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Team Dynamics in Student Engineering Design Teams: Correlations to Women Retention and Careers in Mechanical and Motorsport Professions

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Introduction

This student-led research paper describes the social-cultural environment of a design and build engineering club team.

In 2022 the number of women employed as mechanical engineers was 8.5% [1] of the profession in the United States, Mechanical Engineering degrees rank the highest awarded at the baccalaureate level, with only 17.6 % awarded to women [2]. One factor that aids recent graduates in obtaining employment is experience, such as internships, co-ops, research opportunities or participating in design and build engineering teams. Many of the design and build teams that engage mechanical engineering students are run through the Society of Automotive Engineers (SAE). These include eight collegiate design series SAE Aero Design, AutoDrive Challenge ll, Baja SAE, SAE Clean Snowmobile Challenge, Formula Hybrid, Formula SAE, Formula SAE Electric, and Mission Autono that provide undergraduate and graduate students with pre-professional educational opportunities outside of the traditional classroom [3].

Experience on teams like these builds hands-on technical design skills including designing, planning, and manufacturing; critical skills that will contribute to future success in the profession [4]. Current SAE teams are typically dominated by men, mirroring the percentage of women (10%) working professionally in mechanical engineering [5] and the social dynamics students will eventually find in the professional world [6].

We provide an example of the typical composition of teams in Table 1, which details the results from the top ten performing teams from the 2023 Oshkosh Baja competition. The average participation of women on these ten university teams is 17.5%, with the lowest number of women making up 4% of one team and the highest with 50%. This table follows a trend the first author has seen within similar competitions that teams with more diverse demographics typically place higher than less diverse teams.

Table 1:Top 10 Competition Results - Baja SAE Oshkosh Team Members (Based on Team Pictures) [24]

Top 10 Competition Results - Baja SAE Oshkosh Team Members (Based on Team Pictures)					
Place	Team	Total Team Members	Women	Men	Percentage of Team Comprised of Women (%)
1	University of Michigan - Ann Arbor Michigan Baja Racing	23	6	17	26
2	Ecole de Technologie Superieure Baja ETS	31	4	27	13
3	Cornell University Cornell Baja Racing	52	26	26	50
4	Rochester Institute of Technology RIOT RACING	53	2	51	4
5	Case Western Reserve Univ CWRU Motorsports	55	8	47	15
6	Purdue University - West Lafayette Purdue Baja Racing	23	3	20	13
7	California Polytechnic State University-SLO Cal Poly Racing	34	5	29	15
8	Michigan Tech University Blizzard Baja Racing	23	3	20	13
9	University of Maryland - College Park Terps Racing Baja	23	2	21	8
10	Johns Hopkins Univ Blue Jay Racing	37	7	30	18

The participation of women within design and build teams is approximately equal to the percentage of women within the motorsport industry. As of 2021 the percentage of women in core performance roles reported from Formula 1 teams include: Mercedes at 6% (4 women), McLaren at 8% (5 women), Alfa Romeo at 8% (5 women), and Alpha Tauri at 0% who reported "Whilst we do have a high level of females in senior roles here at the factory we don't have any in the race team" [7], [8].

Research has studied the experiences of women in academic, co-ops and professional settings and the impacts social gendered constructs have on if women end up staying within the field of engineering. Women's experiences in the professional world greatly rely on the sense of community and identity within the workplace. Through the collected experiences of women common themes have been identified by researchers that show the impact of gender stereotypes

within the workplace and on women's individual professional identity. A common experience shared by participants are examples of covert and overt cases of sexism and bias in the workplace. One researcher recalled a student being told by their male engineering professor “you know, I feel very sorry for you in your profession. Everybody will always look at you as a woman first and an engineer second” (p. 1) [9].

Social constructs surrounding gender have been a common theme seen by researchers that impact interaction and cultures experienced by women in industry. Engineering is seen as a masculine field where masculine values are appreciated and seen as the cultural norm. STEM, engineering, and mathematics culturally are viewed as masculine in comparison to communication, and liberal arts which are viewed as feminine [10].

For many women these social constructs around gender impact how they are treated and how they are viewed in academic and professional settings. Women have shared experiences where they were given menial tasks that their male counterparts wrote off as under their value [7]. Researchers have observed the parallels of gendered social constructs in the professional world and within engineering education. Academic ability, difficulty of engineering curriculum, and lack of interest are not the primary reasons that determine why women and minorities are underrepresented in mechanical engineering [11]. However, the socio-cultural environments and experiences of undergraduate engineering students participating in co-curricular activities and peer interaction significantly impact the future aspirations and professional identity in both negative and positive ways. This is especially true of women participating in male dominated educational and work environments. Negative interactions impact women’s participation in technical extracurricular activities, causing them to leave the team or be given less opportunities to contribute and learn, limiting their skill and career building opportunities.

This study is from the perspective of a current engineering build and design team member who acted as a participant-researcher and served in a leadership role within this organization. The participant-researcher's intention in this leadership role was to improve the social-cultural environment within the team to provide opportunities for everyone. She aimed to accomplish this by developing a cultural understanding and acceptance of marginalized groups among the majority of participants (team members); while at the same time providing a safe and collaborative work environment for development of technical skills and opportunities.

The pursuit of these goals led the authors to initiate a semester-long ethnographic study of the design and build engineering club team. In our investigation of the team we ask the following questions:

1. What are the current social environmental conditions including language and mentoring within the engineering build and design team?

2. What elements of the inter team dynamics and culture within a design and build team aid in retaining women as part of the team?

Background

A literature review reveals research related to the experiences of women within undergraduate engineering programs and how their experiences impact their professional aspirations. Most of the studies identified, focus on cohorts that are currently working within the industry and not directly within the academic pipeline.

Study of women in the engineering workforce [12] found that a lack of female representation in leadership and mentorship roles impacted women's desire to continue pursuing careers in engineering related fields. Other studies found that women shared common complaints of not having any women to look up to, anyone to confide in, and feelings of being isolated and alone. Women in these studies also conveyed that if there was female mentorship they potentially would have stayed in those engineering positions. Additionally, feelings of not learning anything on the job and lack of respect from their peers also impacted the retention of women in the engineering field [12], [13].

Observed culture within the engineering industry is also another factor that is pushing women out of the engineering sector. Studies of women in male dominated engineering fields observed a common heterosexual male culture within engineering organizations and its employees interactions. This mentality within pop culture is commonly referred to as the old boys club [14]. This ideology stems back to when certain behaviors, derogatory language, and interactions were accepted as the norm and received no backlash from society. Studies found that some of the participants described their professional workplaces as boys clubs as they were run by aged white heterosexual men who do not know how to interact with women and integrate women into the community of a company. This lack of ability to integrate women into the culture and accepted practices within an organization has been observed to negatively and positively impact women experiences in the workplace. Positively women expressed the ability for them to surprise their supervisors with their technical abilities. On the contrary women also expressed that due to the lack of integration they were not respected or recognized for their achievements in comparison to their male counterparts. There were common trends within participants feeling that as women they had to work twice as hard to get less recognition than that of male peers [15]. Additionally the lack of social integration perpetuated anti-social behaviors within professional engineering workplaces which women expressed negative feelings towards. Anti-social skills of male peers and the culture of the old boys club resulted in women in studies stating that it made them feel like outsiders and that the boys club mentality allowed for the exclusion of women employees in peer bonding activities hindering the networking of women professionally in the organization [12]. The take away from the studies was that the interactions and identity of

women within the workplace is made up of gender stereotypes that place more value on being a man than a woman [16].

Anticipatory socialization in Engineering Examples

In research of interactions and dynamics between women and male peers in established male dominated spaces there is a common theme of anticipatory socialization. Anticipatory socialization in this paper is referred "to as the process, facilitated by social interactions, in which non-group-members learn to take on the values and standards of groups that they aspire to join, so as to ease their entry into the group and help them interact competently once they have been accepted by it" (p.247) [17].Therefore women who seek entry into male-dominated cultures either have to act like men in order to be successful and accepted, or leave if they are not adaptable to the established culture [18].

A study of cohorts at Massachusetts Institute of Technology (MIT), Franklin W. Olin College of Engineering (Olin), Picker Engineering Program at Smith College (Smith), and the University of Massachusetts Amherst (UMass) was conducted observing the professional socialization processes across engineering education and the resulting impact on women's and men's perspectives on the engineering curriculum. Further, the study looked at student's future aspirations based on experiences in co-curricular activities and internships. The study accumulated data through 3,383 submissions of journal entries and individual interviews [19]. The study concluded that women face more obstacles in regards to inequities in co-curricular activities outside of the traditional academic environment, such as sexual harassment within professional internships. The literature also reveals extensive research on how intergroup dynamics impact the self-identities of individuals within groups. Additionally the literature alluded to the importance of representation within organizations of minoritized populations as it is a necessity when creating positive group dynamics [20].

Methods

Positionality

The authors of this paper are an undergraduate participant researcher and an engineering professor. The first author is an undergraduate in a mechanical engineering degree program. The second author is an engineering education researcher who holds graduate and undergraduate degrees in mechanical engineering. Both authors have participated in design and build teams during their time as undergraduate engineering students and were the only or one of two women on the team. Both authors have a strong dedication to diversity, equity, inclusion, and justice and approach our research work with the intention of creating positive change within engineering departments, programs, and schools. Having experienced gendered, exclusionary comments

while as students, we approach this work hoping that shining a light on and thinking critically about these extracurricular spaces are constructed through language and actions may cause professors and administrators to think of their own clubs and organizations.

Study Context

The competitions in which the design and build team compete are managed and run by the governing body SAE International under the University Design Series [3]. The first collegiate design series, the design and build team actively participate in, is an international event with approximately 100 other university design and build teams competing. SAE International Design Series runs sanctioned collegiate design series competitions in North America, South Africa, Brazil, Korea, Mexico, and North America. In North America the inaugural competition was held at University of South Carolina in 1976. The North American competition season is broken up into three competitions located in the East, Midwest, and West with annual location rotations within regions [21].

The secondary competition in which the design and build team participates is also run by the SAE International Design Series. This competition takes place annually in the upper midwest of the United States and its participating teams come from the United States and Canada. The objective of SAE International Design Series is to provide design and build team members with the challenge and opportunity of working on projects that involve design, planning, and manufacturing of current projects outside of the traditional academic setting [22].

Purple University, a large R1 public university, has a unique organizational structure compared to other university design and build teams. Purple University competes in two different sanctioned design competitions. This is different from other universities; as most teams focus solely on one series and do not intertwin, or work in parallel on multiple series.

The design and build team is composed of 75 plus interdisciplinary student members. Task 1 of the design and build team is to design and build an off-road single-seat, all terrain, sporting vehicle whose prototype is reliable, maintainable, and ergonomic and will survive the severe punishment of rough terrain. The vehicle is powered by a 14hp Kohler Command Pro CH440 engine with a modified restrictor plate [21].

Task 2 of the design and build team is to design, modify, and assemble a cost-efficient and comfortable vehicle that can be utilized in environmentally sensitive areas covered in snow. The tailpipe emissions engine noise levels will be significantly less than current production machines demonstrating innovation within the design. The lower emissions and noise levels will not impact the overall performance of the machine [22].

Intervention

During the Fall of 2023 the first author and team leadership attempted to increase recruitment of minoritized groups and retain new and returning members. The team implemented the following practices into the organization during the fall 2023 semester:

- Two open houses at the beginning of the semester.
- Women represented in team leadership and physically present in the shop.
- Implementation of skill building workshops (Solidworks, machining, assembly, and disassembly of vehicles).
- Diversity, equity, and inclusion training, including the discussion of linguistic practices with veteran members. Acknowledging body language and tone, and impacts it has on the team learning environment.
- Weekly scheduled subsystem groups.
- Acknowledging the importance and proper use of pronouns, names, and proper pronunciations.

Data Collection

Observation methods

The first author observed a cohort of students within a microenvironment of a singular engineering design and build team organization that focused on vehicle and machine mechanics. This study is not representative of all design and build teams across disciplines within Purple University. All participation in the engineering design and build team was done voluntarily and was not a requirement for the curriculum within Purple University.

The methods used by the authors when conducting this research was through the use of longitudinal and naturalistic observation methods. The field notes collected by the first author through naturalistic observations of the design and build team during their scheduled team meetings and events. Additionally the authors analyzed collected attendance data of the design and build team through the method of longitudinal observations focusing on the relationship of observed group identity and its correlation to retention of women within the design and build team over the course of multiple seasons.

Field Notes

The participant-researcher began by capturing field notes in form of journal entries using techniques from an active participant perspective. The participant-researcher observed the linguistic practices, mannerisms, behavior, and social interactions of the engineering design and build team at Purple University. The majority of observations took place while attending weekly

team meetings and specialized subsystem meetings. The participant-observer documented educational techniques used by leaders of the build and design team to educate and retain new and less experienced members. Observations also focused on linguistic practices, member interaction with peers, and efforts to retain minority groups during the design and build team season.

The field notes were analyzed by the two authors using thematic analysis. They met and discussed their notes and agreed upon themes as well as evidence of shifts in team culture. Their analysis also focused on behaviors and themes that lead to inclusivity or exclusivity within the design and build team. Discrete data from Purple University's virtual involvement hub was also analyzed by the two authors and compared to the observations made in the field notes.
In doing so the authors observed the impact of gender interactions and relationships within the cohort and the impact it had on new members joining the team and their retention.

Attendance Data

Purple University has a policy for all student groups receiving funding from the student activities budget that they must take attendance at all events. This attendance is taken through a phone app club leaders have to scan or check in attendees to events. The authors accessed this data from the university repository for team meetings for the academic years of 2021-2022, 2022-2023, and the fall of 2023 in which the observations of the team took place.

Results

The authors decided to break the results into three subcategories of belonging, identity and interactions which impact the participation of women and minority students within the engineering design and build team. The subcategories reflect three key areas which were observed over the study during in person observation and review of field notes to be main factors of retention regarding women.

Belonging

Sense of belonging was observed as an important component within the design and build team. Both male and female members were noted to reference the desire to feel accepted within the team. The authors observed exclusionary practices to both genders of team members. Through further investigation there was a development of an internal social hierarchy on top of the existing organizational structure. This accepted subculture has been perpetuated through generations of students and passed down through traditions and accepted practices within the design and build team since 1984 when the team was established. This has resulted in an alienation of peers who do not actively participate in anticipatory socialization within the team.

Additionally the accepted cultural practices and behaviors of the design team don't just create an inequitable environment for minoritized groups but also non marginalized groups. Current team members during team dialogue said "Not that my participation or skills matter," "I feel like an outlier and I don't think they are going to give me anything to do," "Even if I was to help I wouldn't know where to start," "No one cares if I'm here anyways" and "They are kind of intimidating." The authors observed that these linguistic practices and self views were displayed by all genders within the design and build team including members who hold leadership positions within the team. The first author also observed the interactions of the design and build team with its surrounding peer design and build teams within Purple University. The authors noted that there was a negative viewpoint of the design and build team by its peers in regards to the interactions and group identity of the design and build team. Further perpetuating views that the design and build team is unwelcoming to newcomers and lacking a sense of comradery.

Interactions

Unconsciously the design and build team members were observed to participate in implicit bias practices. Examples include during recruitment events male team members were observed to approach a majority of male students. In the rare instance they approached female students, team leaders made a pitch to join the team in roles focusing on managerial, social media and communication opportunities. Playing into an implicit bias that has been ingrained into our social constructs and viewed as the stereotypical norm. Other instances of implicit bias observed were during informational organization meetings when discussing how the club will teach any student with no experience or knowledge while directly making only eye contact with the singular women in attendance of a meeting with fifteen plus individuals.

During observations of team meetings and while evaluating the field notes the authors noticed senior members of the design team forcing members to accept the current team culture during meetings and construction of the 4WD all terrain vehicle. It was further observed that the minoritized members of the team and novices of all genders began to participate in anticipatory socialization practices as the semester progressed to gain the acceptance and respect of leadership within the team.

Further evaluation of internal social structure led the authors to observe the creation of two cohorts labeled as outsiders and accepted within the team. This led to clashes between the two groups and perpetuated further issues within the design and build team that created a hostile environment for marginalized groups within the team. The cohorts labeled as outsiders were no longer included in team communications and were not informed about technical testing of the vehicle. Negatively impacting the growth and development of the marginalized team members. Subsequently the accepted cohort was more technical than the outsider cohort which led to conflicts that insinuated technical skills are the only valued and necessary skills within the team.

It was also observed that the accepted cohort was made up of members who acquired technical experience prior to joining the team.

These patterns of behavior are similar to those described in Volkan's article [23] which described discourse interactions where the presence of two fighting subcultures resulted in the creation of an alienated cohort and an accepted cohort. This further amplified inequities within the organization and created further issues such as ongoing power struggles within the organization. The authors noticed patterns of this during the semester specifically when looking at team communication, notifications, and opportunities given to members to further their technical knowledge. This was most significantly observed between technical project leads versus non technical managerial team members and novices.

During the collection of the field notes the author observed that as the semester progressed, there was less willingness of the senior members to introduce new skills to the novices that were not included in the accepted cohort. This behavior was further amplified by approaching competition deadlines faced by the design and build team. The authors also observed that a pattern of exclusionary practices and behaviors correlated to approaching project deadlines for the design and build series.

The authors also observed that within the team there was a belief that no inequities exist because there are token members of minority groups that consistently attend team meetings. The token minority mentality was a theme that was observed by a historic president within the organization. Members of leadership did not perceive an issue with retention of marginalized groups because the team had just enough marginalized members each year to be at the average for a design and build team competing in the collegiate design series. Therefore accepting a lack of representation of minorities because it was the accepted norm of the design series.

Identity

Within the dynamic of the team a social ranking process was created internally within the ranks of the design and build team that determined the "usefulness" of an individual for the design and build team. This ranking process stemmed through the necessity of team leaders to determine who would attend the season's competitions in the spring semester. The ranking system is based around an ideology that if you are not working on something technical you are not doing anything or being helpful or useful to the team and won't be useful at competition. An individual's "usefulness" was also determined by the amount of time spent in team space, availability to commit all time to the team, and bringing in prior knowledge and experiences. This was observed to lead to issues of limiting the exposure of novice team members as the majority of the work being done is occurring between the hours of 9:00 pm to 7:00 am on weekdays. New student members said "I don't really feel like an actual member of the team

because I am not here all the time." It was observed by the authors that members of the design team that identified themselves as "core members" were the members spending 30 plus hours weekly within the design team space.

Attendance Data

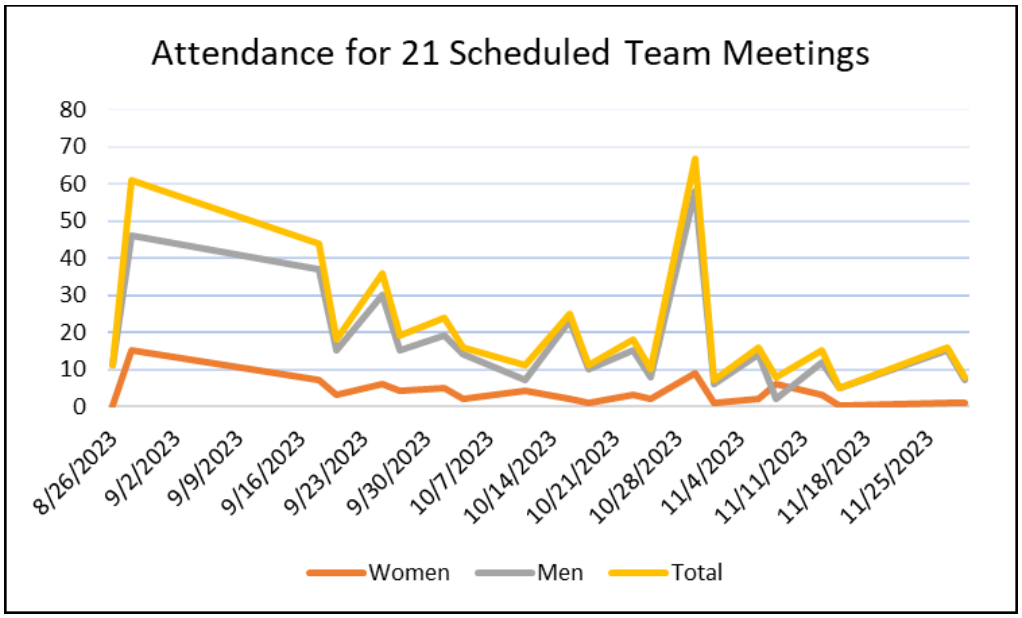

Figure 1: Number of Students in Attendance for 21 Scheduled Events in 2023

Evaluation of Purple University's attendance data showed a trend that the design and build team struggles with the retention of novices of both sexes. The data also shows a continuous decline over the semester except in the outlier points which occurred on 9/23/23, 10/14/23, 10/30/23, and 11/25/23 (Shown Figure 1). The authors also observed that group culture and identity impacted the retention of returning members and novices within the organization throughout the semester. In Figure 1 there is consistent showing of women that attended the design and build team events, however this attendance is not consistent throughout all of the events. The outlier points 9/23/23 and 10/14/23 occurred as a result of implementation of mentored skill building workshops led by members in leadership. 9/23/23 was a welding event opened to all novices and returning members to educate on the fundamentals of welding technique and safety in preparation for team members to pass the SAE welding tests for competition. 10/14/23 was an introductory machining workshop where returning team members assisted novices and members with learning how to use the lathe and the milling machine within the machine shop. 10/30/23 and 11/25/23 saw an increase in attendance by all members due to it being a meeting where the club was offering food and participating in holiday activities.

The first author observed a record number of attendance for the team informational session on 8/26/23 that continued through 9/23/23. The increase in attendance was a result of improved and

inclusive recruitment techniques utilized by the team during the summer holiday and first three weeks of school. The team used different approaches to try and increase retention. Leaders of the team engaged attendees in hands-on activities including assembly of suspensions and deconstruction of previous years vehicles. The first author noted the consistent decline in attendance is a common occurrence within the first four weeks of the semester for the team.

Discussion

Preliminary results show that the addition of supplementary workshops increased the overall participation of marginalized and underrepresented groups. We also identified, measured, and analyzed the conscious and unconscious bias exhibited by majority members of the engineering build team that was directed at minority members. It is understood that such bias manifests through negative linguistic practices, exclusive social interactions, and insensitive mannerisms that often have a deleterious impact on a minority member's sense of inclusion. The implication is that such social constructs create inequities to opportunities in engineering for women and marginalized groups and subsequently discourage participation in the profession. A potential outcome may be to restructure club organizations to implement procedures and behaviors that encourage inclusive and equitable practices in mentoring and training of new members. This will better position organizations such as engineering design and build teams to empower and retain minority students within engineering spaces, therefore setting them up for increased internship and career opportunities.

Initially the authors observed the attempted shift in practices as a failure due to the accepted cultural norm of the team. However, when outside professional mentors were utilized to bring in new perspectives on diversity, equity and inclusion policies there was a shift in opinions within the team. The researchers also noticed patterns that concluded when teammates didn't feel that they were alone and being solely relied upon for technical ideas and knowledge they were more open to implement new practices and include more novices within the design process.

The authors also observed patterns of retention in relation to socially constructed and primed ideals that influenced the design and build teams social categorization due its perceived group identity. Fewer new members were observed joining the design and build team and attending meetings when compared to the peer design and build teams in Purple University. The design and build team had a consistent number of attendees at team events, however, the people in attendance varied. In the beginning of the semester it was recorded that 86 students were interested and registered with the design and build team, however, as of the fourth week in the semester only 48 new students were still active team members of the design and build team.

After the implementation of new practices within the 2023-2024 term, the author observed a shift in cultural practices and an increase in mentorship between team members. Additionally, there

was an increase in time spent in the team space following official events. The authors also noticed that after the implementation of student workshops; novices were more likely to be engaging, asking questions and doing research independently on topics related to both the winter and all terrain vehicles. Despite these positive observations, of increase in engagement and participation in the design and build team, the leadership was still not engaging with the total number of registered team members (70).

The first author also noted during the process of implementing the new practices there was pushback observed from project leads in the beginning phases of new procedures regarding inclusion and diversity. For example, a shift in hours of operation by leadership occurred during the observation period; shifting team work hours from 9:00 pm - 7:00 am to 10:00 am - 11:00 pm on weekdays. This shift in hours resulted in an increase in new member participation during the week, however this change happened with resistance from senior members of the team.

An increase of women representation within leadership positions on the team was observed to increase the weekly attendance of novice women at team subsystem meetings. It was noted by the author that women members of the team were observed to be more engaged with team activities and participate in more technical tasks with more female representation on the team.

The results show that belonging, team interactions, and identity are major factors influencing the success of the design and build team and the continuation of women professionally in the mechanical and motorsport industries. Sense of belonging and identity were observed to be impacted by interactions of team members and the representation of women within the design team space.

Conclusions and Implications

Due to the practices, behaviors and mannerisms observed over the semester it is evident that cultural practices and procedures need continuous change and updating. Not only did the group identity and cultural practices impact the retention and functionality of the design team, but impacted in a negative way the view of the design and build team by their peers and industry professionals. The social constructs making up the design and build team significantly impact the participation of men and women within undergraduate engineering. Subsequently, the development of recruitment and retention strategies needs to be continuously addressed as design and build team interactions greatly impact the professional identity of women and how they perceive the industry. Based on the observations, further research can be conducted on the specific impacts of group interactions on men and women within the scope of undergraduate education.

Over the course of the semester there was a shift observed in the interdynamic culture of the team and a willingness to change practices within the organizations. With further implementation of equitable policies and processes the social conditions that were created through primed behaviors and prejudice will decrease and the retention of all members including women and new members will increase. Additionally, with more women role models, mentors, and team advisors within the design and build team, the culture and the identity of women engineers within the team will continue to shift creating a more inclusive environment. Further research will then have to be conducted on the impacts of improved mechanical design and build team participation with Purple University's graduation rate and rate of alumni working in industry.

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