ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #36012

Inclusive Teamwork: Using Participatory Action Research (PAR) to Improve Teamwork Projects in Intro to Mechanical Engineering

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Emily Deterding is currently a Mechanical Engineering student at the University of Massachusetts Lowell. She is currently working with two professors on a research project to improve teamwork in Mechanical Engineering at UMass Lowell. She has been facilitating focus groups for this project and collecting information to be utilized and analyzed for the project. She has previously worked in the Heating, Ventilation, and Air Conditioning field before and hopes to pursue a career in sustainable HVAC/R design.

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Dr. Susan Thomson Tripathy received a Ph.D. in Anthropology from Harvard University in 1989. Her doctoral research was funded by a Fulbright-Hays Doctoral Dissertation grant, and utilized ethnographic fieldwork in rural Bihar, India, to analyze the politics and artistic development of a local dance form. From 1995-2007, Tripathy taught behavioral sciences at Middlesex Community College (MCC), where she was an active participant and researcher in MCC's extensive community service-learning program. In 2007, she became the Director of Research at Germaine Lawrence, a residential treatment center for adolescent girls in Arlington MA, focusing on program evaluation and outcomes after discharge. Since 2011, Dr. Tripathy has been teaching in the Sociology department at University of Massachusetts Lowell. She received teaching awards for applied and experiential learning in 2013 and 2014, was promoted to Associate Teaching Professor in 2018, and received the UMass Lowell Teaching Excellence Award in Sociology in 2018. From 2016-2019, Dr. Tripathy was the Director of the Bachelor of Liberal Arts program, an interdisciplinary major with an enrollment of 250 undergraduate students. During 2018-2020, she collaborated with Dr. Kavitha Chandra to utilize participatory action research (PAR) as an evaluation approach for the Research, Academics, and Mentoring Pathways (RAMP) summer program for first-year female engineering students.

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Abstract

Teamwork projects can be difficult and unsatisfying experiences for first-year engineering students, especially for those with racial, ethnic, and/or gender identities that have been historically underrepresented in engineering programs. Using participatory action research (PAR) and qualitative research methods, this study explores whether engaging students in a series of focus groups can help disrupt negative teamwork interactions and encourage inclusive student engagement with team projects in an Introduction to Mechanical Engineering class. All participants in this study are engineering students at a college of engineering in New England, and include 6 undergraduates in the focus groups and two undergraduates (one junior, one senior) who served as peer facilitators. This work-in-progress paper describes the process and challenges associated with recruiting participants, training student facilitators, designing PAR focus group activities, and analyzing participant data. Student recommendations to promote positive teamwork experiences are also discussed.

1.0 Introduction

In engineering, teamwork is a vital skill that helps conquer challenges faced in our society. Whether being tasked to create a new prototype or to revise an already existing product, having multiple opinions and ideas can facilitate ease when working through the engineering process and coming to a valid solution. At times, establishing good collaboration practices can be difficult and can lead to unsatisfying experiences for first-year engineering students, especially for those with racial, ethnic, and/or gender identities that have been historically underrepresented in engineering programs. One study found that when a team is composed of more men than women, the minority gender is ignored and submits to the majority gender [1]. Another study conducted to show the difference in peer rating found that non-minority students gave higher ratings to other non-minority students compared with minority students [1]. To explore the problem deeper, one study conducted among 39 professors showed that (1) they were unaware of the gender or racial bias within their classroom and (2) their existing assessments did not take into account the challenges

minority students encounter in collaboration efforts. One participant in this study stated that teamwork can support diversity in engineering, if we knew how to implement it correctly [2].

Given these problems with teamwork projects in engineering classes within all engineering disciplines, a goal of this research study is to involve students themselves in one particular class, Introduction to Mechanical Engineering, in researching and improving the teamwork process. To encourage active student participation, the research team chose participatory action research (PAR) as the primary research framework, due to its emphasis on listening and learning from the people (i.e. engineering students) who are impacted by a particular problem or issue (i.e. teamwork projects) and using this information to create action steps towards positive change [3]. Since the 1960's, PAR has been used extensively in educational settings [4] and was used successfully to improve student satisfaction with an engineering summer bridge program for entering first-year students [5]. A wide variety of research methods may be used within PAR, including focus groups, surveys, mapping exercises, and interviews [3]. PAR focus groups, in particular, are used to empower participants through the process of having one's voice heard and sharing one's own knowledge and experiences in a supportive group.

In this PAR study, the focus groups were designed to create a safe environment for students to sit together with the peer facilitators and engage in activities both to clarify their goals and values and to give feedback regarding the Introduction to Mechanical Engineering teamwork project. Six first-year students enrolled in Introduction to Mechanical Engineering were divided between two student facilitators. These student facilitators were tasked with aiding the discussion, explaining the interactive activities, and collecting data.

The Introduction to Mechanical Engineering course chosen for this study was offered during the Fall 2021 semester. It is a required course for first-year mechanical engineering students where students met once a week for a 50-minute synchronous virtual lecture and a weekly hands-on lab session. These labs were 110-minutes in duration. In Fall 2021 each lab was taught by one of two professors, with the assistance of one of three student lab assistants. In these labs, students were grouped into teams of 3-5 students, and tasked with designing a prototype for a robotic gripper that is capable of moving components on a modeled assembly line using a manually controlled servo motor. After creating the apparatus, students needed to utilize MATLAB to maneuver the gripper and a series of 1-inch, 50-gram plastic cubes through various tasks. Students were assessed on successful implementation of the design process and secondly on task completion. The teamwork project was completed during the weekly lab meetings and additional meetings outside of class time that were arranged by the students themselves.

2.0 Description of the Research project: Recruitment, Participants, and Methods

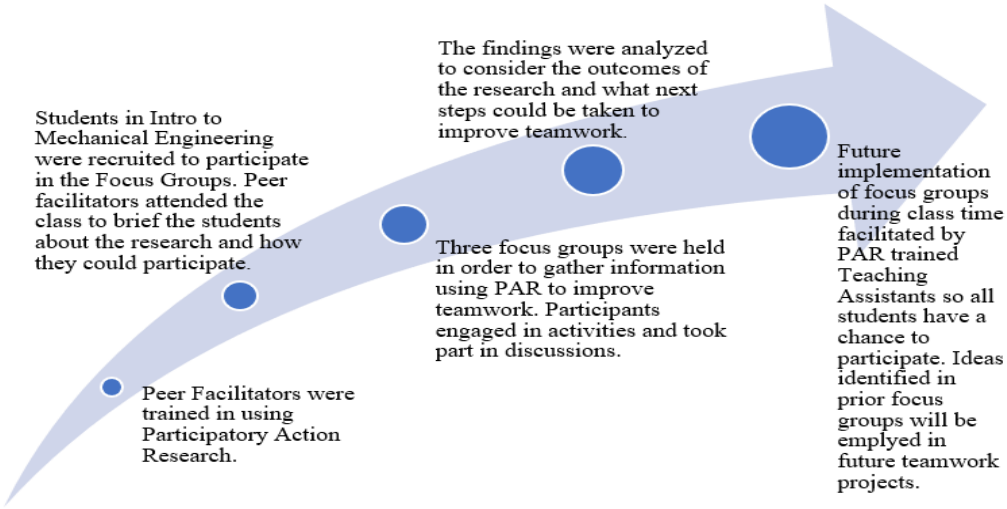

Figure 1. The Sequence of Events of the Research

2.1 Recruitment

After Institutional Review Board (IRB) approval for this project was obtained, the first challenge presented in this study was finding an effective approach for engaging first-year students in the project. This challenge was addressed by coordinating with the professor of the Introduction to Mechanical Engineering class to present the study and answer any questions during the lecture and labs. The presentations were conducted via Zoom for the virtual lectures and in-person for the labs. In these discussions, the format for the PAR focus groups was explained to the potential participants and the impact their involvement could have on improving the teamwork projects was described. Students were then encouraged to show their interest in the project by completing an online survey and stating their availability on a separate form.

Students indicating interest were asked to participate in three, one-hour focus groups about their experiences in their teamwork projects. After polling students about suitable times for the focus groups, it was decided to hold them on campus during weekday evenings. Students who participated in the focus groups were offered incentives. The incentives were light refreshments during the focus groups and a gift card if they had attended all three focus groups

2.2 Participants

182 students were enrolled in the Introduction to Mechanical Engineering course during Fall 2021 semester, and all were eligible to participate in this study. If students were under age 18, parental/guardian consent was required. 90.6% of the class identified as male, 8.8% as female, and 0.6% did not specify gender. 64% identified as White, 13% as Asian, 9% as

African/Black American, 6% as Bi/Multiracial, 4% as Hispanic/Latino, and 4% did not specify race/ethnicity.

Six participants elected to participate in the focus groups, including one white woman, one African American/Latina woman, 3 white men, and one South Asian man. Peer facilitator #1 held the first focus group with two students attending and held the second focus group with one student attending. Peer facilitator #2 held the first focus group with four students attending, the second focus group with three students attending, and the third focus group with four students attending. Only one session of the third focus group was held due to low attendance.

Two peer facilitators helped to design and guide the focus group activities. One peer facilitator is an African-American man who is a senior in Computer Engineering with previous experience in leadership and teamwork. The second peer facilitator is a white woman who is a junior in Mechanical Engineering and had previously taken the Introduction to Mechanical Engineering course.

2.3 Methods

2.3.1 Peer facilitator training

For our PAR teamwork project to be effective, it was necessary for the peer facilitators to understand (1) the objectives of PAR, (2) how PAR would be applied in the research study, and (3) how to listen with an open mind and compassion to participants. Before any hands-on training was done, each facilitator was required by the IRB to complete a Human Subjects Research (HSR) basic training offered by the Collaborative Institutional Training Initiative (CITI). After completing the training, the facilitators were required to go to a two-hour class to learn how to be effective facilitators for PAR focus groups. The class started with the explanation of PAR as a framework that involves researchers and community members working together to bring constructive change, with the goal of prioritizing the perspectives of the community members. After getting a better understanding of PAR, the class shifted to how focus groups may help to accomplish this type of collaboration. A focus group may be used for research purposes and involves small groups of people having a problem-focused discussion led by a facilitator. This process aligns well with PAR because focus groups are designed to empower the participants to speak their truth and identify key problems from their experiences. After discussing the correlation between PAR research and focus groups, the training went over the specific activities for the focus groups and the role of the facilitator in preparing and guiding these activities.

2.3.2 Focus Groups

The first focus group was the catalyst for the research participants to have their initial experience in a PAR focus group and share experiences about teamwork. Before beginning the meeting, the peer facilitator began by introducing themselves and reading a consent document explaining the purpose of the research, the proposed activities, age verification, the permission to record and use the answers given for data purposes. After the consent was given, the facilitator reviewed the ground rules within the focus group, highlighting that everyone's voice is important, respected and there are no wrong answers. Next, the first interactive exercise used was an icebreaker for the group to learn ten unique traits about each other. Using this exercise as our first point of action helped establish an open-space environment where the participants were heard and accepted regardless of their interests. After getting a better understanding of the research participants, the peer facilitator shifted focus onto the main theme of the meeting: teamwork. To begin the main discussion, each participant was asked to submit three words to describe their experience in teamwork to a word cloud created using mentimeter.com that was displayed through a projector. From there, the group was able to collect data on how participants felt about working in team projects and why. Next, using the word based application Jamboard, the peer facilitator gave each participant a list of core values and asked each participant to choose 10-15 values that resonated with their own, and then group all the similar values into 3-4 groups, with one core value from each group being chosen to represent the grouping. After the groups of values were made the next task was to create actionable statements with the lead value from each group. This activity was adapted from the “live your core values exercise” at Taproot.com [6]

Models for the focus group activities in the second and third focus group were suggested by staff at Ekjut, a NGO located in Jharkhand, India that uses PAR methods extensively [7]. These activities have also been used effectively in a summer bridge program for incoming first-year engineering students [5]. In our project, these activities were adapted to focus on teamwork experiences.

The theme of the second focus group was centered around one main question, “How can you keep your teamwork project in orbit?” To explain the idea of “keeping our project in orbit,” the solar system was used as a metaphor because all the planets have different characteristics but all have a similar pathway – they orbit the sun, similar to how students in a teamwork project have diverse backgrounds but are all engaged in a common pursuit. Participants were then asked “What support do you need from others and what do you need to do yourself to keep your team project in orbit?” To give each person time to reflect, students first responded by writing on index cards and then ranked the importance of their answers. The focus group ended with each participant sharing their responses and discussing the significance of their thoughts with regard to improving teamwork projects.

The theme of the third focus group was to link the core values and assets identified in the first focus group to the teamwork activities completed during the semester, or their own personal

goals. The focus group started off with each participant 'checking in' to discuss their well-being at the time. The participants then recalled the 3 core values that they chose during the first focus group and wrote them down on sticky notes. After that, the participants drew a tree on the whiteboard and placed their core values sticky notes at the roots of the tree. They then recalled ways that they used, or in some cases were not able to use their core values during their teamwork projects. They wrote these down on sticky notes and placed them on the trunk of the tree. For the leaves of the tree, the participants wrote down new goals, directions, or growth that emerged from their experiences. Then the students thought of specific people or things that were helpful or harmful to their teamwork projects or personal goals. These helpful or harmful aspects are the surrounding atmosphere of the tree, like sunlight or rain that helps the tree grow. Once the trees were completed, the students shared them with each other and discussed what they learned from this exercise.

3.0 Focus Group Data Analysis

The first focus group was vital in orienting the participants to the nature of Participatory Action Research and the participants forming relationships amongst themselves and the facilitators. Many of the participants found common ground between each other and they sparked a friendship that helped support them throughout their teamwork projects. When asked to describe their prior experiences with teamwork in 3 words, the participants mentioned a combination of positive, negative, and neutral words. Positive words included: "productive, unique, insightful, dope, useful, fun." Negative words included: "overthinking, tedious." And neutral words included: "scouting projects, collaboration, at work, shop projects." When asked, "Describe what your expectations are for the teamwork project in 3 words," positive characteristics included "educational, productive, fun, good, beneficial, complete, meet new people, new ideas" and negative characteristics included "hard and stressful."

The participants then chose words from a list of core values and grouped them together. After grouping them together they chose their most important core value and added an action statement to it. The following action statements were created around the core values (in italics) chosen by each participant:

1. "*Professionalism* doesn't have to correlate to being a stick in the mud," "*Reliability* is a trait that should be important in both people and products."
2. "*Honesty* is the key to make a great project," "Always have in mind that *Collaboration* is important," "*Uniqueness* is something that everyone has, it is always great to see it."
3. "Always stay *Optimistic* in every situation," "*Responsibility* is key to being successful," "Always strive to *Achieve* something, even if it's small."

4. “Being a good *Leader* is understanding your own limits as well as others,” “Being an *Understanding* person is important,” “Having *Fun* is important to keep yourself motivated and can be a way to connect with others,” “*Safety,* ‘duh’.”

In the second focus group, participants identified what they needed from themselves and others in order to keep their teamwork project in orbit. Qualities the participants identified as most important were productivity, cooperation, and communication. One participant said, “I put productivity as my first and most important, Because like I mean if you're not productive while you're working with a group of people you're not gonna get anywhere.” Another participant rebuttals, “it's not THE most important thing, but it is an important one. I would say, cooperation. Cooperation, because you can't be productive if you're not cooperative.” Another participant then had a suggestion about communication: “I'd say that communication … goes hand in hand with those two because, like you got to talk to people and that also sort of counts in the cooperation because you're trying to come to an agreement and … you're figuring out the best aspects of everybody's ideas . . . also communication goes towards being productive because you're figuring stuff out.” In this example, group dialogue helped to clarify understanding of how different positive qualities overlapped and interacted in teamwork projects.

Leadership was also identified as another important trait that would lead to their success in teamwork. As one participant explained, “You can have a group without a leader, but it will often go on organized and people won't do what they’re meant to do, you need a good leader for things to stay organized and on track.” This participant went on to explain the traits that a good leader possesses: “understanding the people they're leading, and then [being] willing to help those that need help and willing to tell what needs to be done and making sure they do it.” The participants were then asked to identify if a leadership dynamic was emerging within their teamwork project. One participant offered: “A little, I feel like we have a couple of leaders in our group, but that's just more because they're already skilled with certain aspects, like CAD (Computer Aided Design).”

The focus group participants identified that equal contribution of work performed by all team members was key in keeping their teamwork projects in orbit, but they seemed to struggle with implementing this in their own groups. They all agreed their teams had a plan to split the project workload up, but so far some team members did not complete their parts. Participants also felt there was too much work to equally split between all of the team members. Other important characteristics for successful teamwork mentioned in this discussion were efficiency, accuracy, and precision.

The third focus group rounded off the research well by connecting the core values the participants chose to their own contributions to their teamwork projects this semester or what they felt was important in their teams (see Table 1).

Table 1. Student Core Values and Connections to Teamwork Projects

Core Value	**Connection with Teamwork Project**
Uniqueness	creating a design for the project group
Honesty	trusting group members would complete their portion of the work
Collaboration	making sure everyone worked together and was on track
Reliability	doing what was expected
Achievement	completing the project
Professionalism	keeping interactions focused and respectful
Fun	it was better in the group if everyone was having fun
Leadership	important for getting things done
Understanding	understand each other's strengths to work efficiently
Optimism	team members need to be happy about the work they're doing
Responsibility	get the work done on time
Achievement	team members collectively want to succeed to their best ability

The personal growth and/or new goals the participants felt developed during their teamwork projects were diverse and far-ranging, including the following: starting more projects, using more SolidWorks and coding software, thinking about their senior year capstone project, finding their desired career path niche, improving their understanding of MatLab and coding, restoring their faith in group projects, making new friends, improving their diet, establishing better priorities, improving studying habits, getting all the information about a topic you can collect ahead of starting a project, improving time management skills, working well with others, having the same goals for the whole group, developing leadership, and maintaining an equal workload for everyone.

As for particular people involved with the teamwork projects that helped the participants grow over the semester, the professor of the course was mentioned most frequently, followed by the following key people: a team member who had amazing energy, teaching assistants, team members in general, the leader of their team, and their parents. The negative aspects or hindrances to their growth included members not responding in the team project's text group chat, lack of communication, talking too much, prior negative experiences with teamwork, the pandemic, not knowing enough, laziness, unwilling teammates, and people not meeting due dates.

In the third focus group, participants were asked to evaluate their experiences in the focus groups by writing responses to three questions. For the first question, "Were the focus groups helpful for your teamwork projects?" all 4 participants responded that they were helpful, adding that they "helped me see where my group was in comparison," "helped with working better as a team," "exposed me to different types of thinking," and helped to identify "what I can bring to the group." For the second question, "Did the focus groups have any benefits for your academic work or personal well-being beyond the teamwork projects?" 3 out of 4 participants felt that they did have these benefits – the one who did not mentioned that they didn't have group projects in their other classes and "I never had to implement the ideas found in the focus group outside of the mechanical class." Benefits mentioned included meeting new people in their major, seeing things from a new perspective, and being willing to let others lead. For the third question, "What recommendations do you have for the focus groups in the future? Do you think they should be offered next year?" all 4 participants felt they should be offered next year. One student further explained: "They are a good way to talk about the project and meet new people. Maybe have them go in-depth more about the project" and another described them as a "way to connect with others and meet new people; learn new things; they're fun." One student also recommended bringing "more Black people to the group. Being in a big college you will think it's going to have more diversity, looking at a classroom it shows less than you think."

During the last week of classes, students in Introduction to Mechanical Engineering were given the opportunity to respond to an online survey that included questions regarding whether they attended the focus groups or not, and if they didn't attend, to provide a reason why not. 71 students responded, and 52% said the primary reason they didn't attend was not having enough time, followed by scheduling conflicts (20%) and not being interested in participating (17%).

4.0 Discussion: Recommendations for Improving Teamwork Projects

In this research study, offering PAR focus groups as an opportunity to reflect on teamwork experiences in an introductory mechanical engineering class had promising results. The participants of the focus groups reported positive effects from attending the focus groups. Students who attended the focus groups seemed to have formed a community within themselves,

and were able to share their thoughts and experiences. They reported that they felt like they made friends within their major and this improved the quality of their teamwork. Participants in the focus groups also became aware of how their own core values can connect with teamwork and seemed to have an in-depth grasp of how they could work on their projects in a positive manner. Connecting core values with teamwork is important, given research suggesting that alignment of personal values with engineering coursework may help students to develop identities as engineers [8]. Participants also recognized the importance the professor of the course plays in their teamwork experiences.

A difficulty that was faced was the participation rates for the focus groups, as the number of participants (6) was very low compared to the size of the class (182), and also varied between the 3 focus groups. One student also pointed out the need for more Black students in these groups. As mentioned above, the most common reasons students did not attend were due to lack of time or scheduling conflicts. However, the students who did attend found the focus group discussions and activities helpful.

Considering these findings, a recommendation would be to incorporate some of the focus group activities into the lab sections as the students work on their teamwork projects, led by the teaching assistants. The teaching assistants could also undergo training as facilitators to learn listening techniques and strategies to promote inclusivity and encourage everyone to participate in the activities and discussions. In this way, all students in the class would be able to experience the benefits of the focus groups.

5.0 Conclusion: Limitations and Future Work

Using PAR to encourage students doing teamwork projects in Introduction to Mechanical Engineering to reflect on their experiences and offer suggestions for change provided valuable insights for creating adjustments to future teamwork projects. Although data received from the focus groups increased our understanding of student experiences with teamwork, the number of participants limited our ability to understand diverse perspectives within the course. The course as a whole also contained limited numbers of women (8.8%) and racial/ethnic minorities (13% Asian, 9% African/Black American, 6% Bi/Multiracial, 4% Hispanic/Latino), which also made it more challenging to have full representation of diverse viewpoints in the focus groups.

With the results from this study, our research team will use the data collected to consider possible changes in Introduction to Mechanical Engineering teamwork projects during Fall 2022. We also hope to involve other Introduction to Engineering courses from different disciplines (i.e., Biomedical Engineering, Electrical Engineering, Civil Engineering, etc.) in a follow-up study to create a larger sample size and have a bigger impact.

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