

Leveraging a Newly Developed Sophomore Design Course to Increase Students' Career Awareness

Dr. Cassandra M Degen, South Dakota School of Mines and Technology

Dr. Cassandra Degen received her B.S. degree in Metallurgical Engineering from the South Dakota School of Mines and Technology in 2007. She received her Ph.D. in Materials Science and Engineering in 2012 from the University of Illinois at Urbana-Champaign, studying mechanochemical reactions of a spiropyran mechanophore in polymeric materials under shear loading. She is currently an Assistant Professor in the Mechanical Engineering department at the South Dakota School of Mines and Technology where her research interests include novel manufacturing and characterization techniques of polymer and composite structures and the incorporation of multifunctionality by inducing desired responses to mechanical loading.

Dr. Shaobo Huang, South Dakota School of Mines and Technology

Dr. Shaobo Huang is an Assistant Professor and the Stensaas Endowed STEM Chair in the Department of Mechanical Engineering at South Dakota School of Mines & Technology. Her research interests include student retention and academic performance in engineering, student achievement evaluation and assessment, and K-12 STEM curriculum design.

Dr. Marius D Ellingsen, South Dakota School of Mines and Technology

Assistant Professor at South Dakota School of Mines and Technology, Mechanical Engineering Department. Teaching solid mechanics related courses. Researches Stem Ed and fracture mechanics in novel material systems.

Dr. Karim Heinz Muci-Kuchler, South Dakota School of Mines and Technology

Karim Muci-Küchler is a Professor of Mechanical Engineering and Co-Director of the Experimental and Computational Mechanics Laboratory at South Dakota School of Mines and Technology (SDSM&T). Before joining SDSM&T, he was an Associate Professor of Mechanical Engineering at the University of Detroit Mercy. He received his Ph.D. in Engineering Mechanics from Iowa State University in 1992. His main interest areas include Computational Mechanics, Solid Mechanics, and Product Design and Development. He has taught several different courses at the undergraduate and graduate level, has over 50 publications, is co-author of one book, and has done consulting for industry in Mexico and the US. He can be reached at Karim.Muci@sdsmt.edu.

Dr. Mark David Bedillion, Carnegie Mellon University

Dr. Bedillion received the BS degree in 1998, the MS degree in 2001, and the PhD degree in 2005, all from the mechanical engineering department of Carnegie Mellon University. After a seven year career in the hard disk drive industry, Dr. Bedillion was on the faculty of the South Dakota School of Mines and Technology for over 5 years before joining Carnegie Mellon University as a Teaching Faculty in August 2016. Dr. Bedillion's research interests include distributed manipulation, control applications in data storage, control applications in manufacturing, and STEM education.

John Ziadat, South Dakota School of Mines and Technology

Mr. Ziadat received his Bachelor's degree in Mechanical Engineering from the South Dakota School of Mines & Technology (SDSM&T) in 2014 before going to work for Space Exploration Technologies (SpaceX) in Hawthorne, CA as a Mechanical Design Engineer. In 2015, his decision to pursue graduate studies in Mechanical Engineering led him back to SDSM&T, where his thesis topic involves the numerical simulation of ballistic impact events. Mr. Ziadat is expected to receive his Master's degree in May 2017, after which he will be working as a Structural Analyst within Blue Origin's Propulsion Analysis group, located in Kent, WA.

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INTRODUCTION

While the numbers of under-represented groups in Mechanical Engineering fields have increased significantly in the last 25 years, the numbers are still small, particularly when compared to their representation within the general public. A survey that queried 62 science, technology, engineering, and mathematics (STEM) occupations, the mechanical engineering occupation had the lowest female representation (6%), and a low non-white population (11%) [1]. This under-representation trickles down to populations of undergraduate students studying mechanical engineering. Women and minorities make up more than two-thirds of the United States workforce, yet only represent 23% of engineering graduates [2].

Many groups' research has indicated a number of items that work to deter women and minorities from pursuing and persisting in engineering. Johnson and Sheppard [3] found that women had a higher potential for disillusionment with engineering and the assumed engineering lifestyle, as well as being less interested in the often competitive engineering education. The ability to pay for college was found to be a major barrier for minority students persisting in engineering [4]. Busch-Vishniac and Jarosz [5] explored the possibility that the curriculum itself is a barrier to underrepresented groups and cited the need for a curriculum that "retains the salient technical material but is more attractive to underrepresented groups and probably majority populations as well." A number of engineering curriculum features have been shown to deter underrepresented groups from entering engineering, such as the lack of integration of engineering topics throughout the curriculum, the lack of social relevance in engineering coursework [5], the lack of exposure to contributions to engineering by minority groups, and the seemingly inflexibility of career choices as perceived by some students [1].

Many mechanical engineering programs indeed tend to have ties to "traditional" teaching methods and curricula, often prevalent in the form of homogeneous examples that faculty may show in lectures and that textbooks tend to utilize for homework problems. Students' pre-conceived ideas about career options for mechanical engineers can impact enrollment and retention, particularly for under-represented groups [6,7]. For instance, textbooks for many mechanical engineering subjects mostly use machinery for example problem. The overabundance of these examples, along with the stereotypes that many prospective students have about what mechanical engineers do, often deter good students from choosing to pursue or from staying in this particular field. While examples in other areas are becoming more prevalent (medical devices, robotics, etc.), significant work is yet to be done to help clarify the question for prospective students of "What do mechanical engineers do?". Providing students with a broader context of careers in mechanical engineering early in their education may help increase both enrollment and retention, particularly of under-represented groups who may be more likely to be turned off by stereotypical examples and career choices, increasing the diversity of professionals in the field [8,9].

At the South Dakota School of Mines and Technology (SDSM&T), the department of Mechanical Engineering has some of the lowest percentages of under-represented groups on campus. Programs across campus have helped enrollment of many groups. The Women in Science and Engineering (WiSE) program has been successful in providing support for women on a campus that offers only science and engineering degrees and is predominantly male. While programs such as WiSE have been successful in increasing diversity in STEM fields on the SDSM&T campus, the department of Mechanical Engineering is still struggling in recruiting and retaining a diverse population of students. In 2016, the Mechanical Engineering department consisted of 599 undergraduate students and just 8.7% of these students were women and 8.3% identified themselves as American-Indian, Asian, or African American. In recent years, retention has been falling as well. The total retention (measured as students who started as Bachelors of Science Mechanical Engineering students and returned as Bachelors of Science Mechanical Engineering students for a second fall) in Mechanical Engineering was 78%, 72% and 65% for cohorts of students in 2012, 2013, and 2014, respectively. The retention of women however, was 85%, 82%, and 39% for the same 2012, 2013, and 2014 cohorts, respectively. These low numbers show that there is still significant work to be done in recruitment and retention of under-represented groups in Mechanical Engineering at SDSM&T.

Significant research has been done on appropriate methods to improve the culture of engineering to increase both enrollment and retention [10-14]. The work presented here reports on a recent curriculum change with the potential to affect students' career awareness in the Mechanical Engineering department at the South Dakota School of Mines and Technology. Beginning in the Fall of 2016, a new track was added to an existing sophomore design course, with the main objective to increasing students' systems thinking skills. Within this new course, systems thinking concepts were presented to the students keeping a second objective in mind: providing a wide variety of examples and case studies representative of different career options that mechanical engineers have. In addition, the topics in the course were presented using an approach designed to not only capture the attention of the students, but to ensure a deep understanding of the topics covered. The examples and case studies presented in the course were based in a number of different fields with the goal of exposing students to different career opportunities within their chosen major. Indirectly, the work aims to increase the recruitment and retention of underrepresented groups in the Mechanical Engineering department at the South Dakota School of Mines and Technology career.

To assess student perceptions of career options for mechanical engineers, a career awareness questionnaire was developed and employed. Sophomore students enrolled in the systems thinking sophomore design course were given the career awareness survey in pre- and post-tests at the beginning and the end of the semester to gauge changes in their perceptions resulting from the new course content. In addition to surveying the sophomore students, freshmen and senior students who had not been exposed to the new course content were also assessed.

CURRICULUM CHANGE

The Mechanical Engineering curriculum at the South Dakota School of Mines and Technology includes a design course at the sophomore level. The department has offered 2 design courses in

the past, each with a different focus, at the sophomore level: Electromechanical Systems Product Development and Design and Energy Systems Product Development and Design. Both courses fulfill the graduation requirement, and students are allowed to choose either course based upon their interests. A team of faculty in the Mechanical Engineering department, the authors, recently created a third option of sophomore design with a focus on systems engineering. This course, Product Design and Development - Introduction to Systems Engineering, was developed and implemented in the fall of 2016 in an effort to increase the systems thinking skills of our graduates.

As a part of the newly developed course, the authors developed primers and case studies associated with core concepts of systems engineering (concept generation, identifying customer requirements, setting target specifications, and systems architecture) [15-17]. The purpose of the primers was to motivate students in each area, and the purpose of the case studies was to further drive the systems engineering concepts home. Both were used as supplements to the regular course lecture material. For each of the primers and case studies, examples of products were carefully chosen to highlight more non-traditional areas of mechanical engineering. As a second goal of the new Introduction to Systems Engineering course, the team was interested in methods to increase student awareness of career options outside fields that are considered traditional fields for mechanical engineers to enter.

CAREER AWARENESS QUESTIONNAIRE

Students' career awareness was assessed with four foci: perceived job scope, career preferences, understanding of the interview process, and job description identification. A questionnaire was developed and given to students in the sophomore level Introduction to Systems Engineering course both before the course began and at the end of the course to investigate whether the specifically chosen examples and case studies impacted the students' career awareness.

Overall perceptions of job scope: Two four-point Likert scale questions were created to investigate students' perceived relevance of positions provided at twelve companies to mechanical engineering field.

1. How closely do positions at the following institutions/organizations relate to mechanical engineering?

The institutions/organizations included automotive companies, battery companies, law consulting firms, food processing companies, international trading companies, hospitals, toy manufacturing companies, sales departments, construction, and government (e.g. an officer at a branch of the military).

2. How has your perspective in each item mentioned below changed because of courses offered by the Mechanical Engineering Department that you took or are currently taking?
 - a. How I can become a mechanical engineer
 - b. The work I can do as a mechanical engineer
 - c. The types of companies that hire mechanical engineers

Career preferences: A total of four questions were involved to assess students' career preferences.

1. Where can you see yourself in five years?

The options included positions at private companies, government organizations, and military relevant institutions.

2. How likely do you think it is you will change your career goal before you graduate? (Rate from Very unlikely to Very likely)
3. Rank the reasons for you to select a career. Please use consecutive numbers starting with 1 for the most important, 2 for the second important, etc. Select N/A if you think that a factor/skill does not help result in a successful job application.

The options for this question included good salary, I have previous experiences relevant to the occupation, my family member(s) is/are in that field, impact from role model(s) who are not my relatives, it is personally satisfying to work in that field, it is important to society to have somebody work in that field, and the job is very interesting to me.

4. Assume you have multiple job offers. What are the top 3 reasons for you to accept a company's offer?

The reasons ranged from subjective reasons such as personal satisfying, to influence of others such as relatives in the same field, and to objective conditions such as salary.

Understanding the interview process: Students were asked to rank the factors that might impact job application and interview results.

1. Rank the following factors by the effect you think they have in the success of a job application. Please use consecutive numbers starting with 1 for the most important, 2 for the second important, etc. Select N/A if you think that a factor/skill does not help result in a successful job application.
2. If a student was not successful in the first round of interviews for an engineering position, what do you think could be the primary reasons? Select the top 3.
3. If a student was not successful in the final round of interviews for an engineering position, what do you think could be the primary reasons? Select the top 3.

Technical factors included internship experience, engineering design skills, computer skills, extra-curricular experience, product design knowledge, and GPA. Non-technical factors included leadership skills, communication skills, foreign language, teamwork, thinking holistically, creativity, salary expectation, and familiarity with the company's business.

Job description identification: Students were given actual job descriptions advertised at various companies for mechanical engineers. Any wording that gave away the particular company was masked. Students were then asked to identify the top 3 companies that were likely to post such a job description. One example of a job description posted by the US Navy given below:

"Duties include reviewing all design and specifications for changes to mechanical systems; writing requests for design-build proposals; conducting technical engineering inspections, studies, and audits of existing infrastructure to facilitate maintenance and provide optimum system performance and reliability; and monitoring construction projects to assure compliance with contract provisions and standards."

For each job description, 12 choices of companies/organizations were given as choices for students: Ford, Caterpillar, Airbus, Lockheed Martin, NASA, U.S. Navy, GE, Maytag, Apple, Exxon/Mobile, Coca Cola, and Disney.

RESULTS

Overall perceptions of job scope:

When asked to rate (1-5 on a Likert-scale) how closely a particular field relates to mechanical engineers, students' perceptions increased slightly after the Introduction to Systems Engineering course for nearly all of the listed industries (Figure 1). The industries with the largest increase of how closely students related them to mechanical engineers were battery companies, international trading companies, hospitals, and government. The increase in students' association of these non-traditional fields for mechanical engineers suggests that the course material of the Introduction to Systems Engineering had a positive impact on students' perception of career choices for mechanical engineers.

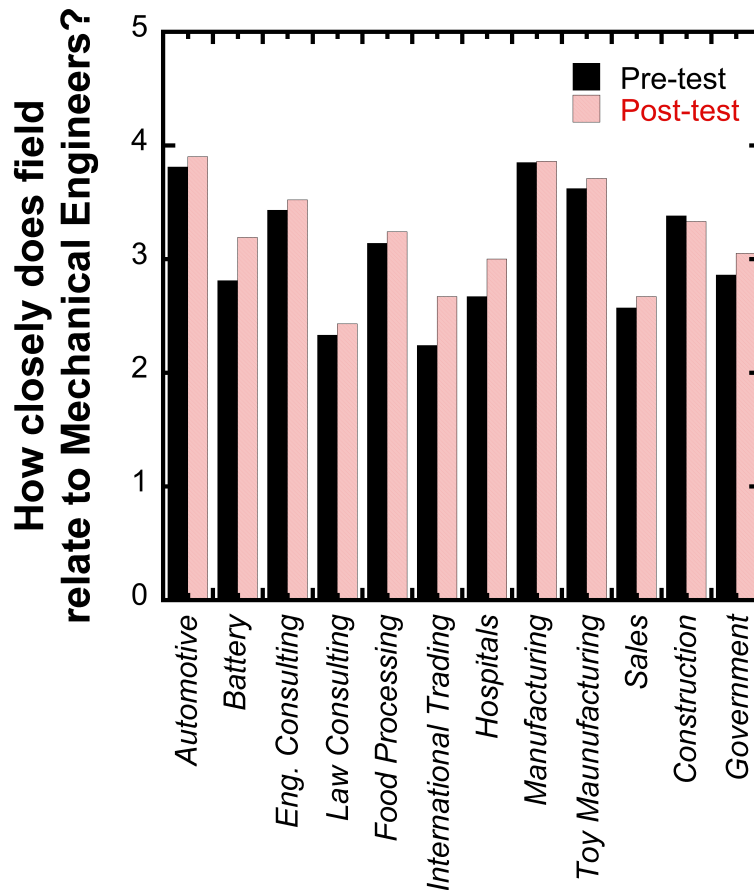


Figure 1: Student perceptions of how closely specific industries relate to mechanical engineers on a 5-point Likert scale both before and after being exposed to material delivered in the new Introduction to Systems Engineering course.

Career preferences:

The results from career preference questions showed that students' knowledge of specific companies increased slightly for nearly all companies listed on the questionnaire. In addition, there was a large increase in the percentage of students who had heard of Airbus. While no specific examples introducing Airbus were given during the course, the authors hypothesize that students' own research for projects during the course may have led to an increase in their knowledge of companies they hadn't heard of before the course.

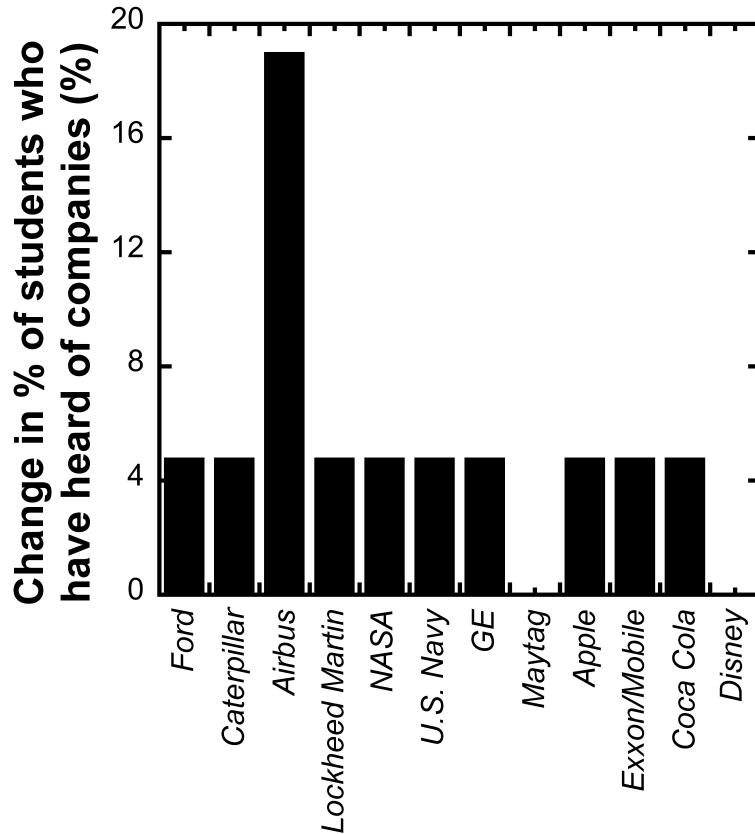


Figure 2: Change in % of students who have heard of specific companies from pre- to post-questionnaire.

Understanding the interview process:

When asked to rank the importance of 11 factors in relation to the job application process before being exposed to the new course material, students listed communication skills, internship/co-op experience, and teamwork skills as the top 3 factors affecting their job application success. Near the end of the semester, the students listed internship/co-op experience, GPA, and communication skills as the first, second, and third most important factors in the job application process, respectively. Although teamwork skills are essential to a successful project, it is hard to present and measure these skills during an interview. In the post-test, students emphasized more on the factors could be measured objectively (i.e. GPA and internship/co-op experience) and be assessed during the interview process (i.e. communication skills).

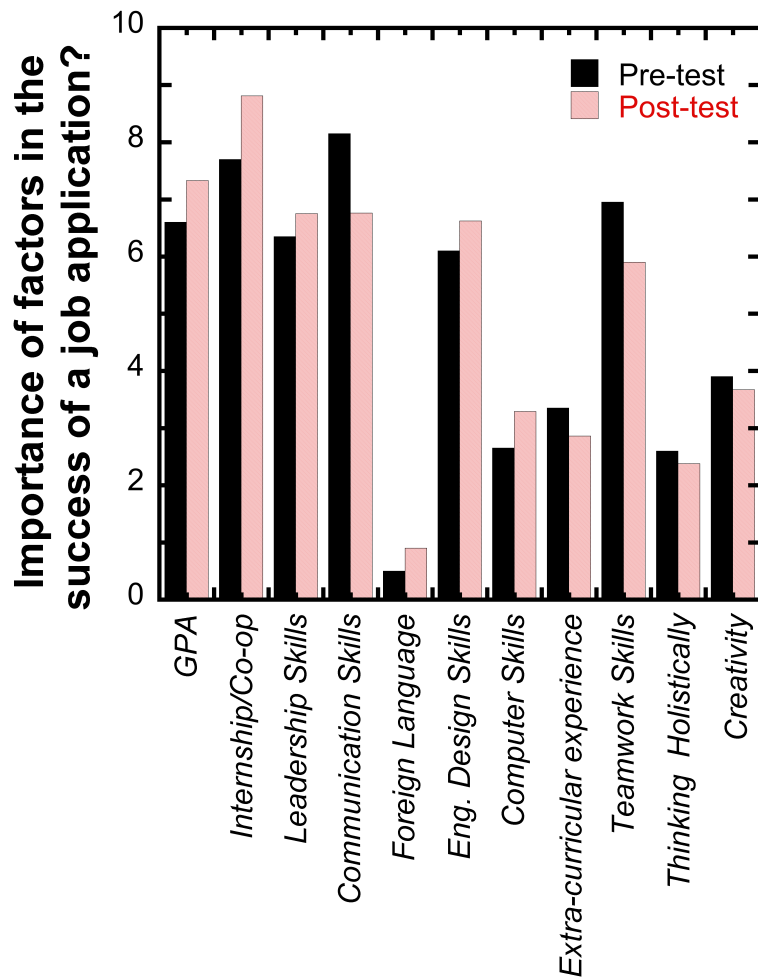


Figure 3: Average student ranking of importance (11 = most important) of various factors in the success of a job application prior to and following the Introduction to Systems Engineering course.

Job description identification:

The final aim of the career awareness questionnaire was to measure the ability of students to recognize job descriptions and their associated companies. The results from the questions asking students to match actual job advertisements for mechanical engineering positions to the company/organization that posted the position showed that over the course of the semester in which the students were enrolled in the new Introduction to Systems Engineering course, they increased their ability to match company to job description. Students were given 10 job descriptions, correlating to 6 companies or organizations. With options to select matching companies from a list of 10 companies, there was a positive increase in the number of students answering correctly for 9 out of 10 of the job descriptions (Figure 4). The authors attribute this increase in awareness of job opportunities at various companies to exposure of the students to a variety of examples from many fields within mechanical engineering over the semester.

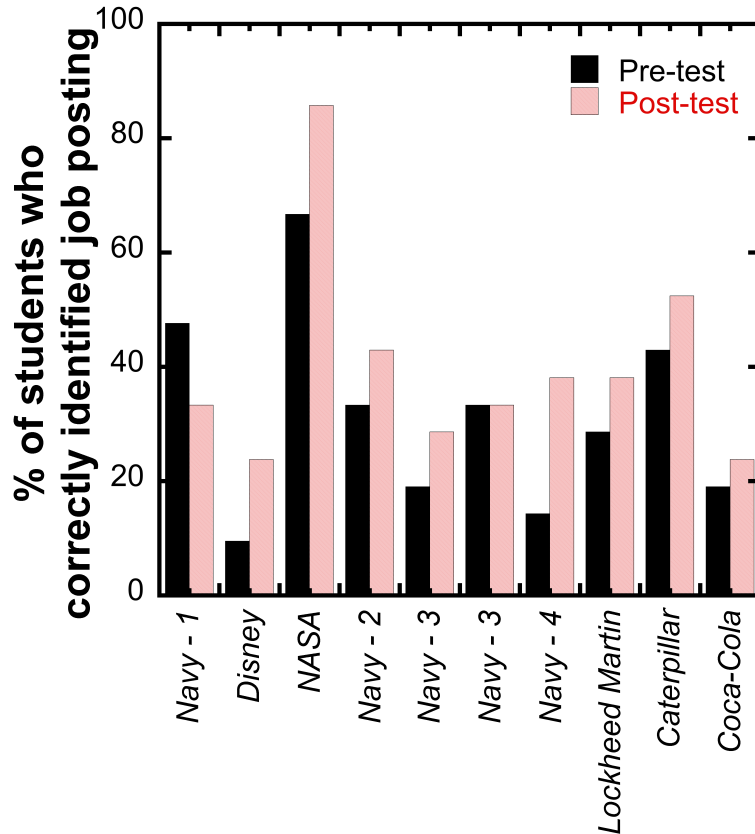


Figure 4: Number of students correctly matching the given job description to the posting company or organization both prior to and following their exposure to material in the Introduction to Systems Engineering course.

CONCLUSIONS

The implementation of a newly developed career awareness questionnaire aimed to assess student perceptions and understanding of a variety of issues associated with career choices. Introducing students to non-traditional career paths can be done in a variety of ways and for this work was done through examples and case studies in a new course at the sophomore level, Introduction to Systems Engineering. Overall, student perceptions of career choices for mechanical engineers were heightened by increasing their knowledge of companies, expanding their insights on fields that mechanical engineers can enter, and increasing their ability to correctly match job descriptions to the correct company or organization. Comparisons between students' responses to the career awareness questionnaire before and after taking the Introduction to Mechanical Engineering course show that the introduction of more non-traditional examples and career paths influenced the students' perceptions of the career options that mechanical engineering graduates can pursue and showcased alternatives that were more attractive to underrepresented students. Future work in this area includes improving the questions by interacting with industry and other academic partners and integrating activities into early curriculum that increase undergraduate engineering, particularly female and minority, students'

awareness of career options as well as preparations. In addition, students will be tracked longitudinally to see the impact of the study over their undergraduate educational career.

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