

Work in Progress: Incorporation of Diversity and Inclusion into Undergraduate Chemical Engineering Curriculum

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Overview

- As a work-in-progress, we aim to improve teamwork and foster more inclusive professional identities for chemical and biological engineering (CBE) undergraduate students.
- Our goal is to continually engage students in instruction related to inclusion and diversity by integrating a variety of activities and assignments throughout their engineering curriculum.

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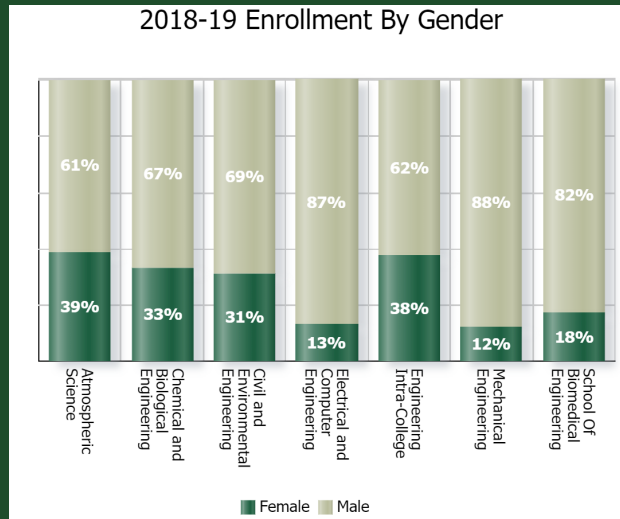
Why are we doing this?

- We hope to assist students in more effectively working with each other throughout their academics
- **We also hope to achieve a more diverse and inclusive engineering workforce that is capable of solving the numerous challenges that face society**
 - This is necessary to create more inclusive engineering designs (also more innovative designs as we leverage the power of diverse perspectives)
 - There are currently issues with facial recognition technology, machine learning, pharmaceuticals, etc.
- We also hope to improve retention of underrepresented students including students of color and women in the CBE program

According to Wulf (2001), “without diversity we limit the set of life experiences that are applied, and as a result we pay an opportunity cost - a cost in products not built, in designs not considered, in constraints not understood, and in processes not invented” [2]

Overview

- According to the CSU Office of Institutional Research, Effectiveness, and Planning [11], the 2018-2019 Enrollment Statistics for CBE were:
 - 322 Students Enrolled
 - 33% Females and 67% Males
 - 17% Pell Recipients
 - 21% First Generation
 - 36.6 % Minority and International



Statistics and figures for all departments in Walter Scott Jr. College of Engineering available in [11].

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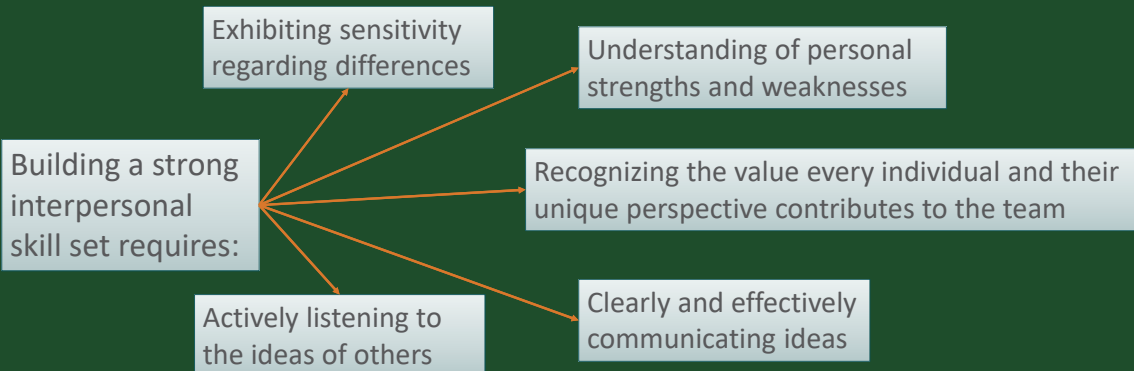
Minority includes students who self-report a minority status; nonminority includes all other students (including international students) – from Institutional Research website

The CBE department has significant enrollment of traditionally underrepresented students and we want to ensure these students are experiencing an inclusive atmosphere.

Overview

Knowledge and Skills to help to recognize cultural barriers to inclusion and work more effectively with difference that we focus on:

- Implicit Bias
- The ability to work well in teams, which requires a strong interpersonal skill set



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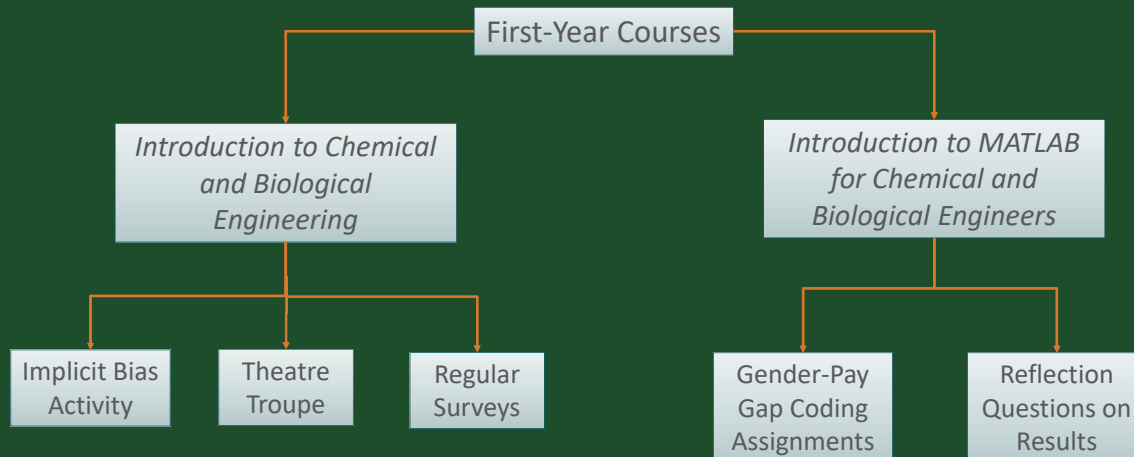
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- While the need for engineering students to be able to work in teams has long been recognized, engineering education has not always recognized the need and sought to develop teamwork as a skill.
- Building a strong interpersonal skill set (for improved teamwork) entails:
 - recognizing the value every individual and their unique perspective contributes to the team
 - having an understanding of personal strengths and weaknesses
 - clearly and effectively communicating ideas
 - actively listening to the ideas of others
 - exhibiting sensitivity regarding differences

Overall Strategy

- To achieve our goal of fostering more inclusive professional identities, students need continual (but not redundant) exposure to these topics throughout their curriculum.
- It is not adequate to only incorporate interventions in the first year introductory course and senior design, but optimally in at least one course every semester.
- This requires integrating diversity and inclusion topics in technical courses and, when possible, providing examples of the importance of diversity and inclusion in engineering design.
- This work-in-progress takes an incremental approach by working with amenable faculty, as well as demonstrating to additional faculty the value added to the curriculum.

Diversity and Inclusion in CBE Curriculum



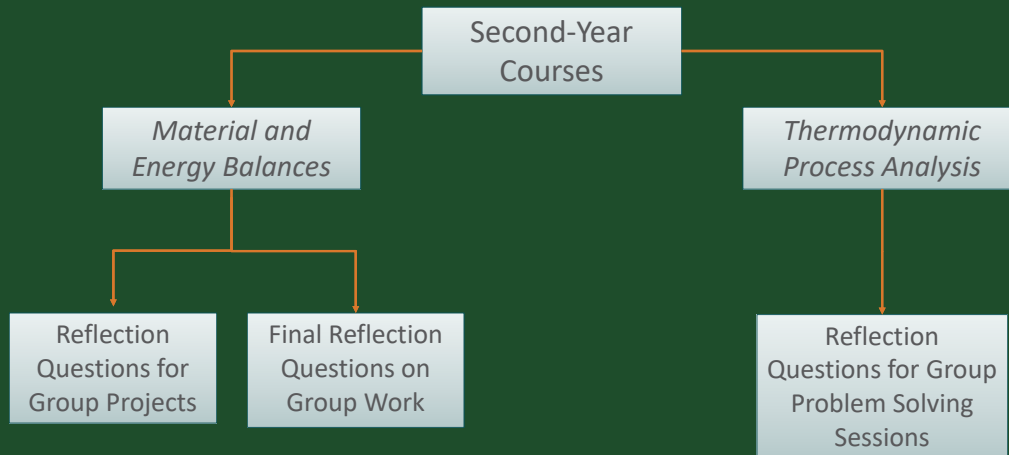
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- I. In the first-year introductory course, *Introduction to Chemical and Biological Engineering*, the students perform multiple assignments:
 - An implicit bias activity in the laboratory sections
 - An interactive theatre sketch of a dysfunctional team interaction is performed, with trained facilitators guiding the activity [7]
 - Regular surveys to assess these various activities
 - **Teamwork with intentional coverage by instructors and professors on things like team norms or dealing with conflict.**

- II. In the first-year computing course, *Introduction to MATLAB for Chemical and Biological Engineers*, the students perform multiple assignments in which they:
 - Apply the programming skills learned in the course to analyze the gender-pay gap and answer reflection questions.

Diversity and Inclusion in CBE Curriculum



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The frequent group projects and group problem solving activities in these courses have provided an opportunity to incorporate diversity related topics with a series of reflection questions after each project or a series of problem solving sessions that address individual behavior within the group, interactions with team members, demonstration of respect for group members contributions, and overall inclusion of group members.

First-Year Courses: Implicit Bias

First-Year Course: Introduction to Chemical and Biological Engineering

- We include multiple diversity related topics because the structure of the course more easily allows for the addition of non-technical course content.

Why introduce implicit bias to first-year students?

- Despite our beliefs and values, implicit biases can often impact our thoughts and actions because they are unconscious and are activated without conscious control.
- The impacts of implicit bias are pervasive in our society, with research showing consequences in fields such as healthcare, education, and criminal justice.

What does the activity consist of?

- Students watch an introductory video on implicit bias (as a group).
- They take either one or two Harvard Implicit Association Tests (IATs) [8].
- They participate in a group discussion.
- They answer (individually) reflection questions regarding their test results.

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- Although the consequences of implicit bias are well supported in the literature, this is still a sensitive subject for some as it can be difficult to acknowledge the limitations of conscious human thought and confront discrepancies between conscious thoughts and unconscious actions.
- Given the sensitive nature of this topic, we discuss the concept of implicit bias before this activity and that:
 - ALL people are susceptible to implicit biases because of unconscious, automatic processes occurring in our brains.
 - They are activated automatically **without our awareness** or control, and can impact our behavior (decisions, actions, etc.) in ways that may be contrary to our explicit beliefs.
- We will compare the results from these two approaches to customized instruction approaches by additional instructors by evaluating the reflection questions and end of semester surveys.
- Questions we seek to answer:

- ii. How do students respond to each instruction approach for teaching implicit bias to first year students?
- iii. Are there significant discrepancies (qualitative and quantitative) between the student responses as a result of the instruction approach used?

First-Year Courses: Theatre Sketch

First-Year Course: Introduction to Chemical and Biological Engineering

An interactive theatre sketch of a dysfunctional team interaction is performed for the class. This activity is described in [7].

What does the activity consist of?

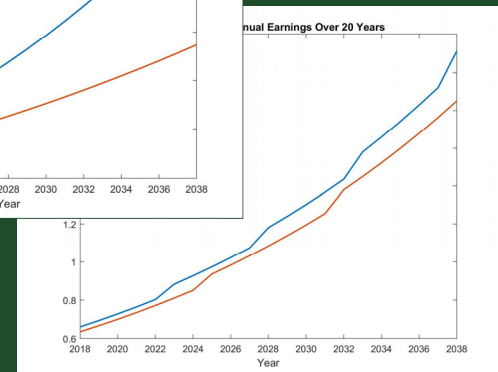
- Trained facilitators guide this interactive activity.
- Students first watch an theatre sketch of a dysfunctional team interaction in entirety.
- The facilitators prompt students on if there were parts of the scene they viewed as problematic.
- Participants can “stop” the scene at a particular point, and join to redirect or modify the interactions.
- Students then answer reflection questions regarding the activity.

This activity happens at a time in the semester when students have had some experience working with their team and are ready to talk about difficult aspects of teamwork.

First-Year Courses: Gender-Pay Gap

First-Year Course: Introduction to MATLAB for Chemical and Biological Engineers

- The gender-pay gap is one topic related to diversity and inclusion which can be easily implemented in a coding course because of the quantitative nature.
- The students apply the programming skills learned in the course to analyze the gender-pay gap as a result of different starting pay rates, annual raises, and promotion periods.
- They also answer reflection questions regarding their results.



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When this assignment is introduced, discussion on the intersectionality of pay disparities based on race and sexual orientation in addition to gender are discussed.

- One possible addition is adding in an additional assignment in which they combine the two (different promotion periods and different annual raises).
- Another possible addition is adding in pay disparities based on race and sexual orientation.
- Adding reflection questions after each portion of the assignment.
- Another possible addition is incorporating reflection questions on group interactions after completing the final project.

Note: Salaries used for comparison are general across all engineering disciplines. These are currently in the process of being updated based on recent statistics from 2019.

Second-Year Courses: Group Project Reflections

Second-Year Course: Material and Energy Balances

Incorporating these topics in second-year courses is more challenging as a result of the highly technical course content.

How is diversity and inclusion incorporated?

- There are four group projects throughout the semester.
- The students answer a series of reflection questions after each project that address:
 - Individual strengths and weaknesses
 - Individual behavior within the group
 - Interactions with team members
 - Demonstration of respect for group members contributions
 - Overall inclusion of group members
- The students also answer a final question set regarding all team interactions.
- These questions are designed to promote a growth mindset in how the students view their individual group contributions, as well as interactions within the group.

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This course introduces the material and energy balancing concepts critical to solving a range of chemically and biologically relevant process and system examples. These include traditional chemical engineering unit operations involving reactors and separations, biological engineering analogs of these operations, as well as some simple transient material flow problems such as those encountered in controlled (drug, chemical) release, fermentation and cell culture systems, etc. (from course syllabus -- to give an overview of technical content of course).

This is an easily implemented strategy for enabling students to learn effective teamwork skills while not infringing on the technical course content. Reflecting on their experiences interacting with their classmates and working in groups can provide students insight into their individual strengths and weaknesses, help them in communicating their ideas more effectively, and can provide improved understanding into what skills, actions, and strategies are useful for creating a more open, supportive, and respectful team environment.

Second-Year Courses: Group Project Reflections

Second-Year Course: Material and Energy Balances

How are the reflection questions selected and grouped?

- Each question set is designed to address **all** of the following:
 - Individual behavior (self reflection)
 - Teamwork (group reflection)
 - Inclusivity (inclusion, appreciation for differences, and respect for group members)
- Each subsequent question set builds upon the previous set, often asking students to:
 - reflect on previous interactions compared with the most recent interactions
 - and/or discuss what changes they can make to improve future interactions
- Subsequent question sets also are designed for students to recognize and reflect on both the positive and negative aspects of their group interactions.

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- We are currently researching a theoretical framework and process with which to analyze the data.
- To analyze the results obtained by all of the reflection question sets throughout the semester, we will implement “coding” as well as attempting to extract quantitative information from the data by utilizing the categories / themes developed in the coding process.

Second-Year Courses: Group Project Reflections

Second-Year Course: Material and Energy Balances

First Question Set for Each Project:

1. What strategies or actions did your group take to get to know each other and come together as a team? What have you enjoyed the most/the least about getting to know your group members?
2. What is the most valuable skill you learned from your teammates / project group that you will incorporate in future teamwork?
3. Did everyone have an opportunity to share their ideas with the group? How did you respond to others' ideas? How did they respond to yours? What could be improved?
4. If you were to work with this same group again, what is one change the group could make to work together more effectively? What changes could you make personally to work more effectively with this group or another group?

Second-Year Courses: Group Project Reflections

Second-Year Course: Material and Energy Balances

Some Final Questions To Reflect on All Team Interactions:

1. Consider your project teams throughout the semester. What were the most effective aspects about the ways the groups worked? What were the least effective?
2. Reflect to the first project group of this semester. Over the course of the semester, did you personally make changes to work more effectively with your groups and improve your team interactions? What were these changes? Considering all of project teams throughout the semester, how did these changes impact your interactions?
3. In this class, you worked with people who were similar to you in that they are students in this class learning the same content. In the future, it is likely that your team might have much greater diversity in terms of expertise (other types of engineering, business, and other fields) and prior experiences. How would the lessons you learned during this semester carry over to situations with more diversity? Or what other considerations might become important?

Second-Year Courses: Group Project Reflections

Second-Year Course: Thermodynamic Process Analysis

Course Structure:

- The students will complete group problem solving sessions each week.
- They will rotate groups and work with three different groups throughout the semester.

What interventions are incorporated?

- We will have students answer reflection questions after working with each individual group that are different from those in Material and Energy Balances.
- These questions will be more focused on developing an understanding and appreciation in students of:
 - The unique perspectives and experiences each member has
 - How these perspectives affect how each member approaches a problem
 - How the diversity within the group can help the group to more effectively achieve its goals

While the reflection questions in Material and Energy Balances revolve around improving group dynamics and teamwork, the reflection questions in Thermodynamics are being developed to focus more on the individual perspectives each group member has when approaching a particular problem.

- Each group will have 5 students

Second-Year Courses: Group Project Reflections

Second-Year Course: Thermodynamic Process Analysis

First Question Set for Each Project:

1. [Following an introductory paragraph] Describe how you evaluated specific problems, such as what information in a problem stood out to you the most in the problem statements, and how you approached solving these problems while in your group.
2. Did another group member approach solving the problems in a different way that you had not thought of? Describe how their approach was both similar and different to your approach.
3. Did the group brainstorm how to solve each problem, or was another approach taken, such as working independently and comparing solutions? Did every group member agree on this overall approach? If not, how did the group reconcile these different preferences?

Introduction for the first question: When reading a problem statement, each individual formulates an approach for solving the problem. These approaches, however, can differ between each individual. For example, some individuals might prefer a visual approach in which they first try to draw a picture or Process Flow Diagram (PFD) of the system while others may choose to compile and organize a list of the given variables provided in the problem statement, or develop a list of equations or formulas which may be useful in solving the problem. Individuals may instead evaluate a problem in reverse, determining what variable or variables they must solve for after reading the problem statement and what equations or formulas include those variables.

- After these questions, we will be asking students to reflect on the strengths and weaknesses of their approach compared to someone else's, whether they have adopted aspects of another person's approach or process, as well as how this has helped them to be more effective at solving problems both alone and in the group.
- We will also be asking about comparing their study habits / methods to the processes of others.

Challenges

- Initially, we intended to attempt incorporation of these concepts throughout the entire curriculum (in at least one course every semester) in this academic year.
- This has presented several challenges, aside from the extremely technical course content and course structure.
 - Broad incorporation requires significant coordination and collaboration with and between faculty members within the CBE department to determine the best approach for each course and avoid redundancy across courses that may result in decreased student participation. This is incredibly time consuming and will continue to be an ongoing process.
 - Individual faculty must not only recognize the value of addressing these topics but must also be willing to make adjustments within their course structure to accommodate these topics in some form.

Challenges

- Demonstrating the minimal course changes necessary for incorporation of these topics as well as the value added as a result of introducing these topics into the curriculum in first- and second-year courses may help assuage some of the concerns expressed by some faculty of upper-level courses.
- Fall 2019 was the first semester collecting data for *Material and Energy Balances*. We did get a high rate of participation for all sets of reflection questions, although we are only beginning to analyze the data.
- Spring 2020 is the first semester implementing these topics in *Thermodynamic Process Analysis*. As a result, the data has not been compiled yet and it is not possible to determine an analysis approach in advance.

Future Work

- Incorporate at least one intervention in CBE curriculum every semester in the third and fourth years of the curriculum.
 - With multiple laboratory courses and senior design, there are many possible approaches that can be utilized to incorporate diversity and inclusion topics in the third and fourth year courses.
- Work with faculty to identify a unique approach for each course in hopes of removing redundancy and maintain student involvement.
- Incorporate additional topics of interest, such as:
 - Assignments on recognizing and understanding the impact of microaggressions
 - Discussions regarding the benefits of inclusive language
 - Case studies which demonstrate the importance of diversity in engineering design

This material is based upon work supported by the National Science Foundation under Grant Nos. 1726268, 1725880 and 1726088. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Thank you.
Questions?

References

- [1] W. W. Wulf, "Diversity in engineering," *Leadership and Management in Engineering*, vol. 1, no. 4, pp. 31–35, 2001.
- [2] C. Staats, K. Capatosto, R. A. Wright, and V. W. Jackson, "State of the science: Implicit bias review," The Ohio State University: Kirwan Institute for the Study of Race and Ethnicity, Tech. Rep., 2016.
- [3] E. Seat, J. R. Parsons, and W. A. Poppen, "Enabling engineering performance skills: A program to teach communication, leadership, and teamwork*," *Journal of Engineering Education*, vol. 90, no. 1, pp. 7–12, 2001.
- [4] A. C. to the National Science Foundation, "Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology," National Science Foundation (NSF), Tech. Rep. NSF 96-139, 1996.
- [5] C. Meyers, "Restructuring engineering education: A focus on change," National Science Foundation (NSF), Report of an NSF workshop on Engineering Education NSF 95-65, April 1995.
- [6] "Comparison of proposal submitted in 2015 to proposal submitted in 2016," ABET Engineering Accreditation Commission (EAC), Tech. Rep., 2016.
- [7] K. E. Rambo-Hernandez, A. Roy, M. L. Morris, R. A. M. Hensel, J. C. Schwartz, R. A. Atadero, and C. Paguyo, "Using interactive theater to promote inclusive behaviors in teams for first-year engineering students: A sustainable approach," in *2018 CoNECD - The Collaborative Network for Engineering and Computing Diversity Conference*. Crystal City, Virginia: ASEE Conferences, April 2018, <https://peer.asee.org/29592>.
- [8] "Project implicit," <https://implicit.harvard.edu/implicit/takeatest.html>.
- [9] C. Seron, S. S. Silbey, E. Cech, and B. Rubineau, "Persistence is cultural: Professional socialization and the reproduction of sex segregation," *Work and Occupations*, vol. 43, no. 2, pp. 178–214, 2016.
- [10] N. Dasgupta, M. M. Scircle, and M. Hunsinger, "Female peers in small work groups enhance women's motivation, verbal participation, and career aspirations in engineering," *Proceedings of the National Academy of Sciences*, vol. 112, no. 16, pp. 4988–4993, 2015.
- [11] "CSU Office of Institutional Research, Effectiveness, and Planning," http://irasp101.ir.colostate.edu:9704/xmlpserver/Public/Reports/RTR_Trends/RTR_Single_Year_Dept_Comparison_Within_College.xdo?&_xmode=2.