A Critical Look at Mechanical Engineering Curriculum: Assessing the Need

Yeow Siow
University of Illinois at Chicago, yeowsiow@uic.edu

Jamison Szwalek
University of Illinois at Chicago, jszwalek@uic.edu

Jonathan Komperda
University of Illinois at Chicago, jonk@uic.edu

Houshang Darabi
University of Illinois at Chicago, hdarabi@uic.edu

Farzad Mashayek
University of Illinois at Chicago, mashayek@uic.edu

A Critical Look at Mechanical Engineering Curriculum: Assessing the Need

Abstract

Since the Morrill Land-Grant Colleges Act in 1862, the U.S. higher education system has been serving the industrial world, and engineering study is the epitome of this ideal: Serve those who will practice it in the immediate future. The mechanical engineering curricula have long been evolving to meet the demand of the changing economy, and it may soon be due for a major update. This paper aims to present an initial effort to explore the need for a systematic redesign, or reform, of the mechanical engineering curriculum at the University of Illinois at Chicago, where curricular changes during the past five decades have been largely isolated, incremental and piecemeal. This paper documents the method in, and results from, an evidence-based study of external data, from which a list of key skills future graduates should acquire is generated. The outcome of this study will inform and guide the next phase of the work, which examines the state of the current curriculum, teaching, and assessment within the department, as well as a comparison of curricula among peer and aspirational institutions.

Keywords: mechanical engineering curriculum, curriculum reform, modernization, market-driven, future economy, key skills.

Introduction

In 1998, Prados [1] presented an overview of engineering curriculum evolution, discussed economic drivers for change, and argued that the industry role was crucial in sustaining a productive workforce. Since the last decade, there has been an astounding rise in “game changers” that have or are bound to have, a significant impact on daily life at the local and global scales. These game changers come primarily in the form of technological innovations and materials breakthrough, with the human factor and human condition being a cornerstone of these advances. Artificial intelligence and machine autonomy aim to remove the burden of decision making from the human operator; immersive and portable visualization may be used to perform surgery remotely; sustainable and affordable energy distribution can serve to reduce or eliminate human suffering in poverty-stricken areas. The promise of these progress has resulted in a major behavioral shift among consumers and a remarkable transformation of business models among product and service providers. What used to be a go-to technology, such as direct injection in a heat engine or the heat engine itself, could soon be obsolete due to the undeniable advantages of alternatives such as the electric motor. The mechanical engineering program must produce graduates who will be well equipped to solve these new problems, and more importantly, be agile in learning new skills and adapting to new environments.

As a reaction to the demand of the present and future economy, there have been many recent examples of systematic changes to the mechanical engineering curricula at higher institutions in the U.S. and abroad. Luxhøsj and Hansen [2] reported an overhaul of the engineering curriculum at Aalborg University in Denmark where project-based learning was implemented to better prepare students for the workforce. Jones et al. [3], a group of multinational collaborators, dissected the market need for mechatronics and discussed ways to incorporate it within the mechanical engineering curricula. Tryggvason et al. [4] presented a reform of the mechanical engineering curriculum at the University of Michigan due to the changing nature of engineering jobs; hands-on experiential learning, teamworking, technical communication, and creativity were integrated in the curriculum as a result.

In this paper, a comprehensive need assessment is presented, whereby external data are gathered and analyzed to establish the need for a mechanical engineering curriculum reform at the University of Illinois at Chicago (UIC). A departmental committee was formed during fall term of 2017, and it focused on several main sources from which to collect data: Meta-analyses and expert reports, global economic trends, and recent job postings. In anticipation of a positive outcome from the current study, and in preparation for a potential continuation of the effort, a preliminary review of mechanical engineering curricula at several peer and aspirational institutions was also conducted.

Many organizations have begun to systematically evaluate the status quo to help shape the future of engineering education. The National Academy of Engineering has an ongoing effort to help face the 'grand challenges' for engineering. The American Society of Mechanical Engineers recently created projects, such as Vision 2030, to define skill sets most demanded by today's employers and to help guide the evolution of mechanical engineering curriculum. The World Economic Forum, KPMG and McKinsey, among others, have conducted large-scale studies and produced compelling reports about the future of jobs. The methodologies, conclusions and recommendations by these organizations have been reviewed and a synopsis is presented below.

In addition to referencing these large-scale external studies, independent research has been conducted to gather data that will inform the need for change. These information include keywords and trends from recent, nationwide engineering job postings, a review of recent editorials, as well as narratives by prominent figures in the scientific, engineering, technological, and social-political realms.

Meta-Analyses and Expert Reports

The National Academy of Engineering (NAE) has an ongoing effort to help face the 'grand challenges' of the profession and prepare for the future of engineering as society and technology evolves. The engineering profession must adapt to the rapid pace of technology innovation and this requires engineering graduates to have traits such as: strong analytical skills, creativity, practical ingenuity, professionalism, and leadership [5].

Creativity has grown in importance as engineering becomes more interdisciplinary. Additionally, as new problems and new contexts arise in the future, engineers require a flexibility or nimbleness to learn new things quickly and have the ability to apply that knowledge [5]. As the routine technical tasks engineers once performed are increasingly carried out by machines, creative skills will be more essential to gaining a competitive advantage [6]. As such, one recommendation from the Institute of Alternative Futures is emphasizing creativity in Mechanical Engineering education [7].

Many colleges and universities are seeking to revitalize their engineering programs to design and deliver a curriculum that is outcome-based and informed by real industry needs. One of the challenges is keeping up with the quick changing pace of industry and how this can affect the content and way teaching is done in the classroom. For example, a 2017 ABET report describes how institutions can innovate to engage student populations effectively and help them develop skill sets that are - and will be - needed by a rapidly evolving global economy [8]. Often, the engineering skills used in industry go beyond specific discipline borders, which requires engineering students to take on interdisciplinary projects, use real-world practices to solve problems and be dynamic, flexible, and agile. According to the ABET report, making key changes to the curriculum has resulted in more prepared graduates and improvements to enrollment and retention.

The American Society of Mechanical Engineers recently created projects, such as ASME Vision 2028 and 2030, to define skill sets most demanded by today's employers and to help guide the evolution of mechanical engineering curriculum [9,10]. The ASME Vision 2030 Task Force describes surveying stakeholders in Mechanical Engineering and Mechanical Engineering Technology: department heads, industry supervisors, and early career engineers. Large discrepancies in opinions were noted between industry supervisors and academic leaders in both areas of program strength and weakness, leading to specific recommendations in how one can strengthen the undergraduate mechanical engineering curricula. The ASME Vision 2030 report emphasizes the need for innovation and creativity and more authentic practice-based engineering throughout the curriculum. Based on the greatest weaknesses of current mechanical engineering graduates, the ASME Vision 2030 report recommends more hands-on activities (design-build-test) in the curriculum, emphasizing communication, and developing a systems perspective, in an effort to strengthen student’s practice-based engineering skills.

Additionally, many recent, large-scale studies of the future economy as conducted by independent bodies such as World Economic Forum [11], McKinsey Global Institute [12], and KPMG International Cooperative [13] all agreed that automation will inevitably be a key component of future jobs, and further advances will occur at a rapid pace. What this means for a young engineer is likely future job changes where new skills will be constantly required. This implies that higher institutions should prepare students to become effective lifelong learners, ones who not only are reactive to change, but also proactive in preparing for a new career.

A similar conclusion was echoed by Klaus Schwab [14], founder and executive chairman of the World Economic Forum, who in 2016 discussed the inevitable forces of change the Fourth Industrial Revolution is bringing. He also concluded that the Revolution is still being shaped, and should be directed by all constituents of the world through the development of “a comprehensive and globally shared view of how technology is affecting our lives and reshaping our economic, social, cultural, and human environments.” Translating this view into higher education - for mechanical engineering in particular, a graduate should not only be technically sound but also have the capacity to appreciate and embrace change.

Finally, a recent report from the National Academies [15] asserts that “U.S. engineering education must continuously adapt both to advances in science and technology fields—especially computing and data science,” and that “the disciplinary foundations of engineering are expanding with the growing influence and incorporation of computing, the life sciences, the social and behavioral sciences, business management concepts and skills, and entrepreneurship.” In other words, an expanded list of technical and “soft” skills will need to be deeply incorporated into the curriculum.

Some Industry Trends

Automation, as mentioned earlier, is and will be a significant requirement of engineering jobs. Since the last industrial revolution, automation has been integral to manufacturing and production. However, automation is poised to play a much larger role in the future economy as it has already penetrated the consumer lives. Autonomous mobility, for example, is quickly becoming ubiquitous as manufacturers such as Tesla and Volvo, and technology giants such as Alphabet (Google), Amazon and Uber, have invested heavily in autonomous driving technology. A 2016 study by McKinsey & Co. [16] concluded that, by the year 2040, the new-vehicle market share of “conditionally autonomous” vehicles will reach nearly 100% under the “high-disruption scenario,” and 30% under the “low-disruption scenario.” Data science, artificial intelligence, control systems, and coding in general will be commonly found in the job description.

Electrification of mobility is another trend the automotive world is currently experiencing, as evidenced by the rising market share of fully-electric vehicles. Tesla alone has transformed the automotive industry [17], while an increasing number of other makers, such as Nissan and General Motors, and startups such as Faraday Future, Lucid and NIO [18] have raised billions of dollars in investments to bring electric vehicles to market. Recently, Volvo announced that it will no longer invest in developing internal combustion engine-only cars [19]. Volkswagen has planned to stop producing fossil fuel-powered vehicles by 2026 [20]. A report by the European Climate Foundation projected that by 2050 nearly all new vehicles will be fully electric, with power coming from either battery or fuel cell [21]. An implication of such a trend is that Thermodynamics course may require a major revision, and new courses or topics such as energy storage and nanotechnology may become necessary.

Mining of Recent Job Data

Over the past couple of decades, the job market has been changing, requiring school programs to change in order to fulfill the industry demands. The first step in assessing necessary skills that should be present in a mechanical engineering curriculum was to study the current job market requirements. To accomplish this, a framework similar to the Skill Miner System, proposed by Darabi et al. [22], was implemented. The purpose of this framework was to study the job market trends and demands of the job market.

Initially, over 5000 unique nationwide mechanical engineering job postings from November 2017 to January 2018 were collected from Indeed, CareerBuilder and Monster [23-25] through a web crawler. These job postings contain job titles, company name, company background, job requirements, and preferred qualifications. The web crawler, designed using the package Beautiful Soup in Python [26], collected mechanical engineering job postings daily such that only new job postings were collected.

Once all the job postings were extracted, a Natural Language Processing (NLP) model was applied to detect the professional and technical skills outlined in the job postings. This was done by initially parsing the job posting texts into parts of speech (POS) tags. Subsequently, the pattern of these POS tags were used to extract important keywords and phrases from the job descriptions. In addition, a list of stop words and phrases were used to filter out the words and phrases that were deemed unnecessary. Some of these stop words or phrases include “someone,” “today,” and “job description.” Finally, the frequency of each unique keyword or phrase appearing at least once in a job posting was measured.

The frequency of each keyword or phrase was utilized to gauge the demand of specific skills required for modern mechanical engineering jobs. The most common programming language required by the mechanical engineering job market was found to be R, Java, Python and Matlab, and the most common modeling tools required by the job market were AutoCAD, SolidWorks, and Creo. Other common technical skills required by the job market included CNC machining, Engineering Dynamics, Failure Mode and Effect Analysis (FMEA), Manufacturing, Microcontroller, Six Sigma, and Technical Drawing.

Synthesis and Analysis of Data: Key Skills Extracted

From the collected data, a comprehensive list of “key skills” has been generated and is presented in Table 1 below. “Skill” is a broad term used in this paper to loosely represent a desired mastery or quality of a person. No distinction is made between technical and otherwise. These skills are a direct result of indicators from job posting data, and derivations from meta-analyses of reports and trends. A common thread among these key skills is “future-proofing” an engineering career.

Table 1. Full List of Key Skills Required by Current and Future M.E. Career

Coding (R, Java, Python, Matlab)	Energy Storage
CAD (Solidworks, Creo, AutoCAD)	Creativity
Microcontroller (Arduino, RPi, etc.)	Effective Communication
Electric Motor, Sensors, Circuitry	Design, Modeling
Manufacturing (Subtractive and Additive)	Teamwork
Six Sigma	Critical Thinking
Quality/FMEA/DFMEA	Agility/Nimbleness
Engineering Dynamics, System Control	Ethics
Data Analysis/Data Science	Entrepreneurial Thinking

It should be noted that the specific examples, in parentheses, under Coding, CAD and Microcontroller are strictly based on mined data of current job postings, and may change over time. However, the skill itself should remain unchanged.

A further analysis was performed whereby a condensed list could be produced, by concatenating, grouping, or nesting the list of skills. Additionally, keywords that recur among the various data sources are given a higher importance. “Certificate skills” such as Six Sigma and DFMEA are ranked lower due to their link to a narrower set industries or job titles. Skills such as CAD and Design, while essential to future mechanical engineering jobs, are generally well integrated in today’s curricula and are therefore of lesser concern. Finally, ethics is and should be a fundamental requirement in engineering, and is intrinsic to many of the skills in Table 1.

Taking all the above into consideration, the condensed list of key skills are:

- Agility
- Mechatronics/automation
- Coding and algorithm
- Data science
- Entrepreneurship
- Effective communication
- Creativity

Agility is the ability to learn how to learn, be audacious in learning new skills and going outside of one’s comfort zone. It includes a keen sense of observation, constant awareness and reflection of oneself and the economic landscape, and the willingness to enact and accept change. Entrepreneurship is a broad term that combines critical thinking and effective teamwork. The rest of the key skills are self-explanatory.

Preparing for Phase II: Peer and Aspirational Institution Curricula

In anticipation of a positive outcome from the current needs-assessment study, current implementations of mechanical engineering curricula across a variety of institutions were reviewed as Phase II. This effort sought to determine what approach, if any, should be taken concerning curriculum redesign, specifically investigating the flexibility of a course plan to accommodate innovations in technology and to adapt to trends in industry. The investigation consisted of reviewing publicly available Mechanical Engineering curriculum flowcharts across 17 institutions. The universities selected (Table 2) were in the top undergraduate engineering programs, five geographically competing programs, and five ranked similarly, based on the 2017 US News rankings [27]. Additionally, only top programs with enrollments comparable to UIC were considered. Two programs overlapped these categories, being both geographically competing and top ten or similarly rated institutions.

Table 2. Undergraduate Mechanical Engineering Programs

Colorado State University [28]	Purdue University [37]
Cornell University [29]	Stanford University [38]
Georgia Institute of Technology [30]	Texas Tech University [39]
Illinois Institute of Technology [31]	University of California Berkeley [40]
Marquette University [32]	University of Illinois Urbana-Champaign [41]
Massachusetts Institute of Technology [33]	University of Michigan [42]
Northern Illinois University [34]	University of Oklahoma [43]
Northwestern University [35]	University of Texas Austin [44]
Oregon State University [36]	

The first measure of flexibility observed in the data was the frequency and recency of revision. Specifically, nine of the programs had revised their curriculum in the last year, four in the past two years, and one in the past four years. Three programs did not have dates specified on their course plans or handbooks; therefore, it was not possible to determine the recency of the revision. The frequency at which the curricula updated demonstrates that many programs undergo constant evolution; however, it does not necessarily imply that they mimic the evolving trends of industry or technology. One may deduce from this data that, in general, departments are willing to adapt their curriculum if necessary, meaning that rapid yearly iteration of the curriculum is a possible mechanism for implementing courses that shift with industry trends.

Further investigation of the curricula showed that while the order of classes, titles, and their prerequisites differed substantially between institutions, the general contents remained similar. The most notable differences appeared in the quantity and type of high-level, non-general education electives that a student must take to complete their degree. Some institutions termed these "Technical Electives," others "Specialization Electives," and "Approved Electives," among others. The quantity of these electives in each program ranged from one to five, with an average requirement of three across all institutions. While some programs restricted part or all of these electives to a specific list, many did not, allowing students to select from a wide breadth of courses, including other science and engineering departments.

Based on the gathered data, changes to the curriculum to fill the needs of industry can be implemented in three known ways: 1) by updating the content of individual courses, 2) by revising the course plan, and 3) appropriating an increased number of electives that reflect trending topics. Considering the effectiveness of these approaches has not been studied, a future investigation will be necessary to determine which of these approaches, or combination thereof, should be implemented to allow the curriculum to evolve with industry requirements, both current and future.

Conclusions

A need-based assessment of external data has been conducted, including a nationwide search of job databases to determine skills required for mechanical engineering positions, a review of meta-analyses on future economy, an investigation of large-scale studies on the specific needs of mechanical engineering curricula in the nation, and an overview of recent industry trends. Based on the gathered evidence, a condensed list of “key skills” has been extracted, and are deemed necessary in the mechanical engineering curriculum in order to produce graduates who can successfully navigate the future job market.

The key skills are:

- Agility
- Mechatronics/automation
- Coding and algorithm
- Data science
- Entrepreneurship
- Effective communication
- Creativity

The current mechanical engineering curriculum at UIC includes topics related to many of these key skills. However, multiple curricular deficiencies exist whereby successful acquisition of these skills by students are limited. The next step, Phase II, is currently underway to critically assess the status quo in the curriculum and department culture, identify strengths and deficiencies, and ultimately find ways to impart these core skills in a redesigned curriculum.

References

[1] Prados, J. W. (1998). Engineering Education in the United States: Past, Present, and Future. International Conference on Engineering Education, Rio de Janeiro, Brazil.

[2] Luxhøsj, J. T. and Hansen, P. H. (1996), Engineering Curriculum Reform at Aalborg University. Journal of Engineering Education, 85: 183-186. doi:10.1002/j.2168-9830.1996.tb00231.x.

[3] Jones, Richard & Mace, Brian & Tham, Ming. (2002). The evolution of mechanical engineering curricula: mechatronics. International Conference on Engineering Education.

[4] Tryggvason, G. , Thouless, M. , Dutta, D. , Ceccio, S. L. and Tilbury, D. M. (2001), The New Mechanical Engineering Curriculum at the University of Michigan. Journal of Engineering Education, 90: 437-444. doi:10.1002/j.2168-9830.2001.tb00624.x.

[5] NAE, The Engineer of 2020: Visions of Engineering in the New Century, National Academies Press, 2004.

[6] Pink, D. (2005). "Revenge of the right brain." Wired, Feb. 2005. p. 70-72.

[7] Institute for Alternative Futures, Six Strategic Issues Shaping the Global Future of Mechanical Engineering. ASME, 2005.

[8] Engineering Change: Lessons from Leaders on Modernizing Higher Education, An ABET Issue Brief, Fall 2017.

[9] Kirkpatrick, A., Danielson, S., Warrington, R., Smith, R., Thole, K., Wepfer, W. & Perry, T. (2011). Vision 2030 – Creating the Future of Mechanical Engineering Education. In the *2011 Annual Conference Proceedings*, American Society for Engineering Education, June 27 - 29, Vancouver, BC. New York: American Society for Engineering Education.

[10] 2028 Vision for Mechanical Engineering: A report of the Global Summit on the Future of Mechanical Engineering, American Society of Mechanical Engineering, 2008.

[11] World Economic Forum, "Towards a Reskilling Revolution," 2018. [Online]. Available: https://www.weforum.org/reports/towards-a-reskilling-revolution. [Accessed: 01-Dec-2018]

[12] McKinsey Global Institute, "Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation," 2017. [Online]. Available:

https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages. [Accessed: 27-Jun-2018]

[13] KPMG, “Rise of the Humans 1 & 2 & 3,” 2017. [Online]. Available: https://home.kpmg/xx/en/home/insights/2016/11/rise-of-the-humans.html. [Accessed: 11-May-2018]

[14] Klaus Schwab, “The Fourth Industrial Revolution: what it means, how to respond,” 2016. [Online]. Available: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/. [Accessed: 27-Dec-2018]

[15] National Academy of Engineering (2018). Understanding the Educational and Career Pathways of Engineers. Washington, DC: The National Academies Press. https://doi.org/10.17226/25284.

[16] McKinsey & Co, “Disruptive trends that will transform the auto industry,” 2016. [Online] Available: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/disruptive-trends-that-will-transform-the-auto-industry. [Accessed: 08-Nov-2017]

[17] Forbes, “Tesla's Innovations Are Transforming The Auto Industry,” 2016. [Online] Available: https://www.forbes.com/sites/innovatorsdna/2016/08/24/teslas-innovations-are-transforming-the-auto-industry/#574e63ce19f7. [Accessed: 08-Nov-2017]

[18] Forbes, “Next Up After NIO: Four Other Chinese EV Startups That Could Make A Splash,” 2018. [Online]. Available: https://www.forbes.com/sites/michaeldunne/2018/09/27/nio-cracks-the-nyse-whos-next/#4586eaa01b98. [Accessed: 27-Dec-2018]

[19] Forbes, “Volvo Says It Will Stop Designing Combustion-Engine Only Cars By 2019,” 2017. [Online]. Available: https://www.forbes.com/sites/williampentland/2017/07/05/volvo-says-it-will-stop-designing-combustion-engine-only-cars-by-2019/#5ecc26721fa3. [Accessed: 27-Dec-2018]

[20] Bloomberg, “VW Says the Next Generation of Combustion Cars Will Be Its Last,” 2018. [Online]. Available: https://www.bloomberg.com/news/articles/2018-12-04/vw-says-the-next-generation-of-combustion-cars-will-be-its-last. [Accessed: 27-Dec-2018]

[21] European Climate Foundation, “Fuelling Europe’s Future: How the Transition From Oil Strengthens the Economy,” 2018. [Online]. Available:

https://europeanclimate.org/wp-content/uploads/2018/02/FEF_transition.pdf. [Accessed: 27-Dec-2018]

[22] Darabi, H., Karim, F.S.M., Harford, S.T., Douzali, E. and Nelson, P.C. (2018). Detecting Current Job Market Skills and Requirements Through Text Mining. In ASEE Annual Conference and Exposition, Conference Proceedings (Vol. 2018).

[23] Indeed.com, 2018. [Online]. Available: https://www.indeed.com/. [Accessed: 01-Jun-2018]

[24] Monster.com, 2018. [Online]. Available: https://www.monster.com/. [Accessed: 01-Jun-2018]

[25] CareerBuilder.com, 2018. [Online]. Available: https://www.careerbuilder.com/. [Accessed: 01-Jun-2018]

[26] L. Richardson, "Beautiful Soup 4.4.0 documentation." [Online]. Available: https://www.crummy.com/software/BeautifulSoup/bs4/doc/. [Accessed: 01-Feb-2018].

[27] U.S. News, "Best Undergraduate Engineering Programs." [Online]. Available: https://www.usnews.com/best-colleges/rankings/engineering. [Accessed: 01-Nov-2017]

[28] Colorado State University, "MECHANICAL ENGINEERING CURRICULUM GUIDE." [Online]. Available: http://www.engr.colostate.edu/me/wp-content/uploads/2018/11/UGCurriculumFlowchart Word-November-2018.pdf. [Accessed: 20-Dec-2018].

[29] Cornell Engineering, "Engineering Undergraduate Handbook Fall 2017." [Online]. Available: https://www.engineering.cornell.edu/sites/default/files/departments/main area/pdf files/Fall-2017 Cornell Engineering Handbook.pdf. [Accessed: 03-Nov-2017].

[30] Georgia Tech, "ME Undergraduate Curriculum (Catalog: 2017 - 2018)." [Online]. Available: http://www.me.gatech.edu/files/ug/program_of_study_me1718.pdf. [Accessed: 03-Nov-2017].

[31] Illinois Institute of Technology, "B.S.M.E. Curriculum." [Online]. Available: https://engineering.iit.edu/sites/engineering/files/elements/mmae/pdfs/bsme10_flowchart.pdf. [Accessed: 03-Nov-2017].

[32] Marquette University, "Mechanical Engineering Marquette University (2016-2017)." [Online]. Available: https://www.marquette.edu/mechanical-engineering/documents/flow-chart-2016-2017.pdf. [Accessed: 03-Nov-2017].

[33] Massachusetts Institute of Technology, “Getting Around the Mechanical Engineering Department.” [Online]. Available: http://web.mit.edu/me-ugoffice/gamed.pdf. [Accessed: 02-Nov-2017].

[34] Northern Illinois University, “Mechanical Engineering College of Engineering and Engineering Technology Degree Path - Catalog 2017-2018.” [Online]. Available: https://niu.edu/advising/your-advising-plan/degree-paths/2017-2018/engineering/mechanical-engineering.pdf. [Accessed: 03-Nov-2017].

[35] Northwestern University, “Program of Study Flowchart.” [Online]. Available: https://www.mccormick.northwestern.edu/mechanical/documents/undergraduate/flow-charts/flow-chart.pdf. [Accessed: 03-Nov-2017].

[36] Oregon State, “Mechanical Engineering.” [Online]. Available: https://mime.oregonstate.edu/sites/mime.oregonstate.edu/files/documents/advising-undergrad/me_curriculum.pdf. [Accessed: 03-Nov-2017].

[37] Purdue University, “Mechanical Engineering - Program Map.” [Online]. Available: https://engineering.purdue.edu/ME/Academics/Undergraduate/purdue_undergrad_program_map.pdf. [Accessed: 03-Nov-2017].

[38] Stanford, “Mechanical Engineering Typical Sequence of Courses.” [Online]. Available: https://stanford.app.box.com/s/klrmrl8m80wt79y5wg94nuvtd3ybdsx8. [Accessed: 05-Nov-2017].

[39] Texas Tech University, “Mechanical Engineering BS Curriculum Flowchart.” [Online]. Available: https://www.depts.ttu.edu/me/images/MEflowchart.pdf. [Accessed: 03-Nov-2017].

[40] University of California Berkeley, “Mechanical Engineering Undergraduate Curriculum.” [Online]. Available: https://www.me.berkeley.edu/sites/default/files/undergraduate/CurriculumFlowchart.pdf. [Accessed: 02-Nov-2017].

[41] University of Illinois Urbana-Champaign, “Mechanical Engineering Flowsheet.” [Online]. Available: http://www.mechanical.illinois.edu/sites/default/files/images/2017-05-17_ME_flowsheet-Combined_1.pdf. [Accessed: 02-Nov-2017].

[42] University of Michigan, “Undergrad Handbook.” [Online]. Available: https://me.engin.umich.edu/academics/undergrad/handbook/. [Accessed: 03-Jan-2017].

[43] The University of Oklahoma, “Mechanical (Standard) Engineering Curriculum Advising Worksheet.” [Online]. Available: http://www.ou.edu/content/dam/CoE/AME/flowcharts/2017-2018/ME Curriculum Advising Sheet - Standard (1_21_2016).pdf. [Accessed: 03-Nov-2017].

[44] The University of Texas at Austin, “The University of Texas at Austin Mechanical Engineering 2016-2018 Undergraduate Catalog General Curriculum.” [Online]. Available: http://www.me.utexas.edu/images/undergrad2016-18.pdf. [Accessed: 20-Nov-2017].