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WIP Striving towards Equitable Team Dynamics in First-Year Engineering Design

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Introduction/Background

In its 2022 Report on the state of US science and engineering, the National Science Board highlighted the continued need to broaden participation in engineering [1]. This undoubtedly requires a multifaceted approach, with higher education playing a key role in attracting and retaining students who historically have been underrepresented in STEM. Evidence however suggests that many of these students experience disproportionately higher attrition rates from science and engineering programs [2]. In the same study, the authors note a common set of factors which plague attrition in engineering programs, including a lack of self-confidence or self-efficacy, unwelcoming academic climates, as well as sexism and racism.

Collaborative problem-solving experience is a key quality sought by most employers. It is well documented that effective teamwork can facilitate career progression, often leads to more innovative solutions, and has the potential to increase job satisfaction. Throughout their undergraduate education, students are tasked with team-based projects to provide this required experience, however they are rarely provided with the skills to be a successful team member and leader. Ambrose et al. [3] highlight that in addition to content knowledge, teamwork further requires higher-order qualitative skills such as task delegation, conflict resolution, and content synthesis. Furthermore, research shows that stereotypes and biases towards women and students of color can affect team dynamics, productivity, as well as student learning and experience [4].

In the Industrial and Organizational Psychology literature, effective teams are characterized as those which demonstrate time management, the ability to work together, and have members who contribute similar levels of effort [5]. A variety of team effectiveness models have been used to explore teamwork in engineering education [6]–[8]. In a review paper investigating the application of Team Effectiveness Theory in engineering student project teams, the authors identified a small number of constructs particularly relevant to student teams including trust in teammates [5].

Trust as a construct has been expressed in a variety of ways in literature, with many definitions alluding to "a positive expectation for others' intentions and a willingness to be vulnerable to others". In their review paper, Borrego et al. [5] identified several studies that noted a direct relationship between trust amongst teammates and productivity, team satisfaction, creativity, and innovation. Researchers have further evaluated different components of trust, including cognitive and affective elements. Affective trust is considered as "faith in the trustworthy intentions of others" [9]. Webber [9] found that affective trust developed over time through "citizenship behaviors" such as "doing extra things for team members, willingly helping each other, and taking a personal interest in the team." Cognitive trust relates to the degree of confidence in teammates' abilities. Specifically, it is grounded in an individual's beliefs about the reliability of a groupmate as well as their competence [9]. Research by De Jong et al. [10] on team performance and trust, suggests that both cognitive and affective trust should be developed to maximize team effectiveness. The typical stereotypes and biases found within STEM disciplines has the potential to impact the degree of cognitive trust of teammates.

Positive team experiences not only give students skills that are sought after by employers, but also can increase retention in engineering programs. Geisinger & Raman [2] put forth possible curricular actions to address attrition in STEM programs, including collaborative/group projects, projects of social importance, and clarifying expectations of diversity. The present study applies all three actions in a first-year engineering course comprised of approximately 275 students, split evenly between two sections.

Introduction to Engineering Course and Asset Mapping Framework Inclusion

The first-year Introduction to Engineering at Temple University course is typically the initial point of contact with engineering students. This course is generally taken by students in their first semester and has an enrollment of about 280 students split between two sections. The college plans to offer this in smaller sections in the future to allow for more student/faculty interaction. Since students take this course so early on in their academic career, it represents an early opportunity to introduce and practice team-building skills which are transferable to other aspects of their education and careers. Students take part in a ~6-week-long, team-based design challenge sponsored by Engineers Without Borders UK entitled: Engineering for People Design Challenge. The challenge strives to broaden students' awareness of the societal, environmental, and economic factors which govern a project's success. Each year the challenge is based in a new location and presents real-world problems that the local communities are facing. In addition to a written design brief, EWB provides case studies and video interviews with actual residents. Students are assigned this project in groups and go through a four-step engineering design process to come up with a solution to a problem which the local residents are experiencing.

To prepare students for groupwork, we have implemented activities developed by Pfeifer & Stoddard [11] in their "Diversity, Equity, and Inclusion Tools for Teamwork: Asset Mapping and Team Processing Handbook". The authors suggest the use of individual asset maps and team asset charts to achieve equitable team dynamics. They believe that by self-identifying assets and relating them to team tasks, students: 1) build confidence, including those who have experienced bias and/or stereotyping; 2) see their teammates as people, which may help in overcoming stereotypes; and 3) perform task assignments based on skill and interest, which may help minimize "task bias" [11].

The goals of the Engineering for People Design Challenge module include:

1. Having students create asset maps to self-actualize their strengths and weaknesses, specifically as they relate to an engineering team tackling a complex and diverse challenge.
2. Demonstrating how asset maps may be used to achieve equitable task distribution within groups. Specifically, having students use their maps when creating a breakdown of tasks for a given assignment, taking into consideration students' strengths, experiences, and areas they want to develop.
3. Having students recognize and experience the value of diversity in engineering teams, especially for problem solving and innovation.
4. Applying the engineering design process in the context of a real community taking into consideration social, economic, and environmental criteria.

Research questions posed in this study

The overarching theme of this research is to explore the role of asset mapping on team effectiveness within the context of a first-year introduction to engineering course. The study additionally hopes to understand whether there is a link between asset mapping in the first year and a student's choice to remain in engineering. The following research question is explored:

- Do students' perceptions of team effectiveness (ability to work together to accomplish goals in a timely fashion) shift as a result of individual asset mapping and team asset charts? Specifically, does the asset map protocol promote cognitive trust and thus effective teamwork?

Intervention

We have adopted several modules of the Diversity, Equity and Inclusion Tools for Teamwork: Asset Mapping and Team Processing Handbook [11] to introduce students to important team concepts. Prior to forming groups and as part of the Handbook, students are asked to reflect on their identities, strengths, communication and conflict styles. As part of this, they complete a series of self-assessments [12] and generate an asset map where they give thought to how their life experiences, not only educational experiences, will benefit a team. For an example of what an asset map looks like, see examples in [4], [13]. Further, students read several articles highlighting diversity and engineering and write a short critical reflection where students consider their asset maps, any prior team experiences, as well as the readings. The goal is for them to recognize how their strengths can be leveraged to help a team, how they can work to build weaknesses into strengths throughout a project, and how each team member brings a unique perspective to the group which should strengthen the final engineering design.

Once the initial assessments are completed, students are randomly assigned to small teams of four to five. During their initial team meeting in class, prior to the first assignment, students are given approximately 20 minutes to share their asset maps with each other. The goal is for them to see their peers as people with different experiences and interests and to begin to think how their collective diversity of experiences is a team strength [11]. After this initial team discussion, they receive a series of group assignments for the Engineering Design Challenge project.

Table ***1*** provides a short overview of these assignments. Table 2 shows how student groups split up work and use their asset maps as a guide. The assignment is broken down for the students in small tasks and the second column allows the group members to assign tasks. In addition to assigning the tasks, a short justification must be written as to what asset that group member brings to the task. Lastly, in the third column, the groups assign any students that would like to develop this asset and therefore will work with the student assigned to it to help them develop.

Table 1. Engineering for People Design Challenge Group Assignments

Design Challenge Assignment	Description
Step One: Analyze Context	Students gain an appreciation for the location that the design challenge takes place in by reviewing basic information about the locations economy, history, government, etc. Students then learn more by reviewing interviews of residents.
Step Two: Define Problem	Once students have completed step one, they are usually able to identify a multitude of problems in the local community. For this assignment the groups pick a problem to work on and frame the problem by creating design criteria for the problem. They must identify at least one social, economic, and environmental design criteria.
Step Three: Explore Lots of Options	Using their design criteria developed in step two, the groups use a multicriteria assessment tool to explore solutions and how well they solve the problem using the design criteria to measure success.
Step Four: Justify your Recommendation	Students justify what solution idea solves their problem most effectively and comes up with an implementation plan for their solution including predicted difficulties.

Table 2. Cover Sheet Used for Groups to Organize their Work for Step Three. Adapted from [11].

Assignment Tasks & Roles	Student names and relevant student assets used for task/assignment	Student names and areas which they wish to develop more related to assignment tasks	Date Due
Keeps the group on track by reminding them of their roles and the due dates along the way, including sending a message on teams a day before every due date to the person(s) responsible.	ASSIGN		Ongoing

Reviews Step 2 and uses it is a guide to select ONE Issue/Problem that the group will focus on	All		In Class 10/17 and/or 10/19
Submits this cover sheet to Canvas once completed	ASSIGN		10/19
Brainstorms design criteria without worrying if they are specific or testable	All		In Class 10/19
Edits design criteria to make them specific/testable. Posts a slide here following the instructions: Issue and Design Criteria Feedback F2022.pptx	All		By the end of class 10/19
Updates Background Information (History->Industry and Economy) from Step 1 and brings it into the current document	ASSIGN		Before class 10/21
Does more research on issue/problem outside of the design brief and finds at least five outside sources with more information	ASSIGN		Before class 10/21
Updates Selected Issue/Problem section for the ONE selected problem for step 2 and bring it into current document using the research and outside sources	ASSIGN		Before class 10/21
Reviews feedback from instructor of design criteria and edits accordingly	All		Before and In Class 10/21
Reviews Selected Issue/Problem section and design criteria to make sure they are consistent with each other and makes necessary edits	ASSIGN		10/23
Puts sources in APA citation format. Contact library for help if needed.	ASSIGN		10/24
Final edit for spelling, grammar, etc. Making an appointment with the writing center for help on this. Checks rubric closely before/during/after this step.	ASSIGN		10/25
Final edit and submission which includes checking the rubric and the template to make sure nothing has been missed AND submits the final assignment to Canvas	ASSIGN		10/26

Initial feedback

When this course and module was first run in the Fall of 2022, we gathered feedback from students in two manners. The first was the student feedback forms which are given to all students in the university. The second was a CATME [14] survey where the students could evaluate each other as well as the overall group experience. This included blocks of questions looking at 'interacting with teammates' and 'keeping the team on track'.

Figure 1 shows the results from the question "Group projects helped me build skills to work collaboratively and productively within a group context" asked on the student feedback forms. You can see that a vast majority (83%) of the students agreed or strongly agreed with this statement.

Group projects helped me build skills to work collaboratively and productively within a group context.

	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree	Not Applicable	Mean
n = 55	(24)	(21)	(6)	(3)	(0)	(1)	
Section	44%	39%	11%	6%	0%		4.2

Figure 1: Results from Fall 2022 question about group projects given to students on their course evaluations

At the end of the CATME survey in which students evaluated their team members, students were asked to leave comments to their instructors. Here are several of the positive student responses:

> "I enjoyed this semester despite not being the biggest fan of group projects."
>
> "We really worked hard this semester and are a great group I'm going to miss having people I can rely on when I'm not my best and vice versa. We all had our fair share of moments and all contributed different aspects to the group."
>
> "The team project really helped us utilize each other's strengths while also learning from them."
>
> "I really enjoyed working in teams and I think it is very important to work with people we do not choose as this is how it will be in our future careers."

Here are some negative student responses:

> "I don't want my other group members to receive zeros for the last assignment, but at the same time, I believe that it is only fair as the amount of work that I put in without any help was strenuous on me. I understand that we all have finals this week, and I would have completely understood if they reached out to me previously and discussed their situation or at least have given me a heads-up. But since I received no communication from anyone I feel like this is the only fair option."
>
> "I completed most of the work for all of the assignments. It did not bother me as it was all manageable."
>
> "I hated the teamwork"

> "[Student Name] and I were the only two who consistently worked on the assignments and showed up to class. We did at least 85% of the work ourselves towards the back end of the semester."

While there were some negative comments, the positive comments far outweighed them. It's our hope that through this intervention (and a few iterations), that we'll foster an environment where students are provided with the opportunity to practice and gain experience in different aspects of teams/teamwork and that these negative experiences will decrease. We also hope that our decrease in section size (from 140 in Fall 2022 to a planned 70 in Fall 2023) will allow the instructor to more actively intercede in group problems earlier in the semester.

Discussion/Future Work

After the first iteration of the asset map protocol in Fall 2022, we solicited general feedback from students. Moving forward, a reflection essay assignment will be administered to students at the end of their group project. Similar to the initial reflection essay, students will be asked to evaluate several readings about student teams and compare/contrast them with their previous and current team experiences. Additionally, the students will be asked to reflect on stereotyping and what role, if any, the asset map protocol played in overcoming them throughout their project. The readings and assignment will be modified from page 20 of Pfeifer and Stoddard [11]. The student essays will subsequently be evaluated by the course instructors together with the university's Center for the Advancement of Teaching to understand whether asset maps had any bearing on cognitive trust and thereby, team effectiveness.

In future work, we also hope to explore these two other research questions:

1. To what extent do students capitalize on their strengths and develop their growth areas as a result of the team asset mapping protocol?
2. Are students who are provided with the opportunity to identify, share, and capitalize on their strengths in the context of a group project more likely to remain in an engineering program?

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