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# Hair Dryer Design as a Synergistic Tool for Combining Thermodynamics and the Importance of Diversity in Design Team Composition

**Dr. Breigh Nonte Roszelle, University of Denver**

Dr. Breigh Roszelle currently serves as the Associate Dean for Undergraduate Studies in the Ritchie School of Engineering and Computer Science and a Teaching Professor in the Department of Mechanical and Materials Engineering at the University of Denver.

**Dr. Jason Andrew Roney, University of Denver**

Dr. Roney is currently a Teaching Professor of Mechanical and Materials Engineering. Dr. Roney joined the University of Denver (DU) in Autumn 2014. Prior to joining DU, Dr. Roney held both industry and academic positions.

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## Introduction

The past few years have shown an increasing emphasis on justice, equity, diversity, and inclusion (JEDI) within engineering curriculums [1]. This emphasis on JEDI, also referred to as diversity, equity, and inclusion (DEI), has been reinforced by changes made by the major accreditation body for engineering programs, ABET. In 2016, ABET proposed changes to include language highlighting an outcome of "creating a collaborative and inclusive environment" for teams [2] and in 2021 ABET proposed changes to Criterion 5 and 6, focused on curriculum and faculty, that specifically highlight DEI [1]. While the commitment to JEDI in engineering curriculum is clear, the task of embedding this knowledge into engineering courses, many of which traditionally contain highly technical content, may seem overwhelming.

To help engineering and computer science programs tackle this issue, an NSF funded five-year, multi-institutional project was run with the purpose of developing activities to embed in technical curriculums that both promote inclusive engineering identities within undergraduate students and highlight the benefits of diversity in professional environments [3], [4], [5]. The project has led to dozens of activities that can be used throughout various engineering and computer science courses from first year to upper division [5].

As part of this project, the University of Denver (DU) has developed and implemented several activities, including a group-based hairdryer design task for second year thermodynamics students. The pilot of the activity took place in spring of 2019 and this initial experience was presented at ASEE in 2020 [6]. Since then, the activity has been run four times and iterated to help strengthen the goals of the activity and assess its effectiveness. Changes since the initial pilot have included options for remote courses, added reflection time, and a focus on overall design process instead of detailed mathematical questions. The current activity format and an explanation of changes from the pilot is described in detail along with observations from assessment of the activity via surveys and student reflections.

## Activity Description

The benefit of using a tool such as a hairdryer for a thermodynamic design activity is that nearly all students know what a hairdryer is and have most likely seen one in person, however not everyone will be a user of the product. Additionally, a hairdryer is a tool that is used more often by female identifying users than male identifying users. According to a survey from Philips Global Beauty Index, in 2017 79% of women used a hairdryer at least once that year [7] and a study on business traveler's lodging preferences showed that female lodgers were significantly more likely to use a hotel hairdryer than men [8]. This unique perspective means the hairdryer is an object where almost everyone knows how it works, but only a subset of the population uses it regularly. The specific benefit of using a hairdryer for a thermodynamics class is that it works based on multiple thermodynamic topics including conservation of mass, conservation of energy, flow energy, and open system energy analysis.

While the logistics of the activity have iterated over the past four years, the general set up remains the same. The in-class activity is run during a typical 80-minute lecture period. At the beginning of the class, students are placed into predetermined groups of three to four classmates to include a mix of all-female groups, all male-groups, and co-ed groups. The co-ed groups always contain two members of each gender for a total of four members to ensure that no student is the only group member of their own gender. The number of groups for each type varied each year based on the gender distribution of the class, however there was always at least one of each composition.

Once the students are placed into assigned groups they move to sit together and are given a handout of questions regarding hairdryers to complete. The questions are related to both the technical aspects of the design, including mathematical questions, and open-ended design questions. Students are allowed to use any resource they find helpful including class notes, their textbook, and internet sources. They are asked to both cite any sources they used and asked to be cognizant of vetting sources, especially those found online. Groups are given 45 minutes to work through the questions together. During this time the instructor circulates the room to check in with groups and answer any questions they may have. The instructor also pauses the activity about every 10 minutes to discuss answers to the questions with the full class. This pause is helpful in keeping the class engaged and on track during the process. At the end of this 45-minute period the instructor has each group report out their design ideas from the final question.

An observation from the pilot was that students became fixated on the mathematical problems and were not moving along through the additional questions within the given time. Because a major focus of the activity was the discussion on design ideas, it was decided to change some of the questions to help students think about the thermodynamics of the system overall, but not focus on "finding the right answer." Table 1 shows how the questions changed from the pilot in 2019 to the most recent iteration in 2022.

In spring 2020 the class was run as fully remote. The activity was facilitated over Zoom and used breakout rooms to split students into their groups. The instructor visited the breakout rooms and sent messages to the students via Zoom to answer questions and help keep groups engaged in the activity. Additionally, the handouts were sent as electronic templates that could be filled in by the students together remotely and then uploaded to the course management system.

After the groups answer the handout questions and discuss their design ideas, roughly 30 minutes is used for reflection and discussion. In the pilot, the instructor went straight to the discussion portion, however it was later decided to add a quick reflection activity prior. The discussion questions, shown in Table 2, lead the students to the topics that address considering diversity in design. By having the students complete a quick reflection before the discussion begins, it allows the students to consider the design contributions without hearing from others first and being led to a specific answer. The prompt for the quick reflection states: "What did you notice about the different designs people suggested? Did the composition of the group influence the suggested designs?" They are given 2-3 minutes to complete their reflection as a text entry on the course management system.

Table 1 – Hairdryer Activity Questions

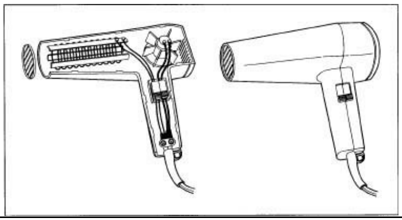
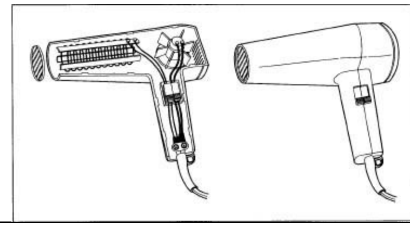
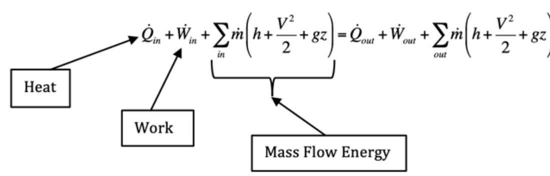
| 2019 Version | 2022 Version |
|---|---|
| 1. How does a hair dryer work? | 1. How does a hair dryer work? Think about both the parts and how it actually dries hair. |
| 2. Label the relevant parts of the following image [10]  | 2. Label the relevant parts of the following image [10]  |
| | 3. How is a hairdryer related to thermodynamics? Explain, what forms of energy are found in the hairdryer and how these forms are transformed as it is used (aka what are the forms of work and heat, and how are they related). Use the equation below to consider the energy balance.   $\dot{Q}_{in} + \dot{W}_{in} + \sum_{in} \dot{m}\left(h + \frac{V^2}{2} + gz\right) = \dot{Q}_{out} + \dot{W}_{out} + \sum_{out} \dot{m}\left(h + \frac{V^2}{2} + gz\right)$ |
| 3. The fan pulls quiescent air from the outside and moves it through the front nozzle. If the 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. The fan pulls quiescent (aka still) 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. $\dot{E} = \dot{m} \cdot e_{mech} = \dot{m}\left(\frac{P}{\rho} \cdot \frac{V^2}{2} \cdot gz\right)$ |
| 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. 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? | 6. What range of temperatures should the hair dryer provide? Why? How would you design the hair dryer to accomplish this? |

Table 2 – Discussion questions in order

| |
|---|
| What was the most difficult part of the design? |
| Do you think your experience with the product reflected how you looked at the design? |
| What about the experience of your teammates? |
| Did you consider a specific population? Why? |
| What design consideration did you have? Economics, safety? |
| Did the makeup of your team affect how you looked at the design? |
| 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? |
| Were you able to find information (via Google, books, etc) that helped if you didn't know something about the product? |

Once the discussion was completed, the students were given an additional reflection piece as a homework assignment. They were asked to answer two questions via a one-page or less typed response. For the pilot the two 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?" It was later decided to change the prompt to "How did the composition of the groups affect the design process? Explain why group composition would matter for all types of design projects." The reason for the change is that the instructors felt the initial prompt indicated the response the was desired by the students by using the language that implied having a diverse team was helpful, and not allowing students to come to that conclusion on their own. The word 'diverse' was also removed since many students may only think of race or gender when they think of diversity in engineering, and not consider other types of diversity such as ability, neurodiversity, culture, etc.

## Assessment Methods

The activity was assessed by considering two pieces of information, a survey completed before and after the activity and the student reflections.

The survey was developed as part of the larger NSF study and has been described in full previously [3], [4], [5], [6]. The survey includes questions concerning student thoughts about engineering identity, including their sense of belonging on a university level, diversity topics, climate, the activity they performed, and more. For non-open-ended 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).

Students received credit for completing both surveys, however they could opt out of their responses being recorded as part of the study. On average, 81% of students completed the first survey and allowed their responses to be used and 63% completed the second survey and allowed their responses to be used. If a student completed the first survey but not the second, their responses were not used when calculating changes in responses before and after the survey. It should be noted that due to the small class sizes and response numbers no statistical analysis was performed on the survey data, and instead it was used to observe trends and help assess change ideas for the activity. As a note, survey data was not able to be obtained in 2020, but reflection responses were collected.

The student reflections, both the quick reflection and take-home assignment, were reviewed for common themes, phrases, and terms. Reflections from one year to the next were compared to help analyze the effect of activity changes.

## Results and Discussion

As described previously by Atedero et al., the overall goal of the NSF study is to develop and execute activities that help students cultivate inclusive professional identities that include the following four 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 [4]. The thermodynamics activity focused on helping develop attributes a, b, and d.

Both the quick and long student reflection pieces showed that students understood the overall effect group composition can have on the design process, helping reiterate attribute (b). In the quick reflection, 73% of students indicated that group composition mattered when coming up with design ideas and 100% of students agreed with this in their long reflection. Interestingly, 10% of students specifically said group composition did not matter in their quick reflection but switched this opinion when completing their long reflection. This observation is similar to a finding in the pilot paper by Roszelle et al. where it was found that having a discussion period about the ideas of group composition and diversity helped reiterate these ideas to the students [6]. One student who initially did not think the group composition mattered reflected, "*When the question was first asked if we thought the composition of our group mattered, I didn't think it affected the total outcome of our group's decisions. The more we discussed the question with multiple groups I started to realize that the group composition really did affect our group. . . Without diversity you won't be able to tackle all of the issues in a problem you're trying to solve. No matter how hard a group tries to figure out an issue, certain things just won't be obvious to a certain group of people*."

It is also noteworthy that over half of the students (59%) mentioned an additional type of diversity besides gender and user experience in their long reflections. The types of diversity mentioned race, age, religion, ability, culture, background, and more. This observation helps strengthen attribute (d), having students consider multiple forms of diversity and not just the type specifically discussed during this activity. Several students even came up with their own examples of how diversity could help solve other engineering problems. These examples spanned the spectrum from farm equipment to shoes. Some of these are presented below:

"*For example, a person who grew up operating farm equipment may design an agricultural tool with extra margins for durability and reliability, whereas someone without this experience may decide to try to make it as cheaply as possible while meeting the minimum requirements."*

*"If every team member is from one part of the country for example, around Florida, if they are tasked on designing a car the likely anticipated user of the car would be someone like them. If they design the car to be a convertible this would work well in Florida but not in other parts of the country."*

*"Focusing on shoe designs, those with medical conditions, such as arthritis, might need specific inserts or shoes depending on the severity. As a result, when designing a shoe to compensate for these individuals, designers not only need to understand how to design a shoe, but they also need input from those suffering from the mentioned medical condition to modify a traditional shoe, in addition to understanding if their product is increasing the quality of life for the affected population."*

The reflections from 2020, when the class was run fully remote, showed the same level of engagement and understanding of the topic by the students. One of the students commented in their reflection, "*It was nice to work in a live team for the first time this quarter and to hear the opinions and designs from other students. I wish we could do more of these activities in the future.*" It appears that moving to a remote format did not lessen the impact of the activity, and in fact gave students the opportunity to engage with other students who they had been missing due to being required to be fully remote for the quarter.

For all iterations of the activity the design suggestions by each team composition showed consistency. Groups that included a user typically proposed design ideas to improve their user experience such as making the hairdryer light weight, avoiding interference by the cord, or considering ways to avoid hair damage. Teams with no users tended to focus on either the thermodynamic efficiency of the device or propose more "out of the box" ideas such as having the hairdryer play music while you were using it. After discussing the group ideas, the students often came to the conclusion that groups with both users and non-users were ideal. One student stated, "*Because I use a hairdryer so often, my improvements were more practical and less imaginative. Since boys are not known for using hairdryers, they can approach this problem from a different more creative perspective. In this activity, the boys and girls could have merged their practical and out of the box ideas to create one solid design improvement.*"

One interesting, shared experience for both users and non-users was the noise of a hairdryer. One student commented, "*I know that the hairdryer that my mom and sister use makes a ton of noise and has actually woken me up before from across the house.*" This was a good way for students to realize that non-users of a product may also be affected by its use.

The survey data was analyzed to observe changes in student responses before and after they completed the class activity. The majority of the survey data showed very small to no changes in student responses pre and post activity, however if a question did show an average change of +/- 0.5 it is shown in table 3. As a reminder, the responses for each year were small (less than 30) and so statistical analysis was not performed. These changes were instead observed and analyzed within the context of the activity and reflection responses.

Table 3: Survey questions that yielded a change of more than 0.5 points from pre- to post-survey.

| Year | Question | Response Scale | Change of Mean Score from 1st to 2nd Survey |
|---|---|---|---|
| **2019** | There are many other people like me in DU's Ritchie School of Engineering and Computer Science. | Strongly Disagree (1) to Strongly Agree (7) | 0.9 |
| | I feel like I fit in DU's Ritchie School of Engineering and Computer Science. | Strongly Disagree (1) to Strongly Agree (7) | 0.9 |
| | I prefer to work in engineering teams with people who are like me. | Strongly Disagree (1) to Strongly Agree (7) | -0.6 |
| | I prefer working on engineering projects with people of the same sex. | Strongly Disagree (1) to Strongly Agree (7) | -0.5 |
| | When working on a team how likely are you to challenge sexist behaviors. | Very Unlikely (1) to Very Likely (7) | -0.6 |
| | 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 |
| **2021** | I feel alienated in DU's Ritchie School of Engineering and Computer Science. | Strongly Disagree (1) to Strongly Agree (7) | -0.6 |
| | I am a typical student in DU's Ritchie School of Engineering and Computer Science. | Strongly Disagree (1) to Strongly Agree (7) | 0.7 |
| | I prefer to work in engineering teams with people who are like me. | Strongly Disagree (1) to Strongly Agree (7) | -0.9 |
| | I would describe DU’s Ritchie School of Engineering and Computer Science as having a diverse student population | Strongly Disagree (1) to Strongly Agree (7) | 0.5 |
| | I think DU’s Ritchie School of Engineering and Computer Science is considerate of a diverse student population | Strongly Disagree (1) to Strongly Agree (7) | 0.6 |
| | Having diversity on a team keeps some teams here from performing to their best. | Strongly Disagree (1) to Strongly Agree (7) | 1 |
| **2022** | I feel a sense of belonging to DU's Ritchie School of Engineering and Computer Science. | Strongly Disagree (1) to Strongly Agree (7) | 0.5 |
| | I am considering switching to another major. | Strongly Disagree (1) to Strongly Agree (7) | -0.6 |
| | Engineers should value diversity in order to: - Improve products. | Strongly Disagree (1) to Strongly Agree (7) | 0.6 |
| | I feel I have been treated differently in DU’s Ritchie School of Engineering and Computer Science because of my background, ethnicity, race, gender, religion, or age | Strongly Disagree (1) to Strongly Agree (7) | -0.7 |
| | I think the campus climate encourages diversity | Strongly Disagree (1) to Strongly Agree (7) | -0.6 |

While none of the questions with changes over 0.5 overlapped from year to year, there were some observations of similar themes within question groups. In each year students had an increase in agreement on statements about their belonging within the DU and the engineering and computer science community after performing the in-class activity. Similarly, statements indicating a feeling of alienation, being treated differently due to personal diversity, or a desire to switch majors showed a decrease in agreement. There was also an increase in agreement about the importance of diversity in teams and a decrease in agreement about the desire to work with people who are more like themselves. One question in 2021 that does not seem to align with other conclusions was an increased agreement with the statement “Having diversity on a team keeps some teams here from performing to their best.” When looking at the individual survey responses several respondents switched their responses from a strong disagreement to a strong agreement (example 2 to 7). Because this does not align with the information from references and other survey data, it is hypothesized that the students could have misread this question as stating diversity helps a team instead of hindering its performance.

## Conclusions

Overall, the analysis of the student reflections and survey responses found that the in-class activity reiterated or improved student perspective on the importance of group composition and diversity within design teams. While the survey data does not show that this single activity has a monumental impact, including these types of activities in additional courses may lead to a growth mindset for students when it comes to JEDI. This experience has also shown that the activity can be adjusted for changes in course delivery mode such as during remote learning.

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