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Using a multidisciplinary engineering project in a first-year engineering course for educationally disadvantaged students

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Abstract

A multidisciplinary engineering project experience was developed and incorporated into a first-year engineering course. This course is an academic success and professional development course that aims to retain educationally disadvantaged students in engineering. Students enrolled in this course were non-calculus-ready first-year engineering students. Many were from underserved populations (women, underrepresented minorities, first-generation, low-income, etc.). Students were tasked to apply multiple engineering disciplines (petroleum and natural gas engineering, civil engineering, environmental engineering, and mechanical engineering) to design a scale model of a safe, cost-efficient, and environmentally friendly oil derrick. Non-engineering factors that were to be considered included societal, global, and cultural factors. In addition, a multidisciplinary judge panel, composed of experts from academia and industry in engineering, math, education, business, and library services, was used for the Poster Expo event. Further, an elevator pitch practice session was conducted with a senior entrepreneurship advisor from the business start-up accelerator within the university.

The multidisciplinary project experience was largely enjoyed by the students surveyed (N=16). Eighty eight percent of students reported the multidisciplinary project design experience was positive to their learning experience. Eighty percent of students reported the multidisciplinary judge panel during the Poster Expo had a positive impact on their learning experience. Eighty eight percent of students reported the project increased their interest in engineering. Ninety four percent of students were retained in engineering by the end of the course in 2022 (N=17), which is much higher than the retention rate in the same course in 2021 (58%, N=17).

Introduction

Research has shown that students are losing interest and motivation to continue in engineering within the first two years of college, an important reason for students leaving engineering programs[1]. Therefore, maintaining the interest in engineering for first-year engineering (FYE) students is critical to promote student retention in engineering. Many multidisciplinary engineering experiences have been developed and used in engineering education, particularly undergraduate engineering academic programs, including multidisciplinary projects[2], multidisciplinary teams[3], multidisciplinary design[4], and more. They have shown positive effects on students' interest in engineering, learning experience, engineering entrepreneurship mindset cultivation, and retention within engineering[5-7].

ENGR 112 Professional Development in Engineering at West Virginia University (WVU) was created to support the retention of educationally disadvantaged FYE students in their first semester in college. Students in this course are non-calculus ready and many are from underserved populations (e.g., women, underrepresented minorities, first-generation students, and low-income students). Retaining them in engineering has been challenging. For example, an engineering project (pasta bridge) used in 2021 was attractive to civil engineering students but not for students with other engineering interests. A multidisciplinary project could be a better fit in this course to engage students from all engineering disciplines.

A drilling derrick, or rig, is an important structure used to drill water wells, oil wells, or natural gas extraction wells (Figure 1). The oil derrick supports the load of the drill string above the blowout preventer while working on a well and is responsible for the load of the drill string in tension or compression and in many different environments. They can be found on land or offshore and are constantly modified to keep up with new technologies[8] and the needs of sustainability in industry[9]. Today, they are not only used to support a drill string drilling on fluid with oil or water-based mud as was ten years ago but also equipped to drill using air. Therefore, the design of oil derricks needs multidisciplinary collaboration between petroleum and natural gas engineering, civil engineering, environmental engineering, and mechanical engineering, and outside of engineering for factors such as societal, global, and cultural.

The objective of this research was to develop and incorporate multidisciplinary experiences into this FYE course for educationally disadvantaged students and evaluate their effects on students' learning experience and interest in engineering. The multidisciplinary experience includes both a multidisciplinary engineering project (oil derrick design) and a multidisciplinary technical communication experience.

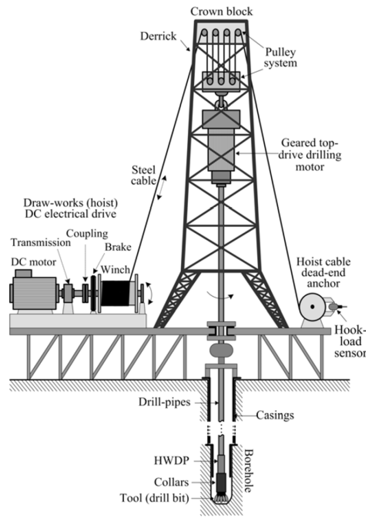

Fig. 1. Oil derrick example[10].

Methodology

Design of the multidisciplinary experience

ENGR 112 in the Fall 2022 incorporated multidisciplinary experiences. Students were tasked to design a working scale model of an oil derrick with a pulley system on top to lift at least 3 kg mass load from a starting position of resting on the floor to at least 15 inches above the floor using a PASCO Structure Kit. Each team was given a PASCO Structure Kit with the following components: different sizes of I-beams (members), full round connectors, half round connectors, angle connectors, axle spares, strews, and drive wheels. The working model was evaluated by the quality of design (professional looking, free-standing, stable, and safe), weight, and dimensions. PASCO wireless Bluetooth sensors that connected to the SparkVue application were used to measure the force on different members of the derrick during the testing so that data analysis on the compression and tension forces applied to different members can be conducted. The design was also required to consider at least three of the following factors: public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors while also engaging in a multidisciplinary discussion on those factors in their technical report and poster presentations. The design followed a five-step engineering design process (Define, Imagine, Evaluate, Create, and Test). Literature review, technical report, and poster presentation were required during the project.

The multidisciplinary technical communication experience created for ENGR 112 includes a multidisciplinary judge panel for the Poster Expo event and elevator pitch practice with business advisors from WVU LaunchLab, a university-operated startup incubator, prior to the Poster Expo. Judges included experts from academia and industry in engineering, math, education, business, and library services.

Assessment of the learning experience and its impact

Direct Assessment of the project includes Team Agreement Assignment (5%), Two Peer Evaluations (15%), Working Model (30%), Poster Presentation (20%), and Technical Report (30%) including 5% Report 1 (Introduction, Problem Statement, and Background), 5% Report 2 (Revised Report 1 plus Methodology), 5% Report 3 (Revised Report 2 plus Results), and 15% Final Report, which assessed students' skills on teamwork, engineering design process, and technical communication.

A qualitative method (survey) was used to assess students' perspectives of the multidisciplinary experience on their learning and its effect on their interests in engineering. The survey was created using the Qualtrics XM service, a suite of online software that includes an online survey package and is often referred to as "Qualtrics" by academics. After the completion of the students' project and poster presentation (Poster Expo), students were provided a scannable Quick Response code to complete the survey. ENGR 112 student demographics was: 24% female, 35% underrepresented minorities, and 24% first-generation students. Low-income student ratio is not available. Their intended engineering major choices are shown by Figure 2. Some students were enrolled in more than one degree (i.e., dual degree programs).

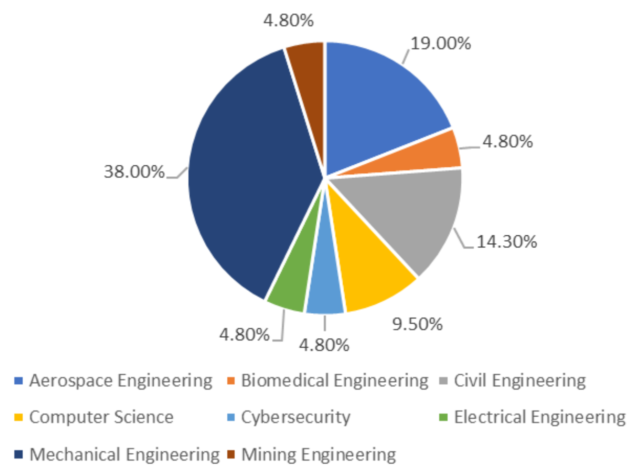

Fig. 2. Student Academic Major Choices in ENGR 112.

Results

Project Results (Direct Assessment of the Project)

There were four teams in this course in Fall 2022. Each student team researched topics related to civil engineering (truss structure), mechanical engineering (pulley system), petroleum and natural gas engineering (oil drilling), and environmental engineering (environmental effects), etc. Student teams heavily considered safety, environmental, and economic factors in their design but some teams also discussed their incorporation of global, social, and cultural factors in their technical report and poster presentation. Students were given up to one week to construct and improve their models in the lab, including one class period, and another class period to test the model with the instructor (Test Day). All teams completed their models on time though Team 3 took significant more iterations than other teams to make their model functional and meeting all constrains. On the Test Day, all models met requirements on professional looking, free-standing, stability, and constrains on weight, dimensions, and weightlifting capability. On the contrary, AY 2021 class only had one team meeting all constrains. Figure 3 shows different final designs from each team. Team 2 wrote the best technical report.

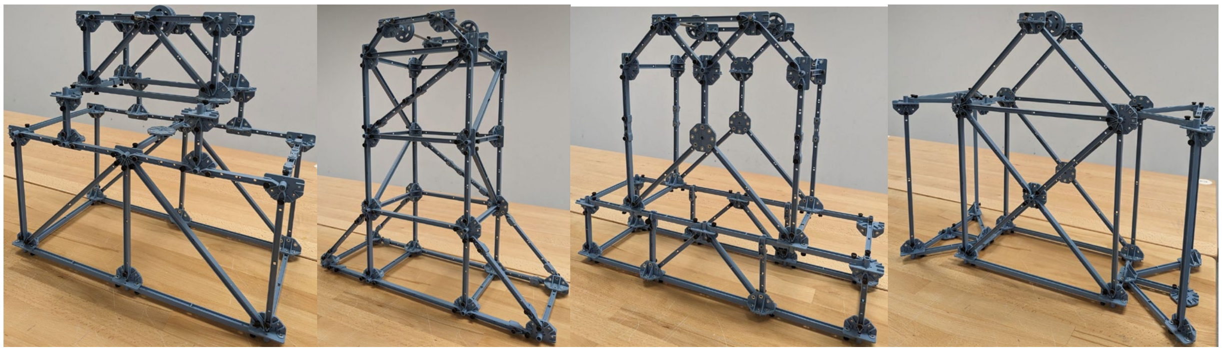

Fig. 3. Different designs from different teams (from left to right: Team 1, 2, 3, and 4)

Survey Results

All enrolled students (N=17) completed the survey. However, one student did not provide consent for their response to be used for this research. For the survey data analysis, 16 student responses were used. Figures 4 through 9 illustrate students' opinion of the multidisciplinary experience on their learning experience. Two students were absent from the Poster Expo due to illness, thus there were only 15 responses to the two questions related to the Poster Expo (Figures 6 and 7).

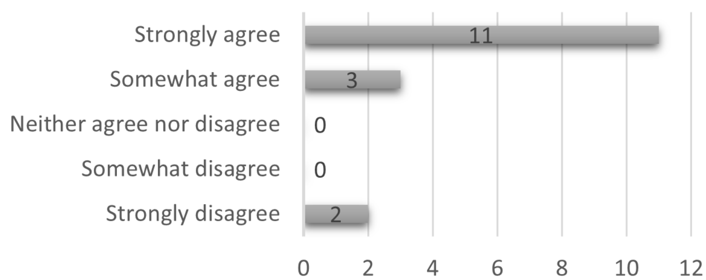

Fig. 4. A multidisciplinary design and discussion experience with multiple engineering fields was positive to my learning experience in this course.

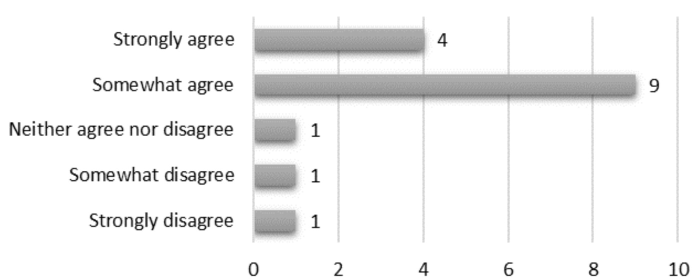

Fig. 5. A multidisciplinary discussion experience on non-engineering fields such as social, global, cultural, and economics was positive to my learning experience in this course.

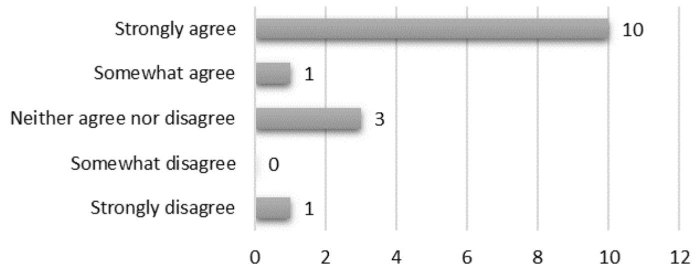

Fig. 6. The Poster Expo was positive to my learning experience in this course.

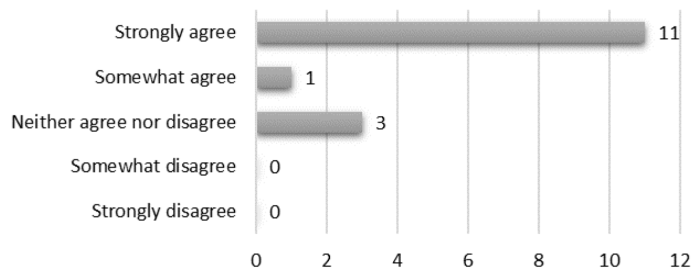

Fig. 7. Having a multidisciplinary expert judge panel was positive to my learning experience.

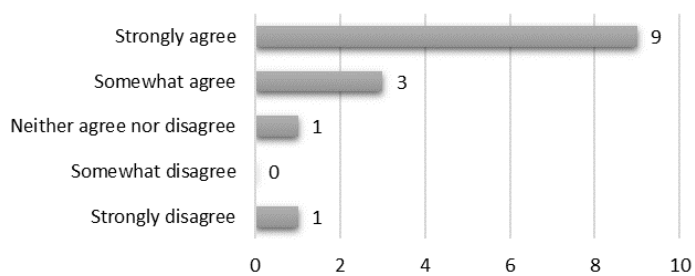

Fig. 8. Having an elevator pitch practice session with experts prior to the Poster Expo was positive to my preparation for the Poster Expo.

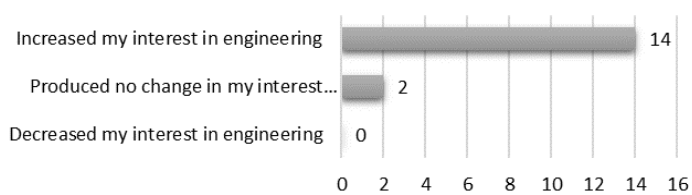

Fig. 9. Effects of the multidisciplinary engineering project experience on engineering interests

Discussion

The multidisciplinary project experience showed positive impacts on students' learning experience in the course and positive effects on engineering student retention with 94% students being retained within engineering by the end of the course in December 2022. As a comparison, the retention rate in the same course in 2021 was only 58% (N=17) where some students felt the project was irrelevant to their majors thus not attractive. AY 2022 students from different majors can contribute to the design of the multidisciplinary project and some students asked to include more different/multiple/variety of engineering disciplines in the future (Figure 10). The survey results showed 88% students reported the multidisciplinary design experience with multiple engineering fields is positive to their learning experience (Figure 4) and 88% students reported the project increased their interest in engineering (Figure 9). There seems to be correlation between the responses to these two questions.

Fig. 10. Word Cloud of student responses on "What are your suggestions on improving the usage of a multidisciplinary engineering project for ENGR 112?"

AY 2022 student project scores were generally better than that of AY 2021 class. First, several teams in AY 2021 ignored some design constrains when working on their model (they acknowledged that they forgot them) but AY 2022 teams met all constrains probably due to better attention to instructions, more in-class discussions on the Evaluate step before model construction, better team collaborations, and more iterations with the help of PASCO kits, which were all signs of better engagement. More difficult criteria and competition mechanism are needed in the future to bring more challenges to the project and better distinguish the winning team. Second, the technical report and poster presentation (both the poster and elevator pitch) were in better quality because (1) the report writing and poster design were broken into multiple revision cycle with feedback from instructor and peer teams given before the final version due, (2) in-class writing practice improved the report quality, and (3) elevator pitch practice session helped students to prepare for the poster presentation. 80% of students reported the multidisciplinary judge panel during the Poster Expo had a positive impact on their learning experience (Figure 7) and 86% students reported the elevator pitch practice with a business advisor before the Expo was positive to their preparation to the Expo (Figure 8). The instructor and FEP faculty who served as judges in both 2021 and 2022 noticed students were better prepared and more engaged during the Expo in 2022, confirming the benefits from elevator pitch practice. In the end of semester feedback, quite a few comments mentioned that they prefer more in-class time on making different models than on the writing although the in-class writing helped with their report quality. This showed students prefer more hands-on project activities ("engineering stuff" in their words) than the professional skills activities even though the course name is "Professional Development in Engineering".

Based on the instructor's observation, engaging a discussion on non-engineering topics and incorporating them into engineering design were still challenging to those students. 81% of students reported the multidisciplinary discussion on the non-engineering factors such as social, global, cultural, and economics were positive to their learning experiences (Figure 5), slightly lower than their rating to the engineering design experience, and less students chose "strongly agree". Therefore, more guidance and practice in this direction are needed to help students to approach those factors. Some students suggested having more information on the cost/budget (Figure 10). Thus, future improvement of this project should develop more guidelines on the cost estimation and analysis. We still had few students who were only interested in a single disciplinary project and individual work. How to motivate them through a multidisciplinary project experience should be addressed in future improvements.

Along with exposure to different engineering disciplines for engineering interests and retention as well as non-engineering factors that are important as ABET outcomes, it was also important to draw students' attention to multidisciplinary collaboration through this project. Although oil derrick belongs to the oil and gas industry, the design of it requires knowledge and collaboration from many disciplines to make the design more sustainable, safe, and cost effective. Many engineering problem-solving needs a similar multidisciplinary approach. Take the oil and gas field as an example, their products and byproducts play a critical role in society such as energy security, public health, transportation, producing plastics, nylon, polyester, lubricants, and waxes[11]. However, there is a growing concern with the environmental impact of fossil fuels. It is important to seek out alternatives and synergistic approaches to balance the societal need on safety and public welfare and the need on environmental protection by incorporating carbon footprint reduction in future designs used in the oil and gas industry. This will need collaboration from petroleum and natural gas engineering, mechanical engineering, civil engineering, environmental engineering, and many other engineering disciplines. Challenging today's first-year engineers to create safe, cost-efficient, and environmentally friendly oil derricks is not only a way to introduce students to a task they may face in their future engineering careers, but also an opportunity for them to think about alternative solutions as future leaders. Therefore, it is necessary for multidisciplinary collaboration amongst engineering, business, local communities, and governments.

Conclusion

The multidisciplinary project experience developed successfully gave a positive learning experience to most first-year educationally disadvantaged engineering students surveyed (N=16), increased their interests in engineering, and retained them in engineering by the end of the semester. A majority of students reported the multidisciplinary design experience and the multidisciplinary judge panel during the Poster Expo were positive to their learning experience. Overall, nearly all students reported the project increased their interest in engineering. The retention rate of ENGR 112 students in engineering by the end of the course was 94% (N=17), much higher than that in the same course last year (58%, N=17). This study demonstrated the possibility and benefit of using a multidisciplinary project experience to retain educationally disadvantaged first-year students in engineering, which can be modeled by other programs and courses.

Future work will include (1) improving the project instructions with more specific and detailed guidelines on cost factor, societal factor, cultural factor, and global factors; (2) incorporating more engineering disciplines into the project such as computer science, industrial engineeirng, and chemical engineering; (3) encouraging students who prefer individual work specific to their chosen engineering disciplines to involve in a multidisciplinary engineering project; and (4) adding competition elements to the project model score. In addition, conduct both quantitative and qualitative studies through pre- and post-surveys and interviews to assess the impact of such a multidisciplinary project on the self-efficacy and self-confidence of educationally disadvantaged first-year engineering students.

References

[1] L. Santiago and O. L. Abioye, "Teaching Electronics to First-year Engineering Students," in *2015 ASEE Annual Conference & Exposition*, 2015, pp. 26.1473. 1-26.1473. 9.

[2] I. Calvo, I. Cabanes, J. Quesada, and O. Barambones, "A Multidisciplinary PBL Approach for Teaching Industrial Informatics and Robotics in Engineering," *IEEE Transactions on Education,* vol. 61, no. 1, pp. 21-28, 2018, doi: 10.1109/te.2017.2721907.

[3] H. G. Denton, "Multidisciplinary team-based project work: planning factors," *Design Studies,* vol. 18, no. 2, pp. 155-170, 1997.

[4] J. K. L. Leung, S. K. W. Chu, T.-C. Pong, D. T. K. Ng, and S. Qiao, "Developing a Framework for Blended Design-Based Learning in a First-Year Multidisciplinary Design Course," *IEEE Transactions on Education,* vol. 65, no. 2, pp. 210-219, 2022, doi: 10.1109/te.2021.3112852.

[5] B. Tiwari, P. Nair, and S. Barua, "Effectiveness of Freshman Level Multi-disciplinary Hands-on Projects in Increasing Student Retention Rate and Reducing Graduation Time for Engineering Students in a Public Comprehensive University," in *2018 ASEE Annual Conference & Exposition*, Salt Lake City, Utah, 2018: American Society for Engineering Education, doi: 10.18260/1-2--30360. [Online]. Available: https://peer.asee.org/30360

[6] J. B. Ochs, T. A. Watkins, and B. W. Boothe, "Creating a Truly Multidisciplinary Entrepreneurial Educational Environment*," *Journal of Engineering Education,* vol. 90, no. 4, pp. 577-583, 2001, doi: 10.1002/j.2168-9830.2001.tb00642.x.

[7] N. Roy, F. Schlosser, and Z. Pasek, "Stimulating Entrepreneurial Interest in Engineers Through an Experiential and Multidisciplinary Course Collaboration," *Entrepreneurship Education and Pedagogy,* vol. 3, no. 1, pp. 14-40, 2019, doi: 10.1177/2515127419856602.

[8] B. Harold and H. S. Sam, "Petroleum and Natural Gas," in *The Mining Industries, 1899–1939: A Study of Output, Employment, and Productivity*. New York, NY: National Bureau of Economic Research, Inc, 1944, ch. 10, pp. 188-208.

[9] L. Arscott "Sustainable Development in the Oil and Gas Industry," *Journal of Energy Resources Technology,* vol. 126, no. 1, pp. 1-5, 2004, doi: 10.1115/1.1653768.

[10] P. Šprljan, D. Pavković, M. Klaić, T. Staroveški, and M. Cipek, "Laboratory prototyping of control system retrofitting designs for oil drilling applications," in *Proceedings of 10 th International Scientific Conference on Management of Technology-Step to Sustainable Production (MOTSP 2018), Primošten, Croatia*, 2018.

[11] T. Gold, "The origin of natural gas and petroleum, and the prognosis for future supplies," *Annual Review of Energy,* vol. 10, no. 1, pp. 53-77, 1985.