Creating the Future of Mechanical Engineering Education

This executive summary document is intended to engage the mechanical engineering and mechanical engineering technology communities in thinking and acting on long term curricular reform. It is also intended to guide the US strategy — and help inspire a more global strategy — for ASME Education over the next decade and beyond

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ASME Board on Education, V2030 Project Group

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Foreword

Change normally occurs when there is a compelling need, and this is particularly true with engineering education. There have been many studies over the years focusing on engineering education and the need for change, but most of them have had little or no impact unless they were associated with a major societal need. The arms race and the shift from engineering practice to engineering science after WWII, the emphasis on science and space during the 1960’s, and the unfortunately short lived emphasis on sustainability and energy in the late 1970’s and early 1980’s all resulted in change.

Today there should be no confusion as to the societal need. The Grand Challenges articulated by the National Academies clearly express societal needs. But what is fundamentally different now than even five years ago or thirty years ago during the first energy crisis? The differences are great with a growing need for alternative clean energy sources, food and fresh water shortages that are prevalent in many regions of the world, global political and social unrest due to many factors not the least of which is poverty, and growing concerns for the environment. Couple all of this with the financial collapse of many institutions and the financial chaos that many governments are experiencing and we have the need for pervasive and comprehensive societal change. What is engineering’s role in such change? Certainly the technical aspects of energy, clean water, food scarcity, and the environment concern the engineering profession. But is there a need for much greater and broader participation of the engineer in society’s progress towards solving these broad and pervasive problems?

Engineering’s history of invention of both products and processes has served society well for over two hundred years, but the recent confluence of events is suggesting that, as Simon Ramo said, “a greater engineering needs to evolve.” Hallmarks of these changes will hopefully be not only increased invention, but also the implementation of invention or innovation. Innovation will require leadership, and that leadership should come from engineers who have the technical insight and ethical courage to address the grand challenges facing this planet for the benefit of all its inhabitants. We can no longer leave our fate entirely in the hands of often ill informed politicians, lawyers, and business executives.

Either the engineering profession will broaden greatly or the society will suffer because the matching (between society and technology) will be too haphazard... a greater engineering needs to evolve...it will come to embrace much more the issues at the technology-society interface.

Simon Ramo
National Academy of Engineering
Engineers must take leadership roles not only on technical projects but in society more generally. Engineers must lead in their communities, in local, state and federal governments, and help lead society to a sustainable world. There are probably no second chances, now is the time for action, and we have to get it right. Now is the time for engineering leadership, our country needs it and our planet needs it.

What does this mean for what and the way we teach our students? Our students will need to lead not only technically but also socially, politically and ethically. Our engineering education models must change to enable our graduates to assume these leadership roles! Future engineers will need outstanding communication and people skills, business sense, a global perspective, and an unparalleled understanding of our environment. This implies a compassion and passion for our planet, ethics beyond the bottom line, not unlimited growth but sustainable growth, an understanding of the importance of economic growth, and more importantly an appreciation for the equitable distribution of that growth.

This report presents new data on the status and long-term outlook for mechanical engineering and mechanical engineering technology education from industry leaders, department heads, faculty, and practicing engineers. We make the case for the need for substantial change in the engineering educational process, and we present possible scenarios for change. In some cases, our conclusions and recommendations are based on reading between the lines or, as is discussed by Sharon Parks’ in Leadership Can be Taught, listening to the music beneath the words.

Hopefully the first edition of this report and its subsequent editions will inform and stimulate thinking, and motivate action, about what we can and need to do. Ultimately it will be the faculty in our engineering education programs that will take on the challenges and make the changes.

As a initial effort, this study focuses on ME education in the US, though the input collected from nearly 2,700 engineering managers, early career engineers, and ME department heads represents a significant swath of global industry. The work is the result of input from a large number of individuals and a sustained effort by the Vision 2030 Project Group and ASME Education staff. The ASME Foundation provided the initial funding that made our work possible. My thanks to them all.

R.O. Warrington, Chair
Vision 2030 Project Group
Preface

The role and scope of the mechanical engineering profession is transforming rapidly. Both what mechanical engineers do, and how they do it, are changing due to global issues, expansion of the discipline’s boundaries, increased professional expectations, and technological innovation. This document suggests the significant changes in mechanical engineering education required to meet this challenging environment.

This report has three primary goals. The first goal is to broadly define the knowledge, skills and abilities that mechanical engineering and mechanical engineering technology graduates should have to be globally successful in the future. The second goal is to provide recommendations on features of the mechanical engineering education curricula that will help provide graduates with the necessary expertise for successful professional practice. The third goal and perhaps the most important goal is to provide recommendations for the development of professional skills in the engineering graduate that will produce the engineering leadership required for implementing the technology and policy to solve the challenges facing their companies, regions, and the planet. Such recommendations are based on a rich set of data drawn from all of the stakeholders of the mechanical engineers and mechanical engineering technology educational process: faculty, academic administration, industry employers and leaders, and practicing engineers.

The ASME Board on Education formed and endorsed the effort, originally called the Body of Knowledge Task Force. The committee was composed of representatives from industry and education, including both engineering and engineering technology educators. Early in the process, the committee felt that a name change to the Vision 2030 Project better reflected its intent and scope and implemented this change in title. The committee adopted a structure and mode of operation found to be successful by other national engineering societies when performing similar work. The committee used a combination of “face-to-face” meetings and conference calls and resolved to not “reinvent the wheel.” Thus, committee members reviewed and assessed the recommendations of related recent publications and meetings as well as gathering new data from a variety of mechanical engineering professionals.
Introduction

Case for Change The role and scope of the engineering practice is transforming rapidly. What mechanical engineers and mechanical engineering technologists do and how they do it are changing owing to the increased need to attend to global challenges, expansion of the disciplinary boundaries, and rapid technological innovation. These and other factors broadly impact the engineering profession, place increased professional expectations on the engineer, and serve as motivators for significant change within the educational process and its content.

Our over arching conclusions are that now is the time for substantive change in the education of mechanical engineers and mechanical engineering technologists, and now is the time for engineering leadership in public and private sectors. Based on the results of two years of work, we offer the following observations.

Innovation and Leadership will be paramount to the US industrial base, the global success of the US economy in the 21st Century, and sustainable resolutions of the challenges facing our planet. As the economies of other nations become more sophisticated and developed, the US economy will more and more depend on the creative power of the engineering workforce and the process of bringing new ideas to market and, just as importantly, global cooperation and creativity will be required to resolve the challenges facing our planet. Creative invention by engineers and engineering technologists are essential to innovation, but so is leadership. The implementation of an invention to become an innovation requires leadership. Leadership in the public and private sectors is needed now more than ever owing to the issues facing both the U.S. and the world. Truly sustainable solutions are needed in companies and at all levels of society. Sustainable growth for our companies, our country and the planet should be foremost in our graduates’ thinking. The technical breadth of mechanical engineering and mechanical engineering technology education means that graduates are better prepared to see the “big picture”.

This big picture thinking could lead to a broader environmental, economic and political role for the engineer and engineering technologist if professional skills, particularly leadership, are fully developed. The latter areas have major implications for degree programs and their content.

Global issues Attention to global issues in engineering practice will become more important to design, product development, and engineering services. Global grand challenges include the scarcity of potable water, developing alternative sources of energy, renewing infrastructure, and assuring sustainable development. Increased cooperation among countries, industries, educational institutions, and nations must occur if the profession is we are to respond effectively to these global challenges.

With the advent of organizations, such as Engineers for a Sustainable World, Engineers Without Borders and others and the publication of “the grand challenges for engineering” facing the world by the National Academy of Engineering (NAE), there are opportunities for mechanical engineering education to participate in activities focused on improving human health and alleviating poverty in the developing world. Many students find such activities attractive and very rewarding, as they provide a framework within which to apply their engineering skills to improve the quality of life of people in less fortunate circumstances.

Sustainable Economies must be driven by long-term perspectives in all areas of professional activity, especially engineering as applied to product development and in the innovation process. Mechanical engineers and mechanical engineering technologists must occupy prominent roles toward sustainable economic futures. We believe industry and the public must understand that sustainable, not unlimited, growth is central to future solutions. Engineering educators, industrial leaders and public leaders must work in concert to address this issue.

Redefinition of Workforce Needs is a challenge for engineering as product conceptualization, design, manufacturing, and technical services have converged within the invention process.
Greater sophistication, often at the interface between basic science and engineering and at the systems level, and leadership for innovation also exert their influence on the kinds of engineering skills needed in the workforce. However, fundamental engineering, very applied and hands on, is a stated need by industry. In addition, the critical need to reestablish world-class manufacturing points to growing need for a redefined and growing engineering technology workforce. Full employment in the US can only be obtained if we start to produce and build things, and much of that must come from world-class manufacturing.

Consequently engineers and engineering technologists, while always faced with an increased need to continually learn and sometimes reinvent themselves over the span of their careers, must begin to reinvent themselves for their respective roles. The implications for re-thinking engineering education are compelling. Further, a relative resizing or restructuring of the engineering and engineering technology content and populations may be a long-term consequence of future workforce needs.

The case for substantive change in engineering education is strongly implied by the observations above. This assertion is validated by our environmental scan and educator workshops which touched a very broad segment of engineering constituencies. The one thing that is clear is that we must engage all of our constituencies in the change process: educators, our students, the graduates and industry. The data seems to indicate that all stakeholder groups must embrace change and the process of change. Industry must fully engage our graduates with challenging, exciting, and meaningful careers, and they must hire the right mix of engineers and engineering technologists. Whether change takes the form of curricular restructuring, change in the content of degree programs, or both is the task ahead for educators.

We fully expect responses of academia to vary widely owing the great diversity within the engineering and engineering technology programs across the nation.

Current framework for practice and education

Blurring Disciplinary Boundaries The earliest engineering disciplines, civil, mechanical and electrical, have given rise to distinct engineering specialties and application-based disciplines, such as aeronautical, chemical, biomedical, environmental, industrial and nuclear engineering. A classic definition of mechanical engineering is that it embodies the generation and use of thermal energy and power and the design and use of tools and machines to produce products. In the past, mechanical engineering problems were defined as those dealing with energy and mechanisms, i.e., bending, breaking, heating, cooling, and moving. Today, the range of applications of the mechanical engineering discipline has expanded greatly to include biological and information-based systems, advanced materials, micro/nano-devices, and many others. Currently, the types of problems and products that mechanical engineers work on are not easy to categorize, and they often include elements of other engineering disciplines and the basic sciences. Many contemporary engineering problems are considered to be multi-disciplinary in nature and require systems thinking in problem formulation and solution. It is clear that we must educate engineering students for a technological era of increased scope, scale and complexity.

Diversity and Workforce Retention The fraction of women and members of minority groups in the mechanical engineering profession has remained essentially constant at about 15% over the last thirty years. This situation exists despite significant efforts by government, industry and academia to increase the attractiveness of the field to both groups. The current mechanical engineering educational process is not attracting and retaining enough women and minorities.

Equally as important is the retention of individuals in engineering practice. Our environmental scan and review of the literature show that a significant fraction of engineers leave the practice of engineering within ten years after the receipt of the baccalaureate degree.
Reasons vary, but most frequently cited is that work assignments do not make meaningful and sufficient use of their skills.

**Student Characteristics** Incoming engineering students have interests and characteristics distinctly different from those of even a few years ago. This age group places a high value on interaction, team activities and social networking. As an example, in their social interaction, they use digital devices such as cell or smart phones and laptop computers for essentially continuous and instantaneous communication. Studies have shown that these students do not respond readily too many of the traditional messages about engineering as either a course of study or a profession.

The demographics of the engineering student cohort will also be a factor in the decades ahead. As the minority groups continue to grow through mid-century, the number of incoming students who are members of under-represented groups will increase. Greater ethnic and racial diversity of entrants into engineering programs will occur, and most of these students will be first generation students with relatively little pre-college exposure to engineering.

With the advent of organizations, such as Engineers for a Sustainable World, Engineers without Borders and others, and the constant reference to the challenges facing the world by the numerous media and organizations, there are opportunities for mechanical engineering students to participate in activities focused on improving human health and alleviating poverty in the developing world. Many students find such activities attractive and very rewarding, as they provide a venue to apply their mechanical engineering skills to improve the quality of life of people in less fortunate circumstances. Our students are voting with their feet and we educators need to respond.

**Global Workforce Issues** The US leadership in engineering education is currently challenged by changes occurring with the European Union (EU) in response to the Bologna Accord. The Peoples Republic of China (PRC), while rapidly expanding its university system, is now looking at the quality of its institutions and instructional programs. India is considering increasing the number of its Institutes of Technology, as well as developing doctoral programs competitive with those in the US and EU. Globally, new and existing mechanical engineering programs are applying for and receiving, accreditation from the Accreditation Board for Engineering and Technology (ABET) for their undergraduate programs.

These developments are positive and could lead to greater innovation in our efforts to develop sustainable solutions to the challenges facing our planet but will require a rethinking of US engineering education. The National Science Foundation (NSF) S5ME workshops, the results of which have been integrated into this work, have looked at US mechanical engineering education from the perspective of needing to add five times the value over their counterparts in countries such as India or China where currently engineering salaries are significantly less than those in the US resulting in outsourcing of many engineering jobs. As foreign economies grow, this difference will decrease, and the longer term arguments will focus on global cooperation and the need for cultural expertise. Global competition will remain for products and services driving the need for greater innovation through engineering. However sustainable global success in alleviating poverty, providing energy, clean water, enough food, and a clean environment will become the benchmarks for success.

**Value added engineers** As discussed above, corporations have the ability to source their engineering expertise worldwide, e.g., the 24/7 design processes that have been adopted in the automotive and computer industries. If the mechanical engineering profession in the US is to remain viable, it will depend on the ability of its workforce to provide value to their employers in this around the clock, around the world work environment. Engineering expertise will be required at a higher intellectual level than currently if value is to be added to the engineering and the business processes.
For example, expertise related to communication, innovation, and leadership will be required to a much larger degree in accelerated product development. Topics such as these are typically not a significant part of the mechanical engineering curriculum.

**Stakeholder Observations**

The findings and discussions from the previous sections are used to propose a framework and alternative curricular structures that could take ME and MET engineering education to new, desired end states. We envision future 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 are involved in policy decisions at many levels of society; and graduates who become leaders in society so as to enable sustainable solutions for the good of all. These considerations are over arching for mechanical engineering and mechanical engineering technology education despite differences in institutional mission, the breadth of the discipline, and the changing nature of engineering practice.

We believe that future technical solutions alone are not enough to meet business and societal needs. 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 their education than presently exists. It implies that engineering and engineers must assume leadership roles not only in the workplace but in other aspects of society as well.

The guiding principles that form the basis for our recommendations are that industry must generate sustainable growth for economic vitality, the United Nation’s Millennium Goals (2002) must be achieved, and the NAE Grand Challenges (2010) must be met and solved.

Now is the time for engineering education and its leadership to begin educational reformation to produce graduates who are both technically and professionally prepared to address the challenges and opportunities of the future.

As we describe the future of mechanical engineering education, alternatives are recommended to move ME and MET programs to desired end states while recognizing that each academic program must align its curricula, instructional modalities, and educational objectives with its overall institutional mission and external constituencies, whether it be a large Land Grant university or a small private college.

Furthermore, recommendations for industry and ASME are made in concert with recommendations for academia – a strong partnership among all three must exist for successful reform of our educational process. ASME’s advocacy role in promoting and supporting educational reform cannot be underestimated if educational reform is expected to succeed.

The following paragraphs briefly summarize what we have learned from literature reviews, surveys and face-to-face meetings with academia, industry, and engineers in the workforce. Taken together they form a framework for the recommendations for mechanical engineering and mechanical engineering technology education, and for ASME in its advocacy role for the mechanical engineering profession as a whole.

**Stakeholder Observations: Industry**

- Engineering managers indicate a lack of practical experience among ME graduates, and ME department heads generally agree.
- Engineering managers also indicate weak inter-personal and communication skills among the ME graduates but ME department heads disagreed.
- Engineering managers are not very interested in specific technical courses outside the traditional engineering fundamentals unless they directly address
their business interests, but department heads feel that courses involving new technologies are important.

- Problem formulation and solving ability is important to both employers and graduates.
- It appears that industry hires too many engineers for tasks better suited to the educational background of a bachelor of science in engineering technology, perhaps causing retention problems, reduced job satisfaction, decreased productivity and diminished creativity.
- Industry’s ongoing need for engineers with more practical experience could be an opportunity either for growth of engineering technology programs or perhaps a shift to a more practiced-based engineering degree, e.g., the Bachelor of Engineering in addition to the Bachelor of Science in Engineering.
- It appears that industry needs to realign its workforce needs and training to better utilize the young engineer’s enthusiasm and creativity. Much of this creativity will occur early in one’s career and be aligned with the young engineer’s passion.

**Stakeholder Observations: Academia**

- New graduates both forget much of the technical content by graduation and never use much of it during their early professional careers.
- ME and MET degree programs do not typically attract high school students with interests and abilities outside of mathematics and science, nor do they attract minority and female students.
- Most engineering faculty members teach based on their own academic experiences and career paths, typically focused on considerable technical detail. They are the content providers of the educational process and, in many cases in ME education, appear to be preparing students to move on to a doctoral program rather than professional practice. We need both.

- An overwhelming majority of faculty, when asked how to develop communication and leadership skills in undergraduates indicate that these skills should be integrated into existing technical coursework.
- Mechanical engineering department heads feel that considerably more post graduate technical education is required and industry managers appear to agree. Department heads generally favor the concept of Bachelor’s Degree plus a professional Masters Degree (as opposed to the Master of Science), while industry managers are more equally divided on the value of the Master’s Degree.
- Department heads feel that faculty time, resources and expertise are the most significant barriers to educational reform. The ABET accreditation process and requirements were considered the least significant barrier.
- About half of industry engineering managers and department heads agree that systems engineering content in undergraduate programs needs to be increased.
- About one third of both the industry engineering managers and academic department heads feel that knowledge of business processes, project management and leadership outcomes need improvement in the skill set of new graduates.

**Stakeholder Observations: Young Engineers**

- There appears to be some workplace dissatisfaction with ME graduates with a large number of them leaving engineering work to find more meaningful careers. Curricular flexibility giving students more ownership of their degree programs and better use of their talents in industry could help retention and greatly benefit everyone.
- Students and young engineers want to make a difference in society and for their employers.
General Observations

- Faculty members tend to agree that the most compelling reason for substantial curricula change are the grand challenges facing our planet and that increased innovation, improved diversity of the student body improved learning outcomes (including professional skills) are necessary.
- Can real change happen without changing the organization and reward structure for faculty members at most universities?
- Considerably more attention must be paid to issues such as sustainable growth and innovation, particularly applied to solving the challenges facing our planet, both in program content and in developing future leaders who will make a difference for industry, our nation and the planet. This process should start at the undergraduate level.
- Industry and academia need to more seriously partner towards developing the full potential of engineering and engineering leadership.
- In order to fully engage the US workforce and take advantage of technological innovation, the US must reinvent high tech manufacturing – certainly an opportunity for ME and also provides a significant opportunity for Mechanical Engineering Technology programs.

Enhanced skill sets are needed

- Graduates’ professional skills such as effective communication, persuasiveness, diplomacy and cultural awareness are as important as technical skills to industry.
- Young engineers often do not have the practical experience or professional skills needed by industry.
- The ability to both formulate and solve complex problems, involving both technical and societal aspects, will be the touchstone of the engineer of 2030.
- Graduate education, both the professional master’s degree and the PhD., are critical to the long term success of technological innovation and the engineering profession.

Actions and Options

The following are the overarching premises for our recommendations on reform of mechanical engineering and mechanical engineering technology education.

Broad societal imperatives must be met

- The “grand challenges” that face society, as articulated by the NAE and others, must be solved, and their solution can and should be led by mechanical engineers.
- Invention and innovation (the implementation of technological invention) should both increase and be led or guided by mechanical engineers who understand all the technical aspects of innovation, such as sustainability, life cycle analysis and climate impact.
- The mechanical engineering profession must play leading roles in developing and maintaining sustainable growth in business and industry.

Elements of educational reform 2030

- The current, typical four year Bachelor’s Degree may not be delivering the optimal education for US-educated engineers to be globally successful in the future.
- Mechanical engineering education programs should be configured somewhat more flexibly in ways that allow students pursue their passion.
- Systems level and big picture thinking is highly valued by industry.
Advocacy required

- All elements of the mechanical engineering community must embrace the notion of curricular change and advocate for it at institutional and national levels.
- At the national level, advocacy for shifts in policy and accreditation standards supporting curricular change must exist in concert with local reform efforts. The leadership of ASME is essential in this advocacy process.
- The role and need for engineering leadership towards creating a sustainable future for society and planet must be continuously and effectively articulated by ASME.

Considerations

Clearly “business as usual” in ME and MET education is not an option if true reform is to be accomplished. But what type of curriculum, or curricular change, is needed? As mentioned earlier, every institution is different, and there will be many different adaptations of any systemic change. But with any change, core engineering fundamentals and the problem formulation and solving abilities of the mechanical engineering and mechanical engineering technology graduate must be retained

Create curricular flexibility.

A more flexible, holistic undergraduate curriculum with a strong professional skills component integrated across the curriculum is envisioned. The curriculum should include major active, discovery-based learning opportunities such as a design spine or other experiences. The curriculum should emphasize problem solving over factual knowledge and include systems level experiences. Breadth is most important, with depth possible in a particular area of the student’s choosing.

Constrain the undergraduate program

It is not necessary to add courses or content to the nominal 120 – 128 semester hour, four year baccalaureate degree program. However, there must be more effective use of existing technical content, the general education program, technology based instructional methods and extracurricular activities. Recognizing that the four-year engineering education program described above will not contain as much technical content, we suggest that undergraduate programs be designed with the expectation that most technical specialization and depth will come later. Strong articulation with graduate programs is warranted as the nature of graduate education may change due to a differently educated undergraduate entering a graduate program.

Create a professional educational paradigm.

Develop a professional school attitude among students in the undergraduate program. Professional skills should be integrated throughout the curriculum, and broaden the skill set to include topics such as global understanding and communication, cultural awareness and leadership.

Create a curriculum that inspires innovation.

Develop curricula that spark the innate creativity and leadership potential within every student. Such curricula must encourage and provide opportunities for active, discovery-based learning, and provide opportunities for not only success, but failure. These curricula should give every student the skill set for leadership and the opportunity to lead at some level. These curricula could, at one level, give every the student the skills and confidence needed so that he or she could start their own company. Topics such as engineering as a part of the business process, entrepreneurship, and leadership become essential.
Advocate for success.

ASME’s corporate position in education must be aligned with proposed reforms and the broad communication of goals and methods of reform accomplished to essential constituencies inside, and outside, of ASME and the educational community. In particular, championing the critical role of mechanical engineering and the need for mechanical engineering leadership in creating a sustainable future with a high quality of life for all must become a high priority.

The following examples are presented to promote discussion among the stakeholders and are representative of the type of change that is needed. Neither minor curricular adjustments, nor the addition of a course within an existing curriculum, are the level of change needed to move mechanical engineering and mechanical engineering technology education to new, desired end states. Each of the examples below suggests a framework for change and a general framework for action at either the program or collegiate level.

- **A holistic undergraduate engineering degree** followed by a professional Masters Degree (or Master of Science for students more interested in research) for technical depth with some breadth. Such an undergraduate degree may, or not be, ABET accredited.

- **A learner-driven undergraduate degree** featuring considerably more curricular flexibility. This could be obtained through predefined multiple paths in the curriculum (e.g., a research track or a manufacturing track, etc.) or by designing the curriculum with a large number of number of electives that would enable the student to define his or her own specialization (learner driven).

- **An undergraduate engineering degree containing considerably more practical (hands-on) and design content** than found in most current engineering programs.

- **A reduction of technical content** in many of engineering courses within a degree program and the pervasive integration of innovation, communications, leadership, ethics, sustainability, business, environment, etc., across the curriculum.

While there are many other options and possibilities, components essential for mechanical engineering and mechanical engineering technology curricula are flexibility (e.g., multiple degree paths); strong professional skills (i.e., developing the leader within); more active, discovery-based learning (let the students create) and less factual content in favor of problem definition and solution within larger contexts. A continued strong emphasis on the fundamentals and outstanding problem formulation and solving is mandatory but forgo significant additional technical content beyond the fundamentals in the curriculum. There should be ample opportunities for students to gain experience dealing with big-picture, systems-level problems and constraints. These concepts should be integrated throughout the four-year undergraduate program, and greater reliance for deeper technical knowledge placed on students getting a professional Master’s Degree (those interested in practice) or a master of science and/or Ph.D. (those interested in research).

These recommendations are different than those of past curricular reform activities, where the debate centered on the mix of math and science, engineering topics and, and hands-on experience and/or design. What is critical now, and in the future, is that we maximize creativity, problem formulation/solution, and leadership ability of all 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. Further, we must enable engineering as a profession and engineers as individuals to take a higher level of responsibility and leadership in the affairs of society.
Creating the Future of Mechanical Engineering Education

An Action Agenda for Educators, Industry, and Government

What should Mechanical Engineering education look like in 2030? Seven aspects of the educational landscape emerge as target areas for change. They encompass a wide range, spanning the educational pathways of mechanical engineering and mechanical engineering technology to the increasingly diverse practice of mechanical engineering. To affect these changes, what specific strategies can educators, industry, and government pursue? The following actions are urged for seven major outcome areas of curricular change:

These recommendations represent the findings of an ASME Board on Education task force appointed in 2009. The task force was charged with defining the knowledge and skills that mechanical engineering and mechanical engineering technology graduates should have to be globally competitive and with advocating for adoption of recommendations for mechanical engineering curricula with the goal of better preparing graduates to meet the demands of a transforming professional environment.

The task force finds many reasons to advocate for fundamental changes in mechanical engineering education. Arguments for change come from recent engineering education studies, analyses of the engineering profession and unique to this study, extensive current surveys of academia, industry, and early career engineers. Major findings of the full V2030 report include:

RICHER PRACTICE-BASED EXPERIENCE

Action: Offer more authentic practice-based engineering experiences such as the design spine or design portfolio approach.

Among the greatest weaknesses noted among current ME and MET graduates by their employers, as well as the early career engineers themselves, are a lack of practical experience in how devices are made or work, a lack of familiarity with industry codes and standards, and a lack of a systems perspective. To address these weaknesses, an increase in and enrichment of applied engineering design-build experience throughout degree programs is urged.

STRONGER PROFESSIONAL SKILLS

Action: Develop students’ professional skills to a higher standard.

Both industry supervisors and early career engineers emphasize that graduates need stronger professional skills, e.g., interpersonal skills, negotiating, conflict management, innovation, oral and written communication, and inter-disciplinary teamwork. To meet this need, a systematic focus on integration of such skills into curricula must approach the priority given to technical topics. Incorporation of a multi-year design spine, or portfolio approach, which incorporates such skills development integrated with technical competency development into curricula, is urged.
MORE FLEXIBLE CURRICULA

**Action: Create curricular flexibility and efficiency with core requirements and specialization options.**

To enable students to develop understanding of mechanical engineering fundamentals but also offer greater strength in context and realization of design, a better systems perspective, and the possibility of focus in an area of interest, there is a need for greater flexibility in the degree path. Thus, the model of a required ME “core” set of fundamental classes, followed by a concentration area is suggested, echoing recommendations of earlier studies.

**Action: Modify ABET program criteria regarding student competencies.**

To enable curriculum change and encourage more flexible curricula, modifications to program criteria for ME and MET, e.g., no longer requiring equal thermal and mechanical competencies, but preparation for professional work in one or the other, with exposure to the area not emphasized, are recommended.

GREATER INNOVATION & CREATIVITY

**Action: Create a curriculum that inspires innovation and creativity.**

The chance to produce practical and technical innovation 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 or portfolio, or other authentic extracurricular engineering experiences — can also enhance motivation and retention. Faculty members who can mentor and coach students through these experiences are also needed.

TECHNICAL DEPTH SPECIALIZATION

**Action: Focus on post graduate education for specialization.**

Additional technical depth and specialization in mechanical engineering topics, plus increasingly sophisticated professional skills, will be required in many aspects of industry, according to both department heads and industry managers. The growing availability of professional Master’s degrees provides increased opportunity for graduates and practitioners to meet such a need.

NEW BALANCE OF FACULTY SKILLS

**Action: Increase faculty expertise in professional practice.**

To produce graduates with the practical and professional skills described above, diversification of faculty capabilities is required. Employing more faculty members with significant industry experience and creating continuous faculty development opportunities for exposure to current industry practice is urged. Faculty with experience in product realization and innovation, project management and business processes, with understanding of the use of codes and standards in different contexts will impart a greater and more authentic sense of the world of practice to students.

**Action: Modify ABET ME program criteria for faculty numbers and qualifications.**

ABET ME Program Criteria should address metrics for minimum faculty size and student to faculty ratio to ensure program quality in design and also address measures that increase the proportion of practice-experienced faculty.
Concluding Thoughts

What mechanical engineers do, and how they do it, constantly changes as boundaries of the discipline expand and professional expectations increase to serve an increasingly global marketplace. ASME’s Vision 2030 project (V2030) analyzed the perspectives of recent engineering graduates, their professors and their employers along with recent engineering education studies to offer recommendations on how mechanical engineers should be educated to meet the demands of their transforming profession as well as the grand societal challenges of the future.

☐ Society’s grand challenges, as articulated by the National Academy of Engineering, offer a compelling reason for substantial curricular change: to better equip mechanical engineering graduates to confront those challenges, not only with a solid technical foundation, but also with creativity, strong professional skills, and leadership within engineering and society.

☐ In a global setting, industry must be successful and able to create sustainable growth. To do so, companies large and small must have a talented and well prepared engineering workforce. In the coming decades, and “well prepared” will mean something more than in the late 20th Century.

☐ According to nearly two-thirds of the over 1,000 industry managers surveyed by the V2030 task force, entry level mechanical engineers need strengthening in how devices are made and work and in communication skills. Other significant shortcomings exist in graduate’s grasp of engineering codes and standards and systems thinking.

☐ Technical solutions are not enough. The roles to be played by mechanical engineering professionals in addressing business and societal challenges should not be limited to technical solutions!

☐ The engineering profession has an obligation to see that technology is implemented in viable economic, social and environmental terms. Engineering leadership will be required in the workplace and in other social arenas as well.

☐ Mechanical engineer’s capacity for invention must be matched by a commitment to all aspects of innovation. Future innovation will require assessment of sustainability, life-cycle analysis, and other societal impacts. Such knowledge and abilities will aid companies, non-profit organizations and government in many positive ways.

☐ Developing a technological workforce that can maximize the leverage of talent demands a priority on increasing the diversity of the mechanical engineering student body and faculty.

☐ Industry, academia, government and professional societies need sustained and focused collaboration in order to develop the full potential of engineering and engineering leadership, and to best effect the recommendations of the task force.

Compelling challenges face society, governments and businesses. Mechanical engineering graduates are a critical resource in providing solutions to meet demands of sustainable wealth creation and resource utilization, enabling successful companies in local and global settings, and leading solutions of the world’s grand challenges. Successfully meeting these challenges requires change in our mechanical engineering educational system to better enable the success of graduates through the span of their career, either in engineering or in related fields.
Approach and Method

The rationale and recommendations described above represent the perspectives of hundreds of stakeholders in ME and MET education, working through the ASME Vision 2030 task force, and surveyed in 2009 and 2010. Started in July 2008, when the ASME Board on Education formed an engineering education task force, the Vision 2030 group has been led by representatives from industry and education, including engineering and engineering technology educators.

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. Events 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).

To develop its recommendations, the project 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 1,100 early career engineers with less than ten years of practice.

The recommendations of the Task Force and subsequent ASME support and advocacy over the next several years is intended to shape the educational landscape of mechanical engineering education, especially its mechanical engineering and mechanical engineering technology programs, for the coming decades. It will take the combined efforts of educators and administrators, professional societies, employers, industry leaders and state and federal governments to ensure that mechanical engineering education pathways and partnerships are sufficiently robust and flexible to produce graduates capable of meeting the challenges of our technologically changing world and the grand challenges facing our planet.

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