2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
ASEE
Paper ID #40251

Bridging the Gap between Industry and Academia, and Developing Students' Engineering Identity

Dr. Betul Bilgin, The University of Illinois, Chicago

Betul Bilgin is Clinical Associate Professor of Chemical Engineering (CHE) at the University of Illinois at Chicago (UIC) . Her research focuses on engineering identity development and industry-academia relationships.

Hasiya Najmin Isa
Emily Seriruk
Cody Wade Mischel

Bridging the gap between industry and academia and developing students' engineering identity

With the evolution and expansion of the chemical industry, the gap between academia and industry is broadened. The skills that the workforce expected from practicing engineers are not taught in the typical chemical engineering undergraduate core curriculum. Students become less engaged and less motivated by not seeing the applications of course content in their courses. Therefore, they struggle to identify with the field and develop skills necessary for the workplace. This NSF PFE: RIEF project aims to bridge the gap by implementing industry-relevant contemporary problems into a sophomore chemical engineering course.

The project's main goal is to understand how the implementation impacts students' engineering identity and self-efficacy development. We employed a design-based research approach (DBR) with one baseline and two full enactment cycles. In each cycle, students are surveyed, and focus groups are interviewed before and after implementation.

In this paper, we will present the details of data collection, analysis, and findings from the results from all three semesters. The challenges and gains of adopting the approach and how to transfer to other programs will be further discussed.

Introduction

The chemical engineering field has expanded, resulting in an increased gap between academia and industry [1-3]. This gap was acknowledged by John Chen at the 2013 American Institute of Chemical Engineering (AIChE) Annual meeting, who highlighted that the areas of growth in engineering research and faculty development differ from the areas that require new workers in engineering fields [4]. To bridge the gap between academia and industry, three main areas require attention: course content, faculty development, and teaching methods. The chemical engineering curriculum mostly focuses on fundamental concepts and lacks contemporary industry applications, and essential interpersonal and intrapersonal skills are expected to be learned later on in activities like senior design and unit operations lab. Faculty members teaching courses are typically specialized in their research areas, but they lack the knowledge and skills in various chemical engineering areas and do not update themselves on modern practices. Traditional lecture-based teaching methods have been ineffective in promoting high-level skill development and self-learning in engineering problem-solving [5-7]. Instead, design thinking, integrated or inductive-learning models, and abductive-thinking, which introduce fundamental principles in the context of solving a given engineering problem, are being used as new paradigms in engineering education [8-13]. These models provide learners with an environment for problem-solving while offering feedback and guidance. There are also many active learning strategies like cooperative learning, problem-based learning, hands-on learning, and computer simulation that have been shown to improve student learning and engagement [14-19]. However, many chemical engineering faculty members are not trained in these educational methods and tools and are unaware of their implementation in today's engineering education.

To sum up, as the chemical engineering field has grown, the gap between industry and academia has widened, with faculty struggling to keep their courses and practices contemporary. The development of interpersonal and intrapersonal skills is not systematically included in programs, leading to disengaged students who lack the necessary knowledge and skills. This gap is particularly significant for first-generation college students, who may lack connections and role models in the engineering field, making it harder for them to develop a professional identity and sense of belonging [20-23]. Research shows that identity and fit are crucial factors in choosing, retaining, and pursuing a career in engineering, with underrepresented groups like women experiencing identity conflicts and gender roles that affect their retention in the field [27-29].

The Current Study

The study aims to update classroom content by introducing contemporary industry-relevant problems designed by industry professionals. The research uses design-based research with multiple implementation cycles to answer the question of how effective this approach is in promoting professional identity formation and industry-relevant competencies. The study also addresses questions about students' understanding and interest in these applications, the relationship between students' identity and course performance, and the impact of the approach on underrepresented groups, especially women. The iterative cycles pursue an answer to the following overall research question:

How effective is the proposed approach in impacting professional identity formation and promoting industry-related competencies?

Answering this overall research question requires that we also address a series of related and precursor questions associated with the design, implementation, and evaluation of the proposed components of the proposed approach in *the CHE 210 "Mass and Energy Balance"* course. Among these are the following:
(1) what are the students' understanding of these applications and their impact on students in terms of interest, knowledge of applications, and professional identity formation?
(2) What is the relationship between students' identity and course performance and assessments?
(3) Is there a significant impact of the proposed approach on underrepresented groups especially women?

Theoretical Framework

The proposed research is based on an engineering identity framework developed by Godwin, which is grounded in Hazari's quantitative measure of physics students' identity [34, 35]. This framework defines engineering identity as a role identity, where students describe themselves and are perceived by others as engineers. Engineering identity is composed of three dimensions: personal **interest** in engineering, **recognition** by others, and belief in one's **competence** in disciplinary tasks [34,35]. This framework has been widely used in measuring engineering identity, particularly among first-year engineering students [36].

Methods

To understand the impacts of the intervention on self-efficacy and engineering identity, contemporary industry-relevant problems were designed and introduced to the targeted course.

Instruments for assessing self-efficacy and engineering identity were developed and employed. Each of these is further explained below:

Contemporary Industry Problems Design

The project team worked with six industry professionals designing a diverse topic of problems. Problems were selected from global issues such as plastic recycling, renewable energy, carbon recycling. Mentors gain and challenges were published in a previous ASEE paper [37]. In addition, videos and details of the problems were also published at 2022 ASEE Annual Conference proceedings [38].

Introduction of Contemporary Industry Problems into Targeted Course

The proposed research aims to evaluate the impact of both curriculum changes and interaction with industry mentors on students' identity development. To do this, the study employs multiple implementation conditions, including a baseline condition where only industry-relevant problems were introduced to the course, without interaction with industry mentors. This baseline condition was implemented in the Spring 2021 semester, which was delivered asynchronously due to the COVID-19 pandemic. In Fall 2021, the course returned to in-person instruction, and the full implementation was introduced, including three problems assigned to students, mentor interactions, and end-of-semester presentations with direct feedback from mentors. Based on the feedback from Fall 2021, the implementation was redesigned and introduced in Spring 2022. Two problems were assigned in Spring 2022 along with mentor interactions and students' presentations.

Instrument Development and Employment

The study used two survey instruments to measure self-efficacy and engineering identity, which were chosen based on literature and piloted in two different courses. The surveys were implemented at the beginning and end of the Spring 2021, Fall 2021 and Spring 2022 semesters. Additionally, the study conducted interviews with randomly selected students, stratified by gender, at the beginning and end of both semesters, as well as with two mentors and the course instructor at the end of the three semesters.

Data Analysis

The research team experienced a low response rate to survey questions in the Spring 2021 semester, possibly due to minimal in-person contact with students because of the asynchronous delivery of the course. To improve response rates in the Fall 2021 semester, incentives such as extra credit were included, resulting in a more than 75% response rate. Following the IRB protocol (Protocol # 2020-1528), students were given the opportunity to earn extra credit by completing the survey. Before distributing the survey, students were provided with an explanation of the purpose of the survey, how the data would be used, and a statement indicating that participation was voluntary and that they could skip any questions they did not feel comfortable answering. All the students completed the survey were provided extra credit . However, responses were analyzed using only the data from students who had given consent for their answers to be used for research purposes. The research team also conducted interviews with randomly selected students, mentors, and the course instructor at the beginning and end of each semester, and the interviews were transcribed and analyzed using content analysis software MAXQDA. This analysis helped the team identify challenges, difficulties, and gains of adopting the proposed approach and evaluate student outcomes.

Results and Discussions

Quantitative analysis has shown that female students have lower self-efficacy compared to male students. Table 1 summarized the sample sizes for four courses where survey was conducted: two CHE 210 (targeted course for two different semesters), one CHE 201 “Introduction to Thermodynamics” (very first courses that students take from chemical engineering department), and one CHE 396 “Senior Design I” (senior year course that one of the last courses from chemical engineering department). As seen in Figure 1, this gap is not significant in the first chemical engineering class (CHE 201, where survey is piloted). However, the gap gets bigger in CHE 210 (targeted course, the Mass and energy balance course) and gets smaller again in CHE 396 (senior design course, where the survey is piloted). This suggests that it is very important to have support mechanisms for women in chemical engineering especially in early chemical engineering courses.

Table 1. Sample sizes for each course

	Number of Students	Percentage
CHE 201 (Fall 2021)		
Female	6	38%
Male	10	63%
CHE 210 (Fall 2021)		
Female	7	35%
Male	13	65%
CHE 210 (Spring 2022)		
Female	7	41%
Male	10	59%
CHE 396 (Fall 2021)		
Female	13	41%
Male	19	59%

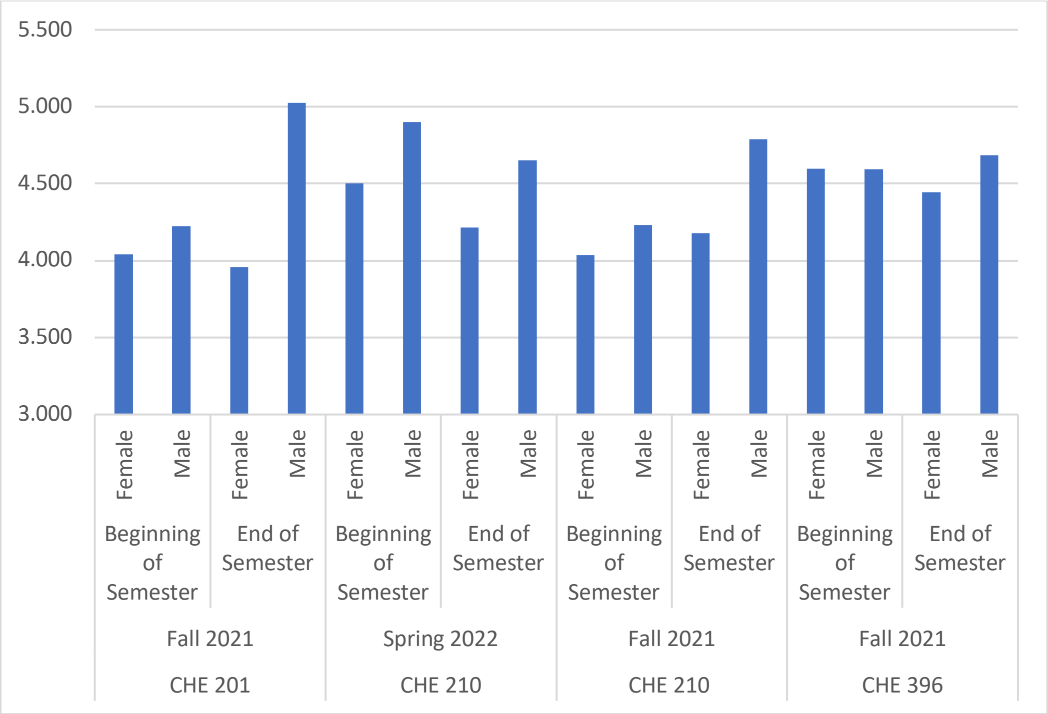

Figure 1: Self-efficacy measurements of female and male students from different courses. Surveys are conducted at the beginning and end of semester.

Survey data analysis is still ongoing, and we will have more accurate picture after we complete the analysis.

Qualitative analysis has shown the following results:

Interest

- Students' interest in chemical engineering mainly stems from their interest in chemistry. They also mention that their interest is stemming from physics. Surprisingly they do not report interest in math, they report that they are good at math instead of they like math. They have different reasons why they choose chemical engineering instead of chemistry: problem solving, more challenging, math/physics component.
- Many students choose chemical engineering influenced by others such as their chemistry teachers, family members etc. Around half of them chose the field influenced by online resources.
- There are very diverse paths that lead to chemical engineering: brewing, Legos, inventing, water science and automotive mainly secondary fields.
- Many students know CHE is a broad field, but they are uncertain about how to define chemical engineering. However, at the end of the semester, when we ask the same question, all of them had a clear definition of chemical engineering.

Overall implementation was impactful on helping students define what chemical engineering is and keep their interest in the field by introducing broad range of applications. Many students lose their interest in sophomore year and quit engineering. Retention rate for both semesters were more than 90%.

Performance/Competence

- Students recognize CHE is a hard degree.
- They measure their performance/competence based on the understanding. Almost all mentioned they want to have deeper understanding of the material. However, it is hard to assess understanding, their currency is grades.
- Implementation helped them to have better understanding as well as a metric to measure their understanding. Since midterm and final exams do not represent real-world, our implementation gave them a metric to see if they are able to perform real-world industry problems.
- They recognize the connectedness of course material with the industry-problems which made them pay more attention to class content and try to understand course material deeply.

Recognition

- Students report that others such as friend and family members recognize them as engineer, however, that does not mean much to them. Those people do not know what chemical engineering is and they recognize students as chemical engineer just because they are pursuing chemical engineering degree.
- Almost all reported that they do not recognize themselves as chemical engineers, instead chemical engineer in progress. They base the recognition on knowledge. "I lack knowledge; thus, I do not recognize myself as a chemical engineer". But they do not define what the knowledge is and how to achieve that.
- They are self-aware and confident, mentioned that if they recognize themselves as chemical engineers, they do not need others to recognize them as chemical engineers.
- For many of them, at this stage, recognition was not important.

The impact of implementation on the recognition scale was seeing mentors as role-models and interacting with them. Almost all students did not know a chemical engineer before, and mentor videos and interactions helped them meeting with professional chemical engineers and seeing their future in them.

Future Work

We had collected both qualitative and quantitative data during three semesters of implementation. All data was cleaned, organized, coded individually and as a group. This data is currently being analyzed.

Acknowledgments

This work was supported through the National Science Foundation's funding under a PFE: RIEF Grant No. (2024960). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the National Science Foundation's views. We wish to thank survey and interview participants for their participation in the study.

References

1. Shinnar, R. (1991). The future of chemical engineering. *Chemical Engineering Progress, 87*(9), 80-85.
2. D'Este, P., & Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry?. *Research policy*, *36*(9), 1295-1313.
3. Klatt, K. U., & Marquardt, W. (2009). Perspectives for process systems engineering—Personal views from academia and industry. *Computers & Chemical Engineering*, *33*(3), 536-550.
4. Curtis, J. S., & Hill, J. C. (2015). Chemical engineering expertise in academe and as sought by industry. *Chem Eng Educ., 49*(1).
5. McCabe, B., Patazidou, M., & Phillips, D. (2012). *Shaking the Foundations of Geo-Engineering Education*, 9-14, Leiden, CRC Press.
6. Vita, G. D. (2001). Learning styles, culture and inclusive instruction in the multicultural classroom: A business and management perspective. *Innovations in Education and Teaching International*, *38*(2), 165-174.
7. Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.
8. Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering education*, *78*(7), 674-681.
9. Felder, R. M. (1996). Matters of style. *ASEE prism*, *6*(4), 18-23.
10. Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of engineering education*, *95*(2), 123-138.
11. Felder, R. M. (2004). Changing Times and Paradigms, *Chem. Engr. Education, 38*(1), 32-33.
12. Kolko, J. (2010). Abductive thinking and sensemaking: The drivers of design synthesis. *Design Issues, 26(1),* 15-28.
13. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education, 94*, 103-120.
14. Rovner, S. L. (2006). Video game aims to engage students. *Chemical & Engineering News, 84*, 15-76.
15. Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). The future of engineering education II. teaching methods that work. *Chemical Engineering Education, 34*(1), 26-39.
16. Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education, 95*(2), 123-138.
17. Newell, J. (2005). Survivor: Classroom-A method of active learning that addresses four types of student motivation. *Chemical Engineering Education, 39*(3), 228.
18. Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative learning returns to college what evidence is there that it works? *Change: The Magazine of Higher Learning, 30*(4), 26-35.
19. Dahm, K. D. (2003). Process simulation and McCabe-thiele modeling: Specific roles in the learning process. *Chemical Engineering Education, 37*(2), 132-135.

20. Atman, C. J., Sheppard, S., Fleming, L., Miller, R., Smith, K., Stevens, R., & Streveler, R. (2009). Findings from the academic pathways study of engineering undergraduates 2003-2008 -- Overview and panel discussion. *American Society for Engineering Education, Austin, TX.*
21. Jocuns, A., Stevens, R., Garrison, L., & Amos, D. (2008). Students' changing images of engineering and engineers. *American Society for Engineering Education, Pittsburgh, PA.*
22. Stevens, R., Amos, D., Jocuns, A., & Garrison, L. (2007). Engineering as lifestyle and a meritocracy of difficulty: Two pervasive beliefs among engineering students and their possible effects. *American Society for Engineering Education, Honolulu, Hawaii.*
23. Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education*, 97(3), 355-368.
24. Dutton, J. E., Dukerich, J. M., & Harquail, C. V. (1994) Organizational Images and Member Identification. *Administrative Science Quarterly*, *39(2)*, 239-263.
25. Cross, S. E., & Vick, N. V. (2001) The Interdependent Self-Construal and Social Support: The Case of Persistence. *Personality and Social Psychology Bulletin,27(7)*, 820-832.
26. Pierrakos, O., Curtis, N. A., & Anderson, R. D. (2016) How salient is the identity of engineering students? On the use of the Engineering Student Identity Survey. *Proceedings of Frontiers in Education Conference, Erie, PA: FIE.*
27. Beam, T. K., Pierrakos, O., Constanz, J., Johri, A., & Anderson, R. (2009) Preliminary findings on freshmen engineering students' professional identity: Implications for recruitment and retention. *Proceedings of American Society for Engineering Education Annual Conference. Washington, DC: ASEE.*
28. Dennehy, T. C., & Nilanjana D. (2017) Female peer mentors early in college increase women's positive academic experiences and retention in engineering. *Proceedings of the National Academy of Sciences 114, no. 23*, 5964-5969.
29. Richman, L. S., Michelle, V., & Wendy, W. (2011) How women cope: Being a numerical minority in a male-dominated profession. *Journal of Social Issues 67, no. 3*, 492-509.
30. Anderson, T., & Shattuck, J. (2012). Design-based research a decade of progress in education research? *Educational Researcher, 41*(1), 16-25.
31. Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational researcher*, *32*(1), 9-13.
32. Shavelson, R. J., Phillips, D. C., Towne, L., & Feuer, M. J. (2003). On the science of education design studies. *Educational researcher*, *32*(1), 25-28.
33. Bannan-Ritland, B., & Baek, J. Y. (2008). Investigating the act of design in design research: The road taken. *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching*, 299-319.
34. Godwin, A. (2016). The development of a measure of engineering identity. *In ASEE Annual Conference & Exposition.*
35. Hazari, Z., Gerhard, S., Philip M. S., & Marie-Claire S. (2010). Connecting highschool physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of research in science teaching* 47, no. 8 : 978-1003.
36. Godwin, A. & Kirn A. (2020). Identity-based motivation: Connections between first-year students' engineering role identities and future-time perspectives. *Journal of Engineering Education* 109, no. 3 : 362-383.

37. Bilgin, B., Pellegrino J. W. & Berry, V. (2021). Work-in-Progress: The design of contemporary industry problems for a sophomore chemical engineering course: Challenges and Gains of industry mentors. *2021 ASEE Annual Conference. Virtual.*
38. Mischel, Cody, Lewis Wedgewood, Betul Bilgin, James Pellegrino, and Vikas Berry. "Impacts of implementing contemporary industry problems on engineering identity development." In *2022 ASEE Annual Conference & Exposition*. 2022.