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Mapping Skill Recognition and Development of Undergraduate Mechanical Engineering Students for the Automotive Industry

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Introduction

Many undergraduate students aspiring to work in the automotive industry will pursue engineering degrees in mechanical engineering to help them attain the knowledge and skills required to compete for a position. This research project explores how undergraduate mechanical engineering students develop an understanding of how their coursework and extracurricular activities give preparation for a career trajectory in the automotive industry. Freshmen enrolled in the undergraduate mechanical engineering degree are required to complete an Introduction to Mechanical Engineering course, ME110. The course is designed to be an introduction to the mechanical engineering profession and overviews engineering fundamentals, CAD basics, professional development, and other related skills. An initial assignment these freshmen complete in this class is to imagine their future career and the steps that they will need to take to achieve it by way of finding future versions of their possible selves through the LinkedIn website. Of the 127 freshmen who completed this assignment, 25% of them aspired to work at a company that self-identifies as Motor Vehicle Manufacturing on LinkedIn. Students who are interested in a future career in the automotive industry are warned that it is a competitive space and are told to stand out with good grades and extracurricular activities that demonstrate their interest and commitment to the field. However, in a self-reported survey of the last 5 years of mechanical engineering graduates at our school (count 383), only 3% of graduates reported their first job as a company that self-identifies as Motor Vehicle Manufacturing on LinkedIn. While some students originally interested in the automotive industry may seek new passions, switch majors, pursue a master's degree, or leave college, it appears that students may not be set up for success in their desired career path. The study examines the recognition, development, and reflection of skills for mechanical engineers in the automotive industry through qualitative, semi-structured critical incident interviews of undergraduate mechanical engineering students (n=2), recent mechanical engineering graduates from our school who successfully obtained a career in the automotive industry (n=15), and technical professional and hiring managers with much experience in the automotive industry. The insights from this research will better inform how careers in mechanical engineering may be presented to 1st-year students and how career planning might be better positioned for future engineers.

Background

The South Dakota School of Mines and Technology is a public engineering-focused university in Rapid City, South Dakota. One of the largest engineering undergraduate programs at South Dakota Mines is mechanical engineering (ME). According to the ME department, the undergraduate program "offers a premier project-based engineering design curriculum and provides [the] graduates with superior educational experience through teaching and learning, research and development, and service & social responsibility" [1].

Many engineering students are attracted to the automotive industry due to its continued excellence in innovation. The automotive industry is comprised of a wide range of companies involved in the research & development, design, manufacturing, and sale of motor vehicles. In 2021, approximately 13.4 million motor vehicles were produced in North America alone [2]. The global automotive manufacturing industry was valued at 2.86 trillion USD in 2021 [3]. The automotive industry continues to grow, especially with the addition of electric vehicles. Figure 1, below, shows a steady growth of employment of workers in the automotive industry at companies involved with motor vehicle and motor vehicle parts manufacturing. The dip occurring in early 2020 corresponds with the global pandemic.

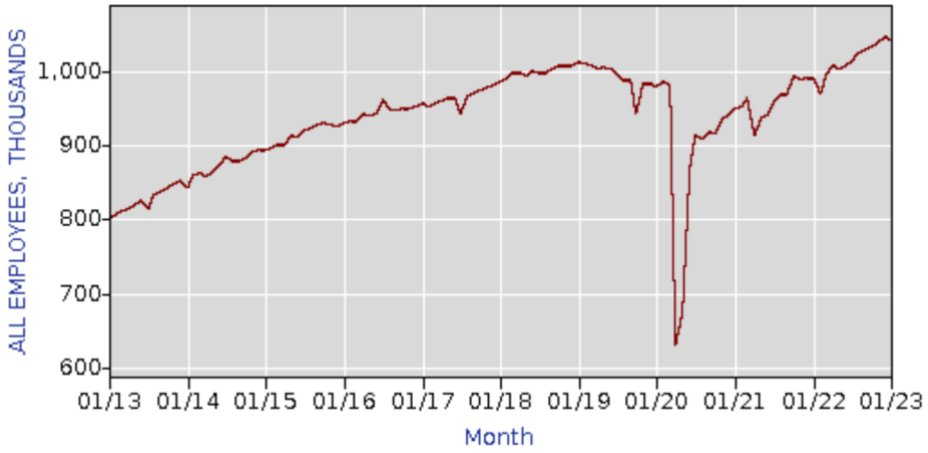

Figure 1: Employees of motor vehicles and parts, seasonally adjusted [4]

The U.S. Bureau of Labor Statistics predicts that employment of mechanical engineers in all industries will grow by 2% over the next 10 years; creating 6,400 new positions [5].

Novel in approach, this study utilizes LinkedIn, a professional networking site that allows its members to create business connections, search for jobs, and find potential clients. LinkedIn launched in early 2003 and currently hosts 900 million members. Microsoft, the owner company of LinkedIn, developed the social platform for "professional networking and career development, and allows job seekers to post their CVs and employers to post jobs" [6] South Dakota Mines students are encouraged at several points during their educational career to create a LinkedIn profile and grow their professional network.

Major automobile manufacturers were initially headquartered in or near Detroit, MI because Henry Ford lived there. Supply chain management was made more simple by rail and port access to the Great Lakes. The southern US has become increasingly attractive for automobile manufacturers with robust infrastructure, increased affordability, and a more mild climate. Figure 2, below, shows the locations of major American automobile manufacturers.

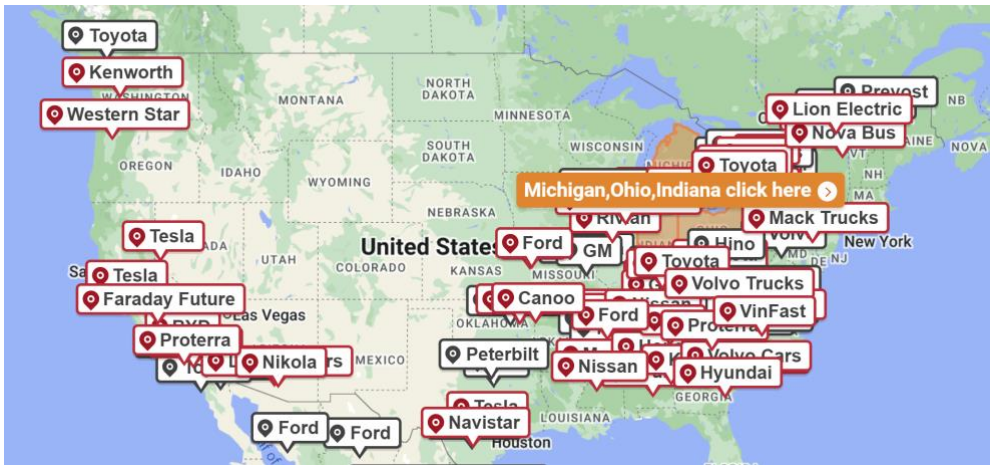

Figure 2: Locations of American Automotive OEMs [7]

Students at South Dakota Mines are geographically disconnected from the automotive industry. The distance between automotive OEM headquarters and the university correlates to weak campus recruiting efforts. South Dakota Mines hosts a career fair each semester connecting over 2,000 students with around 200 employers. [8] One hundred and twenty-six employers attended the career fair in the fall of 2022 looking to hire mechanical engineers. Only 1 employer self-identified as a company in the automotive industry (0.7%).

Literature Review

New Engineers / Students' Vision of the Workplace

There can be a disconnect between the practices of being and engineering student and that of a professional engineer. The transition from engineering student to new engineer is separated by time, but also the constraint of a curriculum teaching technical content knowledge chunked into courses, and the applied nature of work, less bounded by the necessities of academia. Through studies of these new engineers [9-13], the new-found setting of the workplace post-graduation gave rise to both the application and adaption of their school-learning to engineering problems, and the surprise of learning to navigate the social aspects of the workplace.

Future Time Horizon

Students have a foreshortened appreciation of what might be further in time as compared to those older than college age. [14] investigated college students' *future time perspective* through large-scale quantitative means; [15] examined student motivations over a time scale. [16] asked 1st year student and senior to describe and map their understandings of their undergraduate curricular / program map; first-year students looked to only mostly the next term whereas seniors have a much fuller view of their 4-year program and how it can connect to the workforce.

Future of Automotive Industry

There are also novel education programs for bringing engineering students into the automotive industry to benchmark. [17] describes an undergraduate program that offers both technical

content of how cars work with an emphasis on the business aspects of the industry. [18] proposes a holistic curriculum that includes the complexity of the automobile, with knowledge of smart devices and mechatronics as part of the learning outcomes.

LinkedIn

Other studies have used LinkedIn as a database for open-source information to understand engineering graduate placement with Chemical Engineering graduates [19] and information systems alumni [20]. This seems like a rich area of information to be able to be leveraged in increasing ways in the future.

Objective & Motivation

The aim of this study is to assess the current demands of the automotive industry for early-career mechanical engineers. Using qualitative methods, the timeline of skill awareness, development, and reflection will be pieced together. The study hopes to manage student expectations of the demands of the automotive industry and create an intervention strategy to educate underclassmen on the skillsets they can develop to be more attractive candidates for their dream careers. The study is motivated to ensure that student education quality is sufficient to achieve specific student goals.

A hypothesis is that the mechanical engineering coursework alone does not produce adequate engineering skills to meet the demands of the automotive industry. The goal of this research is to connect the skill gap, understand the demands of the automotive industry, and better educate underclassmen on the skills they need to succeed.

Methods

Using student responses and LinkedIn, the frequency of company “type” was determined to find the most desired industry of future employment. First-year students enrolled in mechanical engineering undergraduate program at South Dakota Mines are required to take a course known as “ME110: Introduction to Mechanical Engineering.” At the beginning of the semester-long course, the students were assigned their first homework assignment - to use LinkedIn to find a current job posting that is similar to their career aspiration, identify other LinkedIn users who currently hold positions similar to the freshman’s career aspiration, and evaluate the background of these professionals to create a 5-year plan of steps the freshman should take to achieve their goal. Responses were submitted for grading to D2L (Desire2Learn), “an integrated learning platform designed to create a single place online for instructors and students to interact” [21]. Responses were organized in Microsoft Excel. The student's name, aspiring position and company were recorded. Each student was assigned a number to anonymize their participation.(n=127, 3 semesters). The 127 students surveyed are considered representative of a single-entry class.

Nearly every company the students listed had a LinkedIn business profile page. Using each company profile, the company industry classification was also noted in Excel. Each company self-identifies their industry on their LinkedIn profile page. This provides an objective method of

categorizing the company industry, even when a company services multiple industries. Examples of a company's self-identified industry on LinkedIn are below. Figure 3(a)-(c) are examples of automotive industry company profiles.

Figure 3: LinkedIn Profiles of (a) General Motors [22], (b) Gestamp [23], (c) Toyo Tires [24]

Companies whose industry classification was "Motor Vehicle Manufacturing" or "Motor Vehicle Parts Manufacturing" or "Automotive" were lumped together to become the more ubiquitous term: The Automotive Industry.

Student submissions who identified a future career in the automotive industry were reviewed and 10 students were selected for interview requests. Two undergraduate students responded to the request and completed the interview. Using filter functions on LinkedIn, recent graduates (less than 5 years out of school) of the South Dakota Mines Mechanical Engineering bachelor's program working in the automotive industry were identified. (n=8). Prospective interviewees were reached out to over LinkedIn messaging and asked to schedule interviews. Two undergraduate students participated. The interview questions were qualitative and open-ended. The interview protocol included the following questions:

- How did you choose South Dakota Mines and mechanical engineering?
- What would you like to do with your degree once you graduate? What companies are you considering?
- If you could list the top 5 skills for a mechanical engineer at an automotive manufacturing company, what would they be?
- Looking ahead in your flowchart, what classes do you perceive to be most important to your future career goals?

Two recent graduates also agreed to participate in the interview. Interview questions were qualitative in nature and open-ended. Participants answered questions such as:

- How did you choose South Dakota Mines and the mechanical engineering major?
- How would you rate your satisfaction with your education with respect to your preparedness to enter the workforce?
- What about the automotive industry inspired you to seek a career there? What things keep you interested and engaged each day?
- List the top 5 skills that a mechanical engineer at an automotive manufacturing company needs. Why do you believe these to be the most important skills?
- Looking back at your curriculum flowchart, what classes do you believe were most important for your current position?

Small N

While the number of participants interview with these semi-structured qualitative interviews was 4, the very nature of qualitative research is to identify the complex patterns of participants experience and the interview protocol is aimed to get at the richness and completeness of the context of one's experience [25]. The unit of analysis is the not the person per se but rather the totality of their experiences across the number of constructs embedded in the interview questions. This number of participants is appropriate.

Table 1 Participants

Participant	Major, Status	Pseudonym
A	Mechanical Engineering, Undergraduate	*Aaron*
B	Mechanical Engineering, Undergraduate	*Brittany*
C	Mechanical Engineering, Recent Graduate	*Carl*
D	Mechanical Engineering, Recent Graduate	*Dennis*

Results

Background

The Fall 2022 Career Fair hosted 126 companies. Of those companies, 115 specified hiring mechanical engineering students for internships, co-ops, and full-time positions. Only one company present at the career fair self-identifies as part of the automotive industry.

Table 2 Industries present at Career Fair

Career Fair Company Industry	*Quantity*
Oil/Gas/Mining	18
Construction	17
Appliances, Electrical, and Electronics Manufacturing / Semiconductor Manufacturing / Computers and Electronics Manufacturing	11
Industrial Machinery Manufacturing	9
Utilities	7
Armed Forces	6
Machinery Manufacturing	6
Wholesale Building Materials	5
Civil Engineering	4
Manufacturing	4
Medical Equipment Manufacturing	3
Defense and Space Manufacturing	3
Food and Beverage Manufacturing	3
Automation Machinery Manufacturing	3
Research Services	2
Chemical Manufacturing	2
Hospitals and Health Care	2
Environmental Services	2
Design Services	2
Public Safety	1
Aviation and Aerospace Component Manufacturing	1
Truck Transportation	1

Civic and Social Organizations	1
Motor Vehicle Manufacturing	1
Insurance	1

In the ME110 assignment, 33 of 127 freshmen identified a company classified as “Motor Vehicle Manufacturing” as their ideal/ dream company.

Table 3 Industries of interest identified by students

Industry	*Quantity*
Motor Vehicle Manufacturing	33
Aviation and Aerospace Component Manufacturing	27
Defense and Space Manufacturing	15
Machinery Manufacturing	9
Industrial Machinery Manufacturing	5
Sporting Goods and Manufacturing	5
Technology, Information, & Internet	4
Construction	3
Appliances, Electrical, and Electronics Manufacturing	2
Automation Machinery Manufacturing	2
Chemical Manufacturing	2
Armed Services	1
Design Services	1
Environmental Services	1
Information Technology & Services	1
Musicians	1
Non-profit Organizations	1
Research Services	1
Semiconductor Manufacturing	1
Unidentified	12

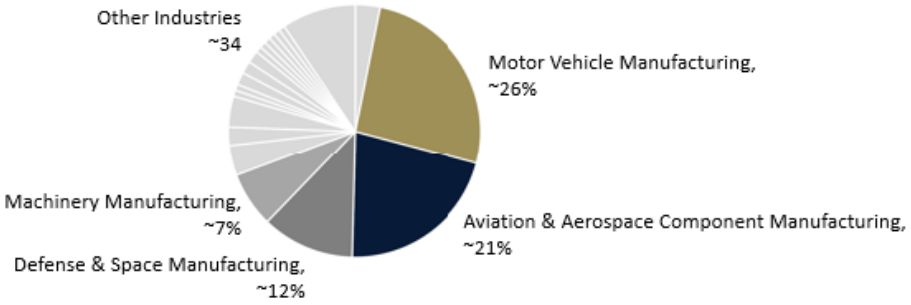

Figure 4 Industries of interest identified by students.

Half of the students indicating a motor vehicle manufacturing company chose Tesla, an American-based electric vehicle manufacturer, as their first-choice company.

Table 4 Automotive companies identified by students.

Company	*Quantity*
Tesla	17
Ford Motor Company	5
General Motors	3
Toyota Motor Company	2
Navistar	1
PACCAR	1
BorgWarner	1
Honda	1
Cooper Tire & Rubber Company	1
Toyo Tires	1

As students prepare for graduation, the career services center at South Dakota Mines requests that students fill out a short survey indicating their post-graduate plans.

Data from the last 5 years of mechanical engineering graduates was combined. Survey data is self-reported, and the survey completion is optional (n=383).

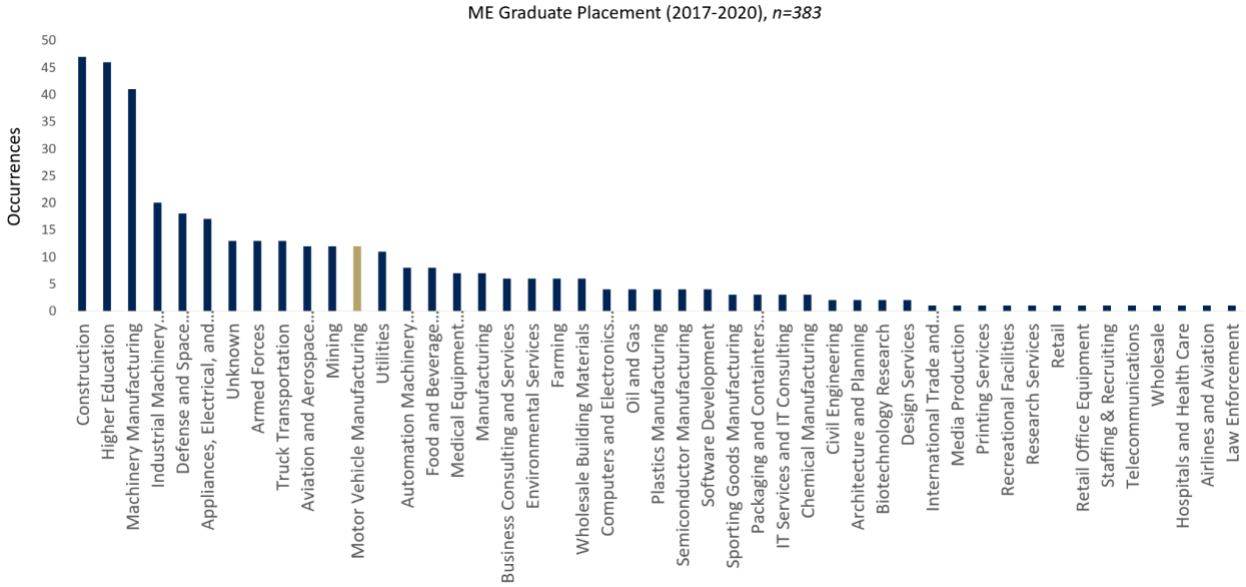

Figure 5 Industry type employing new engineers.

Underclassmen - Skill Recognition

Freshman *Aaron* is interested in a future engineering career at Tesla, Inc. They are interested in new technologies and automobiles and sees a future where those interests can be combined. Freshman *Brittany* is interested in a future engineering career at General Motors Company. They pursue automotive-related hobbies in their free time and feel they would enjoy a career in the automotive industry.

The interviews with the current underclassmen highlighted the range of maturity at this stage in educational development. The linear spectrum is from “the uninformed student” to the “informed student.” The uninformed student did not have many expectations for their core mechanical engineering coursework, no expectations for their career, was near-sighted in planning, and focused on technical skills. The informed student had some emerging expectations for their future coursework and career, had a rough plan for the next 4 years, and valued both soft/intrapersonal and technical skills somewhat equally.

Underclassmen listed Computer-Aided Design (CAD), Communication, Teamwork, Problem Solving, Understanding the Design Process, and Mathematics as the critical skills needed in the automotive industry.

The Freshmen were asked if they have considered further education like a Master’s or PhD program upon completion of their current degree. Both participants answered that the thought had crossed their minds but neither of them had looked into pursuing it.

Recent Graduates - Skill Development

Recent graduate *Carl* is currently employed as a design engineer at a motor vehicle accessory manufacturer. They are passionate about building classic cars and trucks in their free time and find great interest in working with modern automobiles and being a part of the automotive industry.

Recent graduate *Dennis* is currently employed as a mechanical engineer at a company that manufactures refuse trucks. They appreciate problem-solving and facing unknown problems in the automotive industry. They participated in an automotive collegiate design competition team during school. Both recent graduates are still employed at the company they accepted after graduation and have over a year of experience in their current position. When asked to list the critical skills needed in the automotive industry, Recent Graduate *Carl* listed SolidWorks/CAD modelling, interpersonal skills, industry-specific machining/manufacturing knowledge, ability to learn in a hands-on environment, and time management. When asked to list the critical skills needed in the automotive industry, Recent Graduate *Dennis* listed industry-specific manufacturing knowledge, SolidWorks/CAD modelling, stress analysis, interpersonal skills, and the ability to read and understand electrical schematics.

Each recent graduate was asked what they believed to be the biggest problem or challenge the automotive industry faces within the engineering scope. The graduates had different, but not opposing answers. Recent Graduate Carl stated that the biggest challenge is “the rooted belief that this is perfect the way they are.” Recent Graduate Carl continued by explaining that they believe the automotive industry is resistant to change and innovation. Recent Graduate Dennis sees big problems in workforce ability and supply chain issues. Recent Graduate Dennis explained that these are equally large problems that they and their company face every day.

Both recent graduates currently hold only a Bachelor’s Degree in Mechanical Engineering. When asked if they have considered pursuing further education with a Master’s or PhD program,

both participants answered yes. When asked to consider their future career goals and whether or not further education would be required, Recent Graduate Dennis answered that it would provide them with in-depth knowledge of new technologies that they might not have had access to during their early career. Recent Graduate Carl felt that higher education is "the key." Recent Graduate Carl stated that many companies see the 4-year Bachelor's degree as the bare minimum for entry into the automotive industry and that to truly advance in the industry, a Master's degree is "necessary."

Recent Graduates were then asked to respond to the following statement: "*Graduates from the mechanical engineering program at South Dakota Mines find difficulty entering the automotive industry because they lack the skills necessary to meet the demands. The access to these skills is limited by the size and geographic location of South Dakota Mines."*

Recent Graduate Carl felt that they more strongly agree with the above statement. They explained that many of their coworkers are graduates of schools known for their ties to the automotive industry and that it is difficult to get "your next in the door when you are not at that certain level [of automotive knowledge] when you graduate." Recent Graduate Carl said that the Mechanical Engineering program at South Dakota Mines curates good engineers with broad knowledge that can be applied to any industry, but added, a deep dive into automotive-related engineering is missing.

Recent Graduate Dennis stated that they "somewhat agree" with the above statement. Recent Graduate Dennis explained that they believe that automotive companies recruit from larger schools that they have formed partnerships with because of geographic location. Recent Graduate Dennis explained that national conferences are a good place for students at South Dakota Mines to interact with these large automotive companies and that students can participate in these conferences through involvement with student chapters on campus. Recent Graduate Dennis added that they don't believe that graduates lack skills, but lack access to industry-specific knowledge that students at other universities are more readily exposed to.

When asked how they would rate their satisfaction with their education with respect to their sense of preparedness to enter the workforce, both recent graduates gave similar answers. Recent Graduate Carl answered with a 6.5 and Recent Graduate Dennis answered with a 7.5. Both were then asked if there was anything the Mechanical Engineering Department could do to improve their ratings. Recent Graduate Carl said that they felt the electives offered by the department were not career-based, and wished they had formal education on industry documentation and standards. Additionally, they felt the addition of more electives, and more specialized electives in many industries could greatly improve the program and help students make more informed decisions on their future careers. Recent Graduate Dennis express the importance of hiring high-quality instructors and professors that are passionate and well-educated in the subject matter they teach. They added that Mechanical Engineering is a broad degree without much room to make changes to the core curriculum, but that the addition of more electives to explore different career possibilities would be beneficial to students.

Future Work

In progress work for this study includes the interviews and data collection from recent graduates of the mechanical engineering program with current positions in the automotive industry. Future work for this study includes interviews and data collection with industry experts and technical hiring managers and planning an intervention strategy. This project can be extended by using LinkedIn as a search database for mechanical engineers, design engineers, and engineering hiring professionals with over 10 years of experience can be selected to be contacted for interviews. We hope to extend this research to beyond just the sole context of automotive engineering.

Discussion and Implications

The down-selecting from students' interests in automotive engineering from the start of their college experience to graduation is a curious phenomenon. It might be that there are discoveries of ancillary interests, work for OEM or parts manufacturers within the same applied plan. It might be that the paucity of automotive engineering companies geographically stifle possible professional development for students as future engineers.

How might we further expose students to a multiplicity of possible future careers and industries? There may very be additional interventions or mindful efforts to bring automotive engineering companies to campus, or plan for trips to hubs of automotive engineering innovation in Michigan and California and other places where the automotive industry had been well-established.

The novelty of using LinkedIn to have students imagine their future selves is an interesting takeaway from this research project. The notion of future selves well off in a time horizon may be worth future exploration within the context of automotive engineering and across many more areas of mechanical engineering. Already as part of an assignment in a first-year engineering course, we ask students to find people listed on LinkedIn who have achieved their future career goals.

Implications for the Classroom

Mechanical engineering is a broad field, encompassing the transformation of energy and matter in a number of sub-fields. New students certainly have the concrete experience of riding in cars but may not necessarily have the appreciation of the complexity of what goes on under the hood. The application of fundamental engineering concepts can more explicitly be made within introductory engineering courses.

Might it be that engineering graduates cannot be what they can't see? This might highlight an opportunity to be more aware of what examples and contexts are used, both formally and informally, in the service of example of technical content as well as general people from industry who are invited to a college campus. It might be effort to diversity the types of people we may regularly use as examples for what mechanical engineers are, may become, or industries and populations they can be drawn from. We can be more expansive when thinking about the engineers of the future.

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