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# Implementation of a Module to Increase Engineering Students' Awareness of Unconscious Bias

**Emily Lauber, Microsoft**

Emily Lauber graduated in May 2017 with a B.S. in Civil Engineering and a minor in Science, Technology and Society from Arizona State University. Since then, she has worked in various product management roles in software consulting. Most recently, Emily joined Microsoft as a Technical Program Manager.

**Dr. Benjamin Emery Mertz, Rose-Hulman Institute of Technology**

Dr. Benjamin Mertz received his Ph. D. in Aerospace Engineering from the University of Notre Dame in 2010 and B.S. in Mechanical Engineering from Rose-Hulman Institute of Technology in 2005. He spent 7 years as a part of a lecturer team at Arizona State University that focused on the first-year engineering experience, including developing and teaching the Introduction to Engineering course. Currently, he is an assistant professor at Rose-Hulman Institute of Technology in the Mechanical Engineering department. His teaching focus is in fluid mechanics and thermodynamics but has also taught classes such as numerical methods and introduction to engineering. His interests include student pathways and motivations into engineering and developing lab-based curriculum. He has also developed an interest in non-traditional modes of content delivery including online classes and flipped classrooms and incorporating the entrepreneurial mindset into curriculum.

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## Introduction

The engineering discipline has developed a culture which values objectivity and empirically driven decision making, and these empirically driven methods are focused on in engineering education. However, as humans, engineers engage in activities, even engineering activities, in a way that is influenced by their personal beliefs, values, worldview, and background. This diversity of viewpoints is often cited as increasing the creativity and effectiveness of engineering teams [1], yet can have an adverse effect when these viewpoints result in negatively imposed biases. Unconscious bias (or implicit bias) can be defined as "a prejudice in favor of or against one thing, person, or group compared with another usually in a way that's considered to be unfair. Biases may be held by an individual, group, or institution and can have negative or positive consequences" [2]. Unconscious bias is pervasive and affects our decisions, even when we think we are operating objectively. Yet because of identity-protective cognition, engineers who are immersed in a culture of objectivity often pride themselves on only looking at facts, and can have strong emotional reactions and dismiss scientific studies of unconscious bias when those studies undermine a shared cultural belief [3]. This reaction makes teaching a concept such as unconscious bias to engineering students difficult. In response to this engineering specific challenge, a curriculum was created that uses a LEGO activity to challenge engineering culture in a way that teaches about bias mitigation techniques without alienating engineering students. The curriculum was implemented by a peer facilitator in an upper-division engineering classroom at Arizona State University. The curriculum was received with positive qualitative feedback from instructors and students. The curriculum can be implemented in other educational areas with some modifications.

## Why address unconscious bias?

Unconscious bias operates without the person being aware of it, hence the unconscious part. From metacognition theory, individuals must first become aware of this bias before being able to monitor and control such biases so as to not negatively impact others [4]. Many engineering students may be in the pre-awareness phase of their understanding of unconscious bias, or they may lack metacognitive skills to mitigate such biases. Nordell cites research by Divine that suggests that it is possible to identify and mitigate biases, but that it may not be possible to get rid of them [5]. Unconscious bias itself is not inherently bad; unconscious bias enables the brain to process large amounts of information or make quick decisions [6].

Bias is often built on societal messages the person has integrated into their worldview. The societal messages are deeply engrained and normalized. Bias can also be individualized to a person's lived experiences [6]. Addressing bias in a large group can be difficult because individual experiences will affect whether a societal message is incorporated as an individual bias.

The unintentional application of unfair stereotypes is one way that unconscious biases can be expressed negatively. These types of bias can have long-term negative impacts on large groups of people. Here bias moves from a harmless way to process information into a form of discrimination. An example of this can be found in a study by Covert that suggests that unconscious bias can lead to women being less successful negotiating wages, being given less-visible projects, or not being promoted [7]. In academics, women and other minorities are underrepresented and attain tenure and other faculty positions at lower volumes and rates [8]. Women in undergraduate engineering programs describe feelings of not belonging based on experiences of microaggressions in the environment [9]. These are just a few examples of when unconscious bias can have a negative and lasting impact.

More than merely reducing the negative impacts, mitigating unconscious bias can have positive impacts on engineering. Reducing implicit biases in hiring increases diversity in staff and team development. Diverse teams create better products to address broader customer needs [10]. Identifying and overriding our unconscious biases can have a positive impact on interpersonal communication and reduce the barriers for others' success.

## Why engineering education?

Each profession has its own culture, and engineering education culture specifically can be resistant to learning about and addressing unconscious bias. Cech's research identifies three pillars of engineering education culture that decrease a student's level of engagement with public welfare over time [11]. The three pillars: depoliticization, social/technical dualism, and meritocracy; affect how engineers engage with public welfare, which can be extended to apply to other social issues such as unconscious bias. To effectively raise awareness of unconscious bias and encourage practices of mitigating these biases, a curriculum needs to work around or in tandem with these pillars.

The first pillar is depoliticization. Depoliticization is “the belief that engineering work *can* and should be disconnected from ‘social’ and ‘political’ concerns because such considerations may bias otherwise ‘pure’ engineering practice” [11]. This depoliticization allows engineers to cognitively disengage and separate from issues perceived as social or political. If unconscious bias training focuses on an individual’s social or demographic information, such as race, gender, sexual orientation, or disability, the training can fall into identity politics. When engineering students perceive a topic as related to identity politics, the students will disengage under the belief that the social political issue is not applicable to their ‘real’ engineering work. Unconscious bias training must therefore be able to engage with bias in a way that students will not withdraw from the conversation as political.

The second pillar of disengagement is the technical/social dualism. This dualism allows “engineers’ cognitive separation of ‘technical’ and ‘social’ competencies [which] devalues ‘social’ competencies“ [11]. Unconscious bias is historically studied in the social sciences, which engineering education culture places as separate and can thereby be devalued in the engineering classroom. To engage engineering students on the topic of unconscious bias then, a curriculum must articulate how an idea from the social sciences can and will directly impact their lives, both as an engineering professional and in the ‘pure’ engineering design work.

The last pillar of disengagement is the ideology of meritocracy. Meritocracy is “the belief that social advancement structures in the United States are fair and just“ [11]. While several studies have documented the impact of implicit bias contributing to a structural environment that is not fair or just, if engineering students are presented with these studies straight forth, the conflict between the structural impact of bias and engineering culture’s meritocracy can lead students to reject the studies based on identity-protective cognition [3]. Identity-protective cognition is when an individual selectively interprets or dismisses information that contradicts a shared group belief [12]. In an engineering classroom, a shared group belief is the engineering education’s pillar of meritocracy. To avoid identity-protective cognition, an unconscious bias curriculum for engineering education should illustrate how bias mitigation techniques leads to a system more accurately reflective of merit.

Module

The curriculum is designed for a class of approximately 40 upper division engineering students and is intended to take about 45 minutes to run. The curriculum is suitable for lower division students with only minor modifications, though differences in how students would react to the curriculum at different grade levels is beyond the scope of this exploratory study. The curriculum centers on a LEGO activity to demonstrate bias, leading into a discussion of what bias is and how to mitigate it. The implementation was facilitated by a peer teaching assistant. A discussion lead by a professor or authority figure may need adjusted to promote open dialogue if students perceive a discussion of their own biases could affect their standing in the class. This would be an interesting area for future research but is beyond the scope of the present study.

The class starts with an introduction involving optical illusions, see Figure 1. The figure contains four circles, two circles filled in black, each within a larger circle with no fill. The two black circles are the same size while the encompassing no-fill circles are differently sized. Asking questions about the optical illusions, such as which inner circle appears larger, starts a discussion on how the brain uses context to make quick decisions [6] . The illusions demonstrate that human brains automatically make assumptions, even before humans have had a chance to fully evaluate the situation. By using a method that showcases their brains making decisions without all the facts, the engineering students are primed for realizing that their own brain does not always act objectively in all situations.

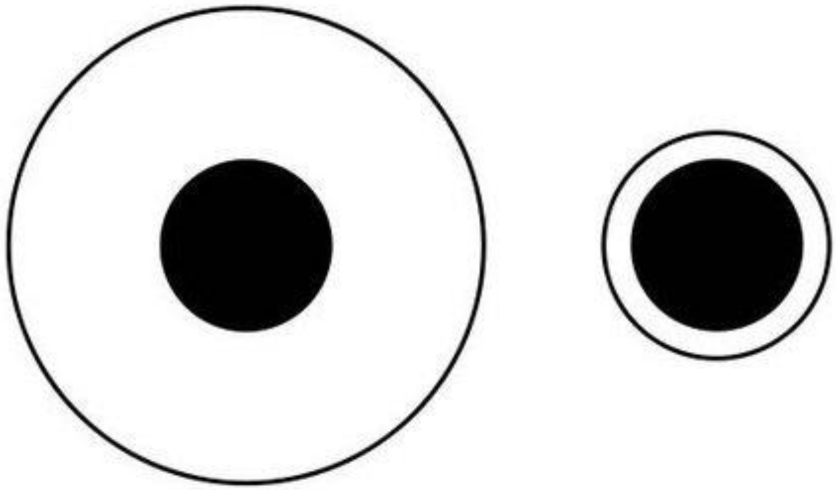

Figure 1 one of the optical illusions used in the module.

Moving from the optical illusions, the curriculum transitions to a LEGO activity also based on decision making. The LEGO activity is an opportunity to explore the effects of bias without requiring students to share vulnerable personal details. The inspiration to use LEGOs came from research on the LEGOs Serious Play activity, which is implemented in business and educational arenas as an engaging and effective way to discuss abstract concepts and problem solving in groups [13]. Research has shown that using games or LEGOs in the classroom can encourage problem-solving and entrepreneurial mindsets for younger and college-age students [14] [15]. The unconscious bias curriculum does not use LEGOs in exactly the same way as the LEGO Serious Play, but elements of the research, such as a hands-on approach and LEGOs as a proxy for abstract discussions, influenced the unconscious bias activity design [16].

To start the LEGO activity, the students need sorted into several affinity groups. The affinity groups can vary by relevancy to the course or pop culture. The affinity groups should not be based on student characteristics like age, disability, race, gender, or sexual orientation. Instead, the affinity groups should be superficial characteristics like favorite food, the color shirt students are wearing, what part of the classroom they are in, what number their student ID ends in, etc. For this implementation, the facilitator chose the Harry Potter Hogwarts's houses. All the students self-sorted into the four Hogwarts' houses plus a group of students self-selected into "No House." A single volunteer from Hufflepuff, Slytherin, Gryffindor, Ravenclaw, and 'no-house' were chosen to come to the front for an unknown activity with the LEGOs. With the volunteers at the front, they were told to build an ornament in under a minute. No further instructions were given other than "build an ornament using the LEGOs in under a minute." It is important that the object to build is not described in any way other than the common name of the object. The object could be anything relatively small to build with LEGOs (a building, a bird, etc.). An ornament was chosen for this implementation since the timing was right before the December break.

After a minute of building, the class ranks the ornaments. The class chosen for the curriculum implementation uses Twitter as a means of discussion, so this classroom was asked to tweet their rankings. Figure 2 contains a small sample of the students' tweeted rankings. Other polling techniques would also work for this activity, but since Twitter is this particular class's norm, other tools could have been disruptive. In the ranking, one object usually comes out consistently first and another consistently last. The in-between is where the rankings vary.


Figure 2 a small sampling of the students' ranking of the ornaments by house.

Students were called upon in the class to defend their rankings. The expectation is when people defend their rankings, they often rely on arbitrary reasons. Some may say the use of color, symmetry, size, etc. helped them decide. The nuance between the middle rankings is interesting because those rankings are where people find it harder to justify why one ornament was third instead of second. That discomfort in being put on the spot to explain their decisions is an opportunity for bias to be realized.

By choosing volunteers based on a pop culture affinity, affinity group bias can be discussed without risking more uncomfortable biases such as gender or race. When the ranking is challenged because of a fictional association (such as Hufflepuff), the students are able to laugh about it while still reevaluating their thinking. Thus, choosing a fictional pop culture affinity group over a personal identity one is critical to the discussion later on.

After a few people have defended their rankings, the facilitator can then start asking questions about trends in people's ranking. For example, did some people rank the Harry Potter house they associate with higher than a different one? Were there preferences for certain color combinations? This can lead into questions about the fact there were no ranking guidelines given. In the United States during December, many might assume ornament means Christmas tree ornament, yet this activity only asked for an ornament. The builders and rankers could have chosen a hood ornament to base their decisions on. This question about the type of ornament, in particular, can be a very tangible expression of unconscious bias that students can identify within their own rankings.

Once students have explored and realized how their biases could have affected their rankings, the discussion moves into what the long-term impact of this bias is. For one ranking, putting someone second instead of third because of the student's house association does not seem likely to have a big impact. Yet if this ranking was done over and over, that slight ranking difference compounds to being a dramatic difference after 10 or 20 rankings. The discussion should emphasize how biases do not operate one-time or in a vacuum.

After some discussion about the impact of bias in the long-term for the ornament rankings, students are tasked with coming up with solutions of mitigating the bias in the LEGO object rankings. These solutions can include not telling the rankers which ornament is associated with which house, giving more specific guidelines of how to rank, compiling rankings to find an average rank value, etc. Pedagogically, student-generated solutions will be more memorable and encourages critical thinking over being lectured on bias mitigation strategies.

The above discussions about rankings and bias should be focused on the LEGO activity only. Any discussion from the students that leads to more serious topics of bias should be redirected back to the activity until after mitigation techniques for the LEGO objects have been discussed. By centering on the LEGO and superficial affinity associations, students are able to explore the discomfort of bias without feeling personally attacked. This ability to explore the discomfort should extend all the way through mitigation techniques. If students are forced to address biases related to others' personal identities before getting a chance to explore mitigation techniques, then the discussion risks being derailed by students' emotions. By waiting until after mitigation is discussed, students are allowed the comfort of knowing mitigation is possible before addressing more serious bias.

Once mitigation techniques for the ornaments are identified, then the discussion can move to other instances where bias exists. To start this, the facilitator should ask what biases students had about the facilitator when they first met. The facilitator should provide a few examples at first if students are shy about voicing their bias. For example, the author who implemented the curriculum has a septum piercing. So, for this part of the discussion, the facilitator asked if the facial jewelry led to certain assumptions by the students. It is important to keep a sense of humor in this discussion and the facilitator to be comfortable with hearing untrue or unfair stereotypes based on their appearance. By keeping it light and laughing or agreeing with the assumptions, students feel able to be more honest in their biases about the facilitator. This kind of discussion may be more difficult for students to have with an authority figure and so faculty may need to be mindful of this as they are preparing for such a discussion. Similarly, this discussion may be difficult for faculty members whose career is subject to students' evaluations. Future study could explore the effect of having a third-party facilitate this discussion.

Following the discussion of implicit assumptions that students may have had about the facilitator, the students are invited to share some of their own experiences with unconscious bias.

This part is based on the students in the classroom so will vary across implementation. In engineering, a common bias that could be brought up and discussed is the belief that women, especially feminine women, are not good at math or technical skills. Depending on the classroom composition, a bias against international students' and their English-speaking ability could also be discussed. If the discussion begins to personally attack particular students and their experience, the facilitator should lead the discussion back to understanding the bias in terms of the LEGO activity.

Mirroring the LEGO object discussion, after identifying biases that exist, the facilitator should guide the discussion into larger implications of these biases. For example, negative effects of these biases can be the gender wage gap, fewer promotions, fewer papers accepted to publish, etc. The impact questions should be immediately followed by mitigation techniques and the documented success of these mitigation techniques. Examples of mitigation techniques for discussion include how double-blind reviews are used to publish research in journals, or how structured guidelines are used during performance reviews in the engineering industry. This discussion should rely on situations the engineers are familiar with or know they will face in the workforce. Using examples that engineering students know they will experience (e.g., promotions), will increase their willingness to engage in the discussion and they will be less likely to classify unconscious bias as a social science topic they can ignore.

Implementation

For the pilot implementation of the curriculum, the class was an upper division required course for civil engineering. The class centered on business practices, so the curriculum was incorporated as part of professional communication. The authors were not professors of this course, but one of the authors was a teaching assistant for the course in the past and the professor of the course allowed the author to teach the curriculum as a guest lecturer.

The curriculum was implemented late in the semester, after the class was already comfortable with each other and with large group discussions. The coursework for this class included several activities that are "outside" the typical technical engineering classrooms, such as using Twitter as the classroom communication tool. Because of this, the students could have been more primed to be receptive to the curriculum based on class experience so far. When the unconscious bias curriculum is positioned as pertinent to the engineering students' development in professional communication, the module could theoretically be implemented in any engineering classroom.

For the curriculum to be successful, the facilitator must be willing to share their own vulnerabilities and experiences with biases. By having vulnerability demonstrated, students are able to reflect on themselves and share their own vulnerabilities without fear of being judged or shamed. This theory stems from social justice organizing techniques of storytelling [17]. The facilitator's vulnerabilities should be shared in two key areas: biases against the facilitator and times when the facilitator was biased. For this author, the biases against her focused on being a young white woman with facial piercings. The implementation for the author is slightly skewed because several of the students in the classroom already knew the author through other activities such as extracurricular clubs or other engineering classes together. This potentially also made it easier for the students to share their biases because they knew the facilitator did not have grading power over students. Faculty could potentially leverage positional statements to express their concern for the topic and their beliefs about its importance to engineering.

When discussing biases the facilitator has held, the author shared a personal story about how when she first met another one of the teaching assistants, she was impressed by his English because he was an international student from Kuwait. The facilitator discussed with the teaching assistant beforehand for permission to share this story. By sharing the story, the facilitator's vulnerability allows the students to recognize that unconscious bias can happen automatically, even by people working to address it.

Feedback

Overall, the module was well-received. Both the professor of the course and the students thanked the author for the lesson and complimented its implementation. The LEGOs added a level of novelty that made the students more willing to participate in the lesson, see Figure 3. A few students valued the lesson so much that they expressed the module should be implemented sooner in engineers' education, see Figure 4. Investigating the effect of this module at different points in a student's career would be interesting for future study.

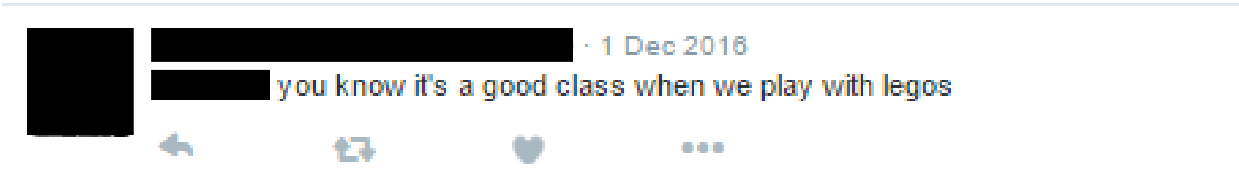


Figure 3 a student expressing joy over Legos.


Figure 4 students expressing desire for the unconscious bias curriculum sooner in their educational careers.

After the curriculum was implemented and tested in the course, the class discussion reached a point where the students understood unconscious bias, the effects, and mitigation techniques. This assessment is based on the stories they were sharing of bias during both the online and in-class discussion. The students continued the discussion on Twitter, sharing more examples of unconscious bias and instances where it was mitigated, even outside the context of engineering. Figure 5 shows a student sharing how a professional orchestra implemented curtains and carpets to mitigate gender bias of people auditioning. Another student asked the effect of this particular mitigation method for professional orchestras, showing an investment in the efficacy of mitigation techniques. This shows the students' comprehension of the topic and creative ways to effectively address it. Since this was a pilot run, there was limited data and a thorough qualitative analysis could not be performed.  A more formal survey could be implemented to explore the effectiveness of the curriculum, but since pilot study was implemented into a pre-existing class, it was desirable to find methods of data collection that would not be outside of typical classroom procedures.


Figure 5 a student describing a situation of bias mitigation used by professional orchestras.

<u>Future study</u>

The initial implementation solidified the timing of the module. After the 45 minutes point, the learning objectives had been met. The class was a total of 65 minutes, so the conversation past the 45 minutes mark was nuanced and students were able to share their personal experiences as a way to build more examples of understanding. The discussion did lead to a question of what to do if you are the victim of someone else’s negative unconscious bias. Individual students shared what they felt was the best response in that situation, but future implementations will need to prepare for the conversation to reach this point and tactical ways to facilitate the discussion.

Some limitations of this exploratory study are: only one implementation with a peer facilitator, no quantitative analysis, and no demographic data collected. Future iterations of the curriculum could involve a pre- and post-survey about a student’s understanding of bias. Outside of this study’s scope, but interesting to explore further, is whether a facilitator with grading power over the students would have a different effect on the discussion of interpersonal biases and individuals' vulnerability than the implementation with a peer facilitator.

## Conclusion

Every individual operates with bias, and unconscious bias can have unintentional negative impacts on marginalized groups' educational and career goals. A way to mitigate unconscious bias is by raising awareness of it and helping students identify their own techniques to mitigate it. Awareness of unconscious bias is difficult specifically for engineers because of the engineering culture fostered during their undergraduate education. The curriculum created in this study utilizes optical illusions, a LEGO activity, and a facilitator's vulnerability to challenge the engineers in a way that is conducive to them learning the topic rather than automatically devaluing unconscious bias as social or political work. Replicating the curriculum implementation is outside the scope of this study but should be further quantitatively investigated for effectiveness.

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