical engineering.

To enable curriculum change and encourage more flexibility, modifications to the ABET general criteria and program criteria[6] for mechanical engineering (ME), e.g., in the ME criteria, no longer requiring both thermal and mechanical competencies, but preparation for professional work in one or the other, with exposure to the area not emphasized, are recommended. The latter change in the program criteria has been drafted and it beginning to move through the ABET process for implementation.

Practice-based engineering -- As per survey results, 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. To strengthen the practical experience component of graduate's skill sets, a significant 'practical experience' component should be added to curricula. A proven, successful approach, recommended by Sheppard et al.,[7] 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.

Professional Skills -- We recommend the development of professional skills in the engineering graduate to produce 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 curricula must approach the priority currently given to technical topics.

New Balance of Faculty Skills -- Employing more faculty with significant industry experience and creating continuous faculty development opportunities, including exposure to current industry practice, is urged. The hiring of "Professor of Practice' faculty with experience in product realization and innovation, project management and business processes, use and understanding of codes and standards in different contexts, could impart a greater, and more authentic, sense of the world of mechanical engineering practice to students. As another route to achieving this goal, the ASME is beginning to develop a specific program to help provide tenured faculty an opportunity to increase or refresh industry experience and/or observe the typical experience of early career mechanical engineers in industry.

Diversity -- 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. Programs should utilize existing research, e.g., the NAE's *Changing the Conversation*[2], as an aid in these efforts. In addition, 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, help increase student retention and diversity. This message should be infused into the first-year engineering 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.

Post graduate education -- At the graduate level, additional technical depth and specialization in mechanical engineering topics, plus increasingly sophisticated professional skills, will be required by some aspects of industry, according to both department heads and industry managers. Increased availability of professional master's degree programs provides opportunity for graduates and practitioners to meet such a need. Such degrees, which often have a different focus than the more traditional research-based Master of Science degrees, will take on more importance as deep technical content is reduced in the undergraduate mechanical engineering degree due to the inclusion of increased professional skills content.

Discussion and Summary

These recommendations are broader than those of past curricular reform efforts, where the debate centered on the mix of math, science, engineering analysis and design knowledge. The ability to both formulate and to solve complex problems, involving both technical and societal aspects, will be the touchstone of the mechanical engineer of 2030. The mechanical engineering profession must ensure that its solutions are implemented in viable economic, social, and environmental terms. This responsibility implies a richer professional framework in engineering education than presently exists.

What is now critical is the acquisition of skills such as problem formulation/solution, innovation, and the leadership ability of all of our students. This skill mix will be needed for engineers to be successful in engineering practice and to support societies' drive for a sustainable future. Many of these recommendations are not new, and some have been implemented and integrated into curricula by a number of mechanical engineering or mechanical engineering technology programs were they have been shown to have a successful impact on desired departmental outcomes. But, such changes and modifications have not been implemented in the pervasive manner necessary to impact the bulk of mechanical engineering education.

A partnership between industry, professional societies, government, and academia is needed to successfully implement these recommendations to develop the full potential of engineering education and engineering leadership. For example, ASME could facilitate faculty-practitioner exchange programs, and practice-based endowed faculty chairs. To enable curriculum change and encourage more flexibility, ASME should seek modifications to the ABET general criteria and program criteria for mechanical engineering as noted above. To help programs at research intensive institutions with growing programs argue for such faculty, the ME Program Criteria could address a minimum faculty size/student ratio to ensure program quality in design and encouraged an increase in the proportion of "practice-experienced" faculty within programs.

Successful implementation of a broader and more holistic curricula will produce graduates who have skills and abilities to coordinate, manage and lead global projects, graduates who can enable sustainable growth, graduates who can create their own jobs and jobs for others, graduates who are always thinking about the world's grand challenges, graduates who become involved in policy decisions at many levels of society, and graduates who become leaders in society to enable sustainable solutions for the good of all.

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