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Using Classroom Activities to Integrate Concepts of Diverse Thinking and Teaming into Engineering Design (Experience)

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Introduction

The recruitment and retention of underrepresented groups in engineering programs has been an ongoing effort for decades [1] However, many of these efforts have focused on support of a specific underrepresented group, but do not necessarily address the independent behaviors or attitudes of all students, or the overall cultural influence of the department, school, or university. The development of a new generation of engineering graduates that is more conscientious of the need for diverse thinking and teams is critical for retaining members of these underrepresented populations outside of a university setting and developing a stronger and more effective engineering workforce.

In order to work towards this goal, an NSF-funded multi-institutional project in its third year is developing unique curriculum activities that highlight how the engineering profession benefits from diversity, as well as promote inclusive engineering identities within undergraduate students [2,3]. This project has included surveying students about how they identify with engineering and their perceptions about diversity in engineering, as well as developing in-class activities for first-year engineering courses to help facilitate the growth of inclusive engineering identities [4]. As it progresses forward, the most recent addition to the project is implementing similar activities in upper-divisional engineering courses. This paper describes two such activities from 2nd and 3rd year engineering courses at the University of Denver (DU) that focused on highlighting the importance of diversity within design groups. This pilot experience included surveying the students about their feelings on diversity and engineering both before and after the activity, an in-class activity focused on design and diversity of teams, and a reflection and discussion period about the students' experiences. A discussion of the successes and opportunities for improvement within the activities is included, along with changes planned for the second trial during the current academic year.

Methods

For the pilot run of the activities, the professors each developed an in-class project that took place during one class period. Each activity contained a technical aspect, a design aspect, and a reflection period. Both projects chose a product to design that had an aspect which was influenced by the background of the designers and possible users. The two specific activities are described in full below.

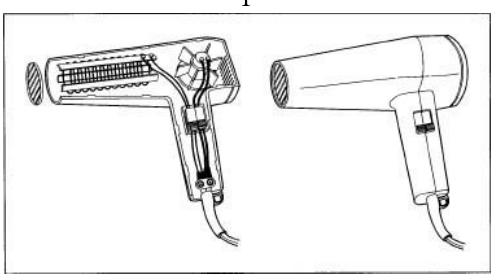
Activity 1 – Thermodynamics

Thermodynamics I is a 2nd year course usually taken by mechanical engineering students in their 6th quarter. There may be additional non-mechanical engineering majors who are taking it for an engineering minor or a mechatronics systems concentration through electrical engineering. In the quarter this activity was piloted (spring 2019) there were 40 students taking the class and 37 participated on the day of the activity. Eight of these students were female and thirty-two were male.

The activity was executed during one lecture period that ran for 80 minutes. For the activity students were split into groups of four, however three groups only had three members because of absences. The groups were strategically formed so that there was one all-female group, two co-ed groups with two male and two female students, and seven all male groups. This was done to ensure the gender make-up of the groups would be varied, but that there was also no group where anyone was the only student of their gender.

Once put into groups students were told that they would be asked to look at how a hair dryer works, and how they may change the current design. A hair dryer was selected because it is something that almost everyone is familiar with, however it is also predominantly used by women. Therefore, the female members of the groups would often have a different personal experience with the product then the males, however the males were aware of what the product was and how it was generally used. Each group was given a handout with seven questions listed here:

1. How does a hair dryer work?
2. Label the relevant parts of the following image [5]



3. The fan pulls quiescent air from the outside and moves it through the front nozzle. If there is 1 kg/s of air brought in and the air moves at a rate of 10 m/s through the nozzle, how much energy is required to run the fan? It can be assumed that you are holding the dryer horizontally, and atmospheric pressure occurs throughout.
4. If you wanted to increase the speed of the air exiting the hair dryer, how would you change the design? Think of more than one option! Also, how fast is too fast?
5. The heating element warms the air from 22°C to 50°C before it exits the nozzle. If the air still goes from 0 to 10 m/s and has a mass flow rate of 1 kg/s, how much heat is required for this temperature change? Assume the work you found in question #3 can be applied and give your answer in Watts.
6. What range of temperatures should the hair dryer provide? Why? How would you design the hair dryer to accomplish this?
7. What other attributes do you think a hairdryer needs? How could you “improve” the current hair dryer design? Have fun and be creative!

Students were told that in order to answer any of the questions they may use their notes, books, laptops, etc. if they cited the information and were cognizant of vetting any of the sources. Students were given about 45 minutes to complete the packet, and during this time the instructor would stop their work and go over a question about every 10 minutes to help keep the class engaged and make sure the groups were on the correct track.

With about 25 minutes left in the class period the work time was stopped and a discussion period began. The instructor went over a few questions with the students, starting with the last question from their packet, which was an open-ended question about how their group would change or improve hairdryer design. The reason this question was picked to begin the discussion was because it allowed all the students to hear what other groups had looked at in terms of design, setting up the rest of the discussion, which was focused on the design experience and how the makeup of their team may have affected this design. The discussion questions are listed below:

1. What other attributes do you think a hair dryer needs?
2. How could you “improve” the current hair dryer design?
3. What was the most difficult part of the design?
4. Do you think your experience with the product reflected how you looked at the design?
5. What about experience of your teammates?
6. Did you consider a specific population? Why?
7. What design consideration did you have? Economics, safety?
8. Did the makeup of your team affect how you looked at the design?
9. Looking at the other teams’ design ideas, did your group not consider something you maybe should have? Did this have to do with the makeup of your team?
10. Were you able to find information (via Google, books, etc) that helped if you didn’t know something about the product?

After completing the discussion students were given a brief outside of class assignment about the activity. They were asked to answer two questions in a one-page or less reflection piece. The questions were: “How would having a diverse design team help during this type of process?” and “Why would having a diverse design team be important for all projects?” The students had a week to complete the assignment. The reflections were not graded, but students received extra credit for completing the piece.

Additionally, the instructor wrote a reflection piece to capture what was noticed during the activity and the post-activity discussion.

Activity 2 – Embedded Systems

Embedded Systems is a course taken by both electrical and computer engineering students in the 3rd year of their curriculum. For the pilot activity, again in spring 2019, there were 22 students in the course. The activity was run during a lab period that ran for 120 minutes.

In comparison to the Thermodynamics I activity, the focus on diversity for the Embedded Systems activity was cultural differences. The class had 11 international students from several different countries and 11 domestic students. The groups were formed to incorporate a mix of both domestic and international students, preferably with the international students being from different countries. A musical instrument digital interface (MIDI) controller was selected as the design project as one’s taste in music can be influenced greatly by their culture.

Each group was asked to fill out a packet handout with seven questions, listed below:

1. How does a midi controller work?
2. Label the relevant parts of the following image (midi controller – Ableton Push):

3. Let's assume that the microcontroller that you are using has only three digital pins available to interact with 16 LEDs. How would you solve this problem? Provide a schematic of your solution
4. Let's assume that the microcontroller that you are using has only four digital pins available to interact with 16 buttons. How would you solve this problem? Provide a schematic of your solution
5. The microcontroller that you are using has a built in 5V – 10bits ADC with 4 channels and max bandwidth of 4 KHz. What is the minimum voltage per bit that you can read? What is the maximum frequency that you can read per channel if you are using all 4 channels?
6. What is the number of bits that you need in your ADC at 3.3V, for a resolution no greater than 0.8mV per bit? What is the bandwidth that you need to have if you want to acquire 800 samples per second per channel and you have two potentiometers in your midi controller?
7. Assume that you have a collection of sounds for a particular genre of music that you like (e.g. snare, flute, high hat). Based on the parts that you identified in question #2 (e.g. potentiometers, faders, buttons, etc.) design a midi controller that plays the sounds of your choice. Have fun and be creative!

After completing the activity, the students were asked to fill out a handout with the same reflection questions used in the Thermodynamics I in-class discussion above. In contrast to the thermodynamics class, the embedded systems class did not have an in-class discussion and was not asked to do any additional activities after the conclusion of the in-class activity.

Survey

As part of the larger NSF study, students were asked to complete a survey at the beginning and end of the quarter, the in-class activity occurring between these two time points. Students received credit for completing the survey but were not required to opt in for their data to be used to receive this credit. The survey has been previously explained [2,3], and contains questions concerning the students' opinions/feelings about a broad range of topics including, their sense of belonging on a university level, their engineering identity, diversity topics, climate, the activity they performed, and more. For the majority of the questions, students responded to a scale from 1-7 depending on the prompt. For example, when asked "I feel like I belong in the field of engineering” students responded between 1 (strongly disagree) to 7 (strongly agree). Some questions did allow for open ended responses.

For the thermodynamics class 16 students agreed to have their responses shared for the 1st survey and 14 also completed the 2nd survey. For the embedded systems course the shared responses were 12 for the 1st survey and 9 for the 2nd. Because of the very small survey numbers for these classes, there was no statistical analysis run for the surveys, but the data was used to observe trends and help determine possible changes for the second round of the in-class activities.

Results and Discussion

The broad focus of this project was on how these types of activities may help students develop their own personal identities as engineers. As published previously by Atadero et al., students with inclusive professional identities will possess four different attributes: (a) the necessary technical knowledge, skills, and abilities to work in their chosen field, (b) an appreciation for how all kinds of diversity strengthen engineering and computer science as disciplines, (c) knowledge of how to act in inclusive ways and create inclusive environments within their fields, and (d) consideration of diverse populations who are impacted by their professional practice [3]. Attributes (a), (b), and (d) were kept in mind when analyzing both the logistics of the activities, as well as the student experience. Attribute (c) was not considered for this study, since there was not a focus on creating inclusive environments for these activities. This analysis also helped drive the decisions about what changes would be made for the second run of the activities in 2020.

Student Reflections

The student reflections for both activities were explored to consider what themes appeared, and what content connected to the attributes described above. The reoccurrence of specific terms or phrases were also noted.

Thermodynamics Reflections

It should be noted that for the thermodynamics activity students participated in an in-class discussion and then wrote their reflection pieces outside of the classroom.

All students who completed the reflection piece wrote something positive about the importance of diversity on teams. Along with this a couple major themes appeared in the reflection pieces: 1) Different knowledge, different opinions, different perspectives lead to group creativity, project success, and/or increased profits (67% of respondents) and 2) Diverse teams lead to better innovation (52% of respondents). It was also noteworthy that while the activity focused on gender, most students brought up other types of diversity in their reflections including race, ability, background, etc.

Students reflected similarly about the results of the activity itself. Members of the all-male teams noticed that their lack of use and knowledge about the product affected how they considered design changes, leading to designs that were less practical and more “out of the box.” A few examples from their reflections included: "From my experience with the activity, and working in an all-male group, I left like I was missing out on so many conversations that I would have had if working with a more diverse team." And ". . . everyone noticed the women in the classroom designing practical things for women (that women would want), and the men designed things (while very cool) were not helpful to the population that uses the hairdryer most." The all-male teams also realized that the type of diversity associated with a group can make a difference: "I participated in a very diverse group, culturally. However, even with being very different from each other, we did all have one thing in common, we were all males who don't use a hair drier. Because of this, we all had a harder time trying to design a better hair drier."

The teams with both male and female group members noted a balance between the practical and more fun or wild ideas: "Being able to be on a team where there were guys along with (females) was really interesting. The ideas the guys had were funny, like attaching a TV to the hair dryer so we weren't bored while drying our hair. We (females) came up with ideas to have a heat protectant spray on our hair as well as a way to regulate the heat, so your hair doesn't burn – Ideas that were more practical." Students did point out that having viewpoints of non-users were also helpful, since they thought of things that were more outlandish, and while may not be completely practical, lead to some more creative improvement ideas that could be possible. Another student commented on this balance, "A group with men and women would help address the problem by using women('s) intel on personal experience on what needs to be improved combined with the men's' forward thinking on how to advance some of its traits to create the best improvement idea. In this case, the diversity stems to include both genders because each one can bring a different perspective to help improve the product."

There was only one group of all-female students, and it was noted during the group discussion that this group came up with the most practical ideas. However, this group also noted that while their group was fortunate to have members that had all used the product, the lack of diversity in their group also led to a different mindset. For example, one member claimed, "I was on a team of all girls in designing a hair dryer and this was extremely helpful because we were all very familiar with hair dryer designs and how they should be improved. If I had been the only girl on the team, it would've been more difficult to convey my perspective and ideas on a better design. However, it would have been helpful to also have males and a more diverse team than just women to also see their perspective on the design." This helped students observe the perspective that all types of viewpoints are important, even those of someone who is not as familiar with a product.

Embedded Systems Reflections

For the embedded systems activity, students completed a hand-out with the same questions used by the thermodynamics activity for an in-class discussion, and there was no in-class discussion beforehand.

Most of the embedded systems reflections focused more on the technical aspects of the activity than the diversity, most likely related to the fact that there was no previous discussion on the latter topic. However, there were still many points made by the students about how diversity was beneficial. For example, one student who was more familiar with the product stated "It gave me experience working with a team on a topic that I had more background in than the group. It turned out that their other backgrounds were equally useful."

Overall, the reflections showed that students had a positive experience with the in-class activities. The experience opened the door for a conversation about the need for diversity in design teams in a way that still related to the technical content of the course, therefore integrating the information instead of treating it as a separate topic.

The first aspect of the team experience and professional identity we looked at was the "technical skills." One of the most interesting things about how the students reacted to the design activities was how much time they spent focused on the technical questions. Students in both classes were very concerned about getting the "right" answer to the questions that asked them to perform a calculation or look at how the devices worked. In comparison, the more open-ended design questions, those without a "correct" answer, were approached with a more casual attitude. It appeared to the instructors that sometimes the students were too focused on these technical questions, which may have interfered with the goal of the activity. Moving forward, the questions will be formulated to have less focus on the technical side.

Another attribute considered was "an appreciation for how all kinds of diversity strengthen engineering and computer science as disciplines." In the thermodynamics course 81% of the reflections referred to a type of diversity besides gender or diversity as a broad topic. The different types included diversity in a person's background or upbringing (62%), cultural diversity (31%), racial diversity (19%), diversity of skills or abilities (15%) and one student brought up diversity in age. In comparison the reflections from the embedded systems course rarely had any mention of diversity outside of the cultural differences which were the focus of the activity. This is most likely because the thermodynamics class participated in an in-class discussion about diversity of groups, and their out-of-class assignment questions asked about diversity in general. In order to drive the conversation this way in the embedded systems course, it may be beneficial to do something similar.

The last attribute focuses on "consideration of diverse populations who are impacted by their professional practice." While not directly asked about the customer or audience for the products they were designing for during the process, students were asked to reflect on this later. In the thermodynamics class this was asked about during the in-class discussion and then several students also discussed this in their reflection pieces. For example, one student stated, "Products need to be designed for the audience that is specific to them, so if the team does not have diversity, the product will be a reflection of who the design team is and only their group." For the embedded systems course students were asked directly on their handout about whether they considered the audience of their product. The answers were split almost perfectly into four different answers: 1) They only considered themselves or their team, 2) They considered a specific type of person, 2) They considered everyone, and 4) They didn't answer or understand the question. In their reflections several of the students did note that they should have considered other populations or thought more about who they were designing their product for. For example, when asked what they could have done during the design process to create a product that would fit the needs of different populations they stated, "Ask questions about other's backgrounds and cultures" and "Consider all needs and desires through interviews with stakeholders."

When considering the overall analysis of the student experience and reflections, it was concluded that the activities allowed the students an opportunity to think about all three attributes above, and many students reflected positively towards these ideas.

Survey Results

The before and after activity surveys were compared to observe any changes in answers. As mentioned previously there were not enough respondents to run statistical analysis, so all observations are of trends. Students were asked the same questions before and after performing the in-class activity, therefore in order to see if the overall class score for a question had changed, a mean average of the response scores was calculated for the students in each class. If a student took the first survey but not the second their responses were taken out of the first survey's average. The majority of the questions did not show a change of more than 0.5 points. Questions that yielded a change of more than 0.5 points are shown in the table below:

Table 1: Survey questions that yielded a change of more than 0.5 points from pre to post-survey.

Question	Response Scale	Change of Mean Score from 1st to 2nd Survey – Thermodynamics Class	Change of Mean Score from 1st to 2nd Survey – Embedded Systems Class
There are many other people like me in (Name of University and School)	Strongly Disagree (1) to Strongly Agree (7)	0.9	-0.8
I feel like I fit in (Name of University and School)	Strongly Disagree (1) to Strongly Agree (7)	0.9	No Change
I feel like I have to hide parts of who I am to fit in (Name of University and School)	Strongly Disagree (1) to Strongly Agree (7)	No Change	0.5
I prefer to work in engineering teams with people who are like me.	Strongly Disagree (1) to Strongly Agree (7)	-0.6	No Change
I prefer working on engineering projects with people of the same sex.	Strongly Disagree (1) to Strongly Agree (7)	-0.5	No Change
When working on a team how likely are you to challenge sexist behaviors.	Very Unlikely (1) to Very Likely (7)	-0.6	No Change
When working on a team how likely are you to challenge xenophobic behaviors, which are behaviors that discriminate against people from other countries	Very Unlikely (1) to Very Likely (7)	-0.5	No Change

The first three questions in the table relate to the students' feelings about their belonging at the Ritchie School of Engineering and Computer Science at DU. The thermodynamics students had a positive increase in agreeing about how they feel they fit in after the activity, while the embedded systems students showed they felt as if they belonged less after the activity. The embedded systems students had no other changes in their pre- and post-survey answers, while the thermodynamics students showed a decrease in their desire to work in teams with people that look like themselves. The thermodynamics students also indicated that after the activities they were more unlikely to challenge sexist or xenophobic behaviors when working on a team, which could indicate that they had a desire to maintain stability within their team dynamics.

Faculty Feedback and Plans for Improvement

The faculty members who ran the activities were asked to reflect on the experience and provide feedback. This feedback was taken into consideration, along with the results from the reflections and surveys when considering what changes would be made to the activities for the second trial.

One issue that was pointed out was that some of the logistics and questions unintentionally led the students to answer questions how they thought they should. It would be beneficial to avoid this in order to get a fresh evaluation of their perceptions on diversity in groups, without influence from conversations. The first way to do this will be to have the students write a quick "minute paper" immediately after the activity, but before any discussion begins. The prompt for the minute paper will not specifically relate to diversity. For example, the students may be asked, "List three things you noticed during the activity that related to how your team worked together" or "Write a 4-5 sentence reflection on how your team worked together during this activity." This way the students' thoughts are captured before any in class discussion.

A second change to help avoid inadvertently affecting the students' answers would be to reword the questions used for the out of class reflections. Instead of asking specifically "why is diversity important" a more open-ended question such as "How did the makeup of your team affect your design decisions?" or "If you were picking team members for a design project, what would you take into consideration?"

One aspect that was different between the two courses, which seemed to affect how the student's reflected on the activity, was the inclusion of an in-class discussion in the thermodynamics course, but not the embedded systems course. As can be seen by the student reflections, the in-class discussion allowed for the instructor to talk more openly about the importance of diversity in teams and focused the activity toward this, and away from the more technical aspects. In future iterations an in-class discussion will be included for all activities. This can also be seen in the survey results, where the thermodynamics students indicated that they felt more comfortable in the school in general and indicated a desire to work with students who looked different than themselves. These changes could be because of what they heard and discussed in class about the need for diversity in groups and the field of engineering in general.

Related to the above difference, the instructor for the thermodynamics activity had previous experience with the project and had worked closely with members of the grant team to develop the activity and associated pieces. In comparison the instructor for the embedded systems course was asked to develop an activity but was given a short explanation and was given the thermodynamics activity as an example. Because of this the thermodynamics activity allowed for more discussion and reflection on diversity of teams in context of the project. In hindsight, this difference inadvertently gave the opportunity to show that it was important to explain the overall goals of the larger project to a faculty member and help them develop their activity accordingly. This faculty education will be given for all future iterations of similar activities.

A few smaller changes will include, changing the technical questions to be less complex as to keep the focus more on the design process, making sure to include a discussion about the audience/customer base of the product and the relation to diversity, and to add a discussion piece about the inclusiveness of a team, not just diversity.

Conclusion

Overall, the pilot run of these activities resulted in a positive response from both the faculty and students involved. The activities led to conversations about the importance of diversity in design teams and synched with three of the four attributes of students with inclusive professional identities. Both strengths and opportunities for improvement were discovered, and changes to help make these activities even more effective are already in place for the next effort. What is particularly significant about our findings is the value of creating time and space for intentional design. We believe this means we need to design not just for student learning, but also for faculty learning so everybody has shared understandings about the scope, purpose, and context of the interventions.

References

1. G. Lichtenstein, H. L. Chen, K. A. Smith, and T. A. Maldonado, “Retention and Persistence of Women and Minorities Along the Engineering Pathway in the United States” In *Cambridge Handbook of Engineering Education Research*, A. Johri and B. M. Olds, Ed. New York: Cambridge, 2014, pp. 311–334.

2. C. H. Paguyo, R. A. Atadero, K. E. Rambo-Hernandez, J. Francis. "Creating inclusive environments in first-year engineering classes to support student retention and learning." In *First Year Division: Proceedings of the 122nd ASEE Annual Conference & Exposition 2015, Seattle, WA, USA, June 14-17th, 2015.*

3. R. A. Atadero, C. H. Paguyo, K. E. Rambo-Hernandez, and H. L. Henderson, "Building inclusive engineering identities: implications for changing engineering culture." *European Journal of Engineering Education,* vol. 43.3, pp. 378-398, 2018.

4. A. Norris, A. Cook, R. A. Atadero, T. J. Siller. "An Evaluation of a First-Year Civil Engineering Student Group Dynamics Intervention ". *2019 FYEE Conference, Penn State University, Pennsylvania, USA, July 28-30th, 2019.*

5. Internal parts of a hairdryer. madehow.com *http://www.madehow.com/Volume-7/Hair-Dryer.html*