Work-in-Progress: Investigating student growth through a multidisciplinary qualifying project of an interactive ball wall display to support Pre-K STEAM learning at a community early education and care center

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Work-in-Progress: Perspectives on a multidisciplinary project of a ball wall to support Pre-K STEAM learning at an early education and care center

Abstract

A multidisciplinary group of four upper class students at University X completed a three-term project that combined elements of technology and society, and over the course of the project, faculty advisors tracked student evolution and growth. The students researched pre-K curriculum and pedagogy, then designed, built, and delivered an interactive kinematic ball wall sculpture. The ball wall was installed in the Science, Technology, Engineering, Art, and Math (STEAM) room at the Town YWCA non-profit early education and care center, where teachers bring children in for daily activities. This project is a first-time collaboration between University X and the Town YWCA, and focused on a building a lasting relationship. The faculty advisors used a combination of assignments to evaluate the evolution and to track growth of students: equity training modules from an instructor handbook and self-reflection assessments based on Edutopia [1]. These assignments were given to the students on a per-term basis to track changes or transformations in student behavior as they discover and address resource limitations, unique design constraints, and working with team members from different disciplines. More specifically, these assessment measurements were: asset maps; changes to interpersonal team dynamics from strangers to colleagues; learning and refining technical engineering skills; overcoming various challenges; learning to set realistic expectations and goals; and self-reflection, assessment, and improvement. All students reported increase in these areas: teamworking skills, respect for others, communication skills, group decision making, and deeper appreciation for strict project management. Recommendations are given to improve outcomes.

Introduction

Multidisciplinary teams are frequently called on in the workplace to solve complex problems. As such, it is important that best practices for working and communicating in engineering design teams are taught, ideally by multidisciplinary faculty teams, at the college level [2]. One place such skills are addressed is in the context of project work. At University X, all students complete a graduation requirement project that examines problems at the intersection of technology and society. This paper highlights one of these projects – addressing an engineering design problem in the context of a community-based organization over 3 academic terms (or 21 weeks). In order to be successful, students had to work together in a multidisciplinary team to develop a technical solution that met the needs of all stakeholders (such as low cost), and address a set of unique design constraints specific to the target audience (such as audience age and room size).

Advisor EE, parent of a child enrolled in the Town YWCA early education and childcare center and Civil Engineer adjunct faculty at University X, discussed the potential for this project with an educator at the Town YWCA. EE then connected with FF, director of the Science Technology Engineering and Math (STEM) Education Center at University X, with the vision of bringing University X together with early education childcare centers across the City. Emphasis was placed on contributing cost-effective and open-source Science Technology Engineering Art and Math (STEAM) opportunities to early education childcare centers. The Town YWCA is non-

profit with a low operating budget, and relies heavily on parent fundraising efforts to create special programs and implement curriculum improvements.

This project encompassed technical (design and engineering) and social (interpersonal skills, team work, communication, time management) aspects. From a technical standpoint, students were tasked with the creation of a "ball wall," a type of interactive kinematic play structure, for pre-K children at the Town YWCA. Socially, students and advisors sought to develop their own interdisciplinary working skills while forging a connection between University X and the Town YWCA. The development of interdisciplinary working skills challenged students to think more broadly about teamwork and engage in learning on how to work equitably and effectively together in a multidisciplinary team, thus experiencing personal growth and learning new skills. The evolution of student growth was tracked over the course of the project with self-reflection questions, with a focus on the most effective outcomes and the underlying nucleation point of growth – was it a result of a specific project component, or was it a broader result of being in a multidisciplinary team with students of different backgrounds and skillsets?

The ball wall project began in September 2019, bringing together a team of students representing four unique disciplines: robotics engineering, mathematical sciences, computer science, and mechanical engineering (student characteristics listed in Table 1). A common underlying set of secondary skills held by the group was identified through an asset mapping activity: skill and passion for art, music, and sculpture. These two sets of skills (technical and artistic) became increasingly important to combine as the project evolved into a work of engineering art. The asset mapping activity also helped to identify common desired areas of growth for each of the team members. These included: developing leadership skills, improving public speaking, learning project management, and conflict resolution.

Table 1: Characteristics of the multidisciplinary student team. The culture and background are self-identified in the individual asset maps.

Student	**Major/Minor**	**Gender**	**Culture/Background**
AA	Robotics engineering / Mechanical engineering	M	Scouting, City 1, City 2
BB	Mathematical sciences	F	Chinese, atheist, Suburb 1
CC	Computer science	M	Chinese American, City 3
DD	Mechanical engineering	M	Jewish, Polish, City 4, City 5

The challenge students were presented with was the creation of a three-foot-tall by twelve-foot-long ball wall installation mounted to the back of bookshelves in the STEAM room of the Town YWCA. In order to be successful, students needed to gather background information and interview stakeholders. They researched pre-K learning, surveyed teachers at the center, presented to the YWCA executive board, prototyped and tested individual ball wall components with children, finalized the digital ball wall design with sketches and CAD drawings, solicited donations from local businesses, built the ball wall, installed it, and trained the teachers on its use. The multidisciplinary nature of the team has been a benefit, with the use of their strengths promoted by initial asset mapping. The installed ball wall is shown in Figure 1.

Figure 1: The finished ball wall installed in the STEAM room at the Town YWCA early education and childcare center.

The consensus among employers is that multidisciplinary team projects in the engineering curriculum are necessary [3]. The Accreditation Board for Engineering and Technology, Inc. (ABET) also emphasizes this need in ABET Criterion 3 Student Outcomes [4]. Student projects with a multidisciplinary team working collaboratively toward solving a real problem for a real client addresses this expressed need in providing students with experiences akin to those of a professional engineer. Multidisciplinary student teams, with faculty guidance as needed, show improvement in interpersonal skills and cohesive teamwork over time [3]. Additionally, such projects garner positive student feedback [5]. When the instructors are also multidisciplinary, and take the time to reflect on their own teamwork as educators teaching these affective skills, the outcomes for student learning and overall performance in a project improve year-to-year [6].

Many avenues exist for learning and practicing interpersonal affective skills throughout a student's educational career [7]. Experiences range from pre-college summer camps taught by multidisciplinary engineering faculty [8] to junior and senior level undergraduate team projects [9]. These experiences are enhanced when combined with asset mapping and self-reflection writing. Asset mapping has been shown to result in stronger, more effective communication, project management, and teamwork [10], and doing so early can lead to more equitable task assignment, as it recognizes skills of each participant [11] [12]. Self-reflection writing assignments as part of a teamwork and leadership activities help students "identify personal strengths and areas for development" in team engineering design and communication [13].

While multidisciplinary student teams display diversity in academic focus, it is important to consider all facets of diversity, namely implicit biases as they relate to teamwork. Diversity has been identified as important for better problem solving in a team setting, and faculty intervention throughout a project or course, which leads to a team that values diversity and inclusive behavior [14]. Reading about and reflecting in writing on stereotyping and implicit bias is important throughout a student's career, and can lead to recognition of implicit bias [11]. Equity training is not only important for students, but professional development for educators is needed to recognize gender stereotype and bias in engineering and such training may lead to more young women and people of color (PoC) being encouraged to pursue an engineering career [15].

Methods

Student growth and evolution was tracked via two methods: the first is the equity training modules from the *Diversity, Equity, and Inclusion Tools for Teamwork: Asset Mapping and Team Processing Handbook* [16], referred to as the SWEET modules (*Supporting [W University] in Equitable and Effective Teamwork)*; and the second is self-reflection questions (see Appendix) based on the *40 Reflection Questions* from Edutopia [1]. The SWEET modules are recommended for students completing a graduation requirement project, but they are not a required curricular component. The SWEET modules were developed in response to observations that first-year/freshmen students often displayed evidence of stereotypical thinking and bias towards women and PoC [11]. Each SWEET module is a written assignment (short answer, essay, form), some with required reading on issues of equity. The SWEET modules aim to expose every student's assets, challenge bias and stereotype, and improve the range of affective skills each student can learn in multidisciplinary teamwork.

The parallel processes of the student work, the SWEET modules, and the reflection questions are shown in Figure 2. The project submittal for the 1st term was a comprehensive background research and literature review document, focused on early child development, the effects of early childcare, interactive learning models, and child safety. The team specifically worked to split up the topics for research and write the background document. Over the 2nd and 3rd terms, the students prototyped and tested components of the ball wall and installed the it in the STEAM room, finalizing their project with a comprehensive written report.

At the project start (September 2019), the students were assigned tasks of creating asset maps and writing critical self-reflection essays from the SWEET modules, and then they created a team asset map. Near the end of the 2nd term (December 2019), they wrote a team dynamics self-reflection essay. A *Team Processing Sheet* was also completed as a group (December 2019), with students rotating the task of writing down the team issues with communication, leadership, decisions and equity, commitment, productivity, and other possible challenges. The SWEET modules concluded with the students writing a team action plan for the remainder of the work.

The custom self-reflection questions followed the Edutopia model to focus student answers [1] (see Appendix). After the 1st term (October 2019), the students wrote short-answer essay questions regarding their perceptions of the project work before they started the project, and how these perceptions were confirmed or changed. After the 2nd term (December 2019), the self-reflection questions focused on their perceptions about the project, their teammates, what they would change had they to do it again, and what changes they wanted to make. After the 3rd term (March 2020), the questions focused on how the students felt about their final product, what they learned about themselves, and what they will take forward.

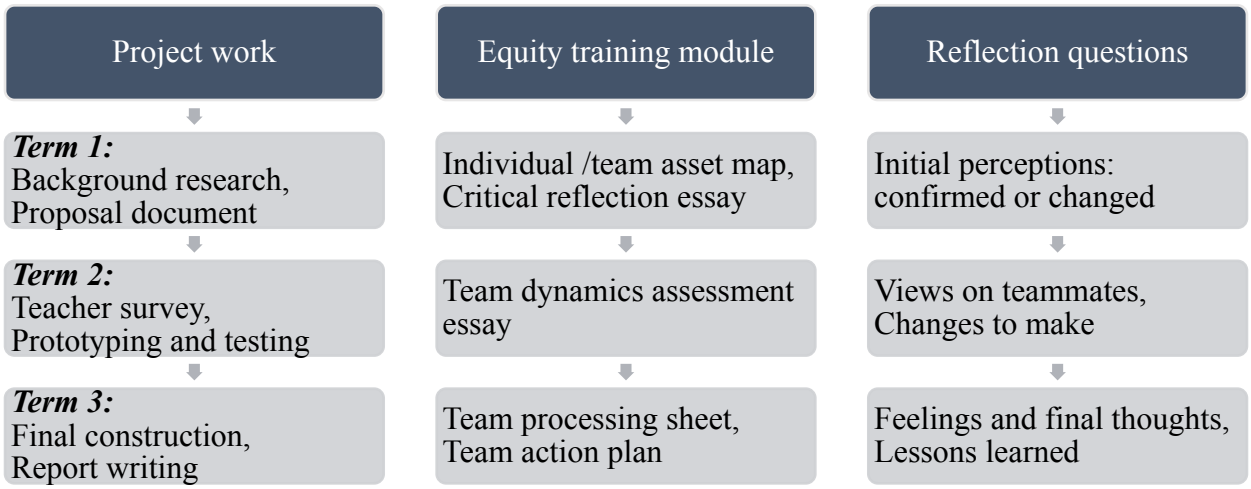

Figure 2: The parallel processes of project work, training, and reflection, where each row represents one term of work. The left column is the project work performed by University X students. The middle column are the assignments from the SWEET modules. The right column are the assigned reflection questions.

Discussion

The components of each student's individual asset map are distilled in Table 2, categorized as assets and areas for growth. Together, the students combined these into a team asset list through an evaluation form, identifying strengths and weakness in assigned topics. Through the team exercise, they identified that most of them actually had experience in areas which they had previously identified a desire for growth: project management and organization, and oral communication and public speaking. The broad areas of data analysis and technical written communication was mapped as ripe for growth by most students, and half of the team had experience with research and synthesis of ideas. All students on the team were lacking in the experience of designing, conducting, and analyzing survey responses. The students reported a strong learning curve from the development of the first survey given to the YWCA teachers, to their observations of the children with prototypes in the STEAM room.

Table 2: Summary of student asset maps created at the start of the project (September 2019).

Student	Self-identified assets	Self-assessed areas for growth
AA	Scouting project leadership experience Technical expertise with computers and manufacturing equipment Passion for art and music Teaching experience in a classroom	Factual writing Education of young children Integrating social learning/STEAM
BB	Summer camp leadership experience Musical skills and graphic design Book-keeping expertise with a computer Proficient in speaking and writing	Public speaking Team leadership/organization Flexibility in work process

CC	Team sports, art and music Programming and computer skills Project management Classroom teaching to young children	Writing proficiency Leadership Public speaking
DD	Extensive physical and digital design Construction, and manufacturing experience Interest in team and individual sports Art, sculpture, and graphic design	Writing proficiency Team leadership/organization Public speaking

One module of the SWEET curriculum tasks students to read articles on equitable teams with a focus on cultural awareness and then reflect on them. Important aspects of each student's self-reflection essays are summarized in Table 3. Some identified an area for growth for themselves was to be fairer and more trusting of others in a team, which has been shown to lead to more equitable teams [14]. A common area for growth among the students was task planning and time management. Advisors also noted this as a challenge near the end of the 1st term, as the students did not set internal deadlines for their work, but rather relied on the typical classroom experience of prescribed due dates. The advisors guided the students on setting deadlines for themselves.

Table 3: Topics identified in the individual Critical Reflection Essay (September 2019).

Student	**Characteristics promoting equitable teamwork**	**Self-identified areas for growth**
AA	Leadership of teams with everyone contributing Organization and planning Positive attitude	Improve writing for target audience Integrate social and emotional learning in STEAM
BB	Chinese background promotes the importance of community, and doing more for others Self-driven	Improve confidence in contributing ideas Communicate fairly without judging Learn to trust group members' work Improve self-motivated leadership Task planning and organization
CC	Background teaching children Conflict resolution	Be more active/less passive in project Public speaking Time management
DD	Willing to take the lead Understands the importance of knowing others strengths	Task planning toward an end goal Acknowledge opinions of others Acknowledge other work at a different pace

At the end of the 2nd term, the students wrote a reflective essay on team dynamics as part of the SWEET training (summarized in Table 4) – broadly speaking about what was and was not working in their team. Commonly, the students shared that the group dynamic was positive, and that teammates care about other's feeling and opinions. However, all student expressed the opinion that the types of work were not being evenly shared. The students had shared these feelings with each other and the advisors, but it appeared that more effort needed to be put into to equitably divide the work.

Table 4: Summary of Team Dynamics Assessment Essay (December 2019).

What is working	What isn't working
• Take everyone seriously and hear ideas • Decision making as a group • Teammates care about project • Self-electing task responsibility • Two students are group leaders • Teaching machine shop skills to others	• Dividing up the writing and prototyping work fairly and evenly • Keeping to a strict timeline • Assigning tasks clearly with due dates • Scheduling meeting times • Not growing skills in new areas • Keep silent about feelings and opinions • Communication need to be more concise

In contrast to the differences and difficulties described in the individual team dynamics assessment essays, the team processing sheet (December 2019) completed as a group told a rosier story with less internal conflict than was evident. This suggests that at the midpoint of the project, the team members were not ready to be truly honest with each other and fair in their assessments. This was supported by the students as they identified an ongoing need to communicate more openly. Additionally, students identified a need for time management as the consistent theme of needing to make and stick to a schedule was mentioned.

Persistent themes from the students' answers to the individual self-reflection questions assigned at the end of each of the three terms are summarized in Table 5. It is interesting to note that students espoused desires were not always reflected in their actions. First term self-reflections showed a desire on the part of students to expand their skill sets and learn to work outside of their strengths and respective disciplines. However, when students were given the opportunity to delegate tasks themselves, they chose tasks aligned with, rather than outside of, their existing skill sets. A discussion of this behavior revealed that students felt pressed for time – they choose tasks in areas they know best to "just get it done" given the time constraints of the academic year. This means that instructors should review task assignments. If it appears that students are solely playing to their strengths, not equitably working in a team, or stereotyping roles, then the instructor should suggest another student be assigned the work, or pair students together to complete a task. This is best accomplished during weekly meetings with the instructor and project team – however it is recommended that students lead meetings to develop such skills.

Table 5: Themes present in the individual self-reflection questions at the end of each term.

Persistent themes from the 1st set of self-reflection questions
• Didn't realize how involved background research was, thought it would be more design • A firm task list with work assignments and deadlines is needed • Communication has improved over the 1st term • As a team they can accomplish more as individuals, with different skills to contribute • Shared desire to improve leadership and technical writing skills • Team mates do not want to be pigeon-holed into one work task • Seeing prototypes and the space in person changes perspectives and ideas vs. on paper • The educational and community aspects of the project are important to all teammates • The students care deeply about doing a good job on this project

Persistent themes from the 2nd set of self-reflection questions
• Communication has improved, but still needs work • Teamwork ethic has improved as a whole, but some think it still needs to speed up • All team members think they are working really hard on this project • Social media outreach didn't work, but librarians are excellent resources • The ball wall design is progressing, but construction needs to speed up/start sooner • Need help and motivation to get writing done from team members and advisors
Persistent themes from the 3rd set of self-reflection questions
• As a group, teamworking skills have improved greatly • All team members think they have grown in leadership skills • Students understand the engineering design process more deeply, having practiced it • In retrospect, make a timeline or plan of the project with due dates at the outset • New or renewed appreciation for hands-on learning and projects

The theme of project management most prominently evolved from a "desire to learn more" to a "necessary and important aspect" of teamwork. In the 1st term, the students expressed that project management is a critical part of teamwork and wanted clearly defined and assigned tasks and due dates. In retrospect (3rd term) all students expressed the need to have more rigid project management; this is an excellent learning outcome. From the advisor's perspective, project documentation and report writing were the most difficult tasks for the students to delegate and complete in a timely manner. However, students were able to align the design of the ball wall with aspects of their pedagogical research, and construct the ball wall within deadline.

The reflections questions did not appear to directly affect change in student behavior, but the students' responses exposed shortcomings in their teamwork. This allowed the advisors to discuss solutions and suggest adjusting the workload. However, the change in students' responses suggests that the nature of the work improved their multidisciplinary teamworking skills of communication, leadership, and group decision making.

Conclusions

The SWEET modules helped students identify strengths and areas for growth through asset maps, and they reflected on how their team addressed equity in project work through case study analysis. Student answers to the self-reflection questions showed what was missing: guidance to assign tasks to a student with an identified deficit in that area, or to pair off students one with a strength in that area and one desiring growth. The latter suggestion, if executed properly, could be a powerful peer-learning experience. This was discussed in meetings between the advisors and students, but it was clear that students fell back onto their strengths as the project wrapped up. This led to the students feeling that work was not distributed equally or equitably: two students compiled the final report, and two students constructed the ball wall. To balance the workload of construction versus documentation, the former being more time intensive, advisor FF reassigned work from one pair to the other during a weekly meeting.

Growth of interpersonal skills such as written and oral communication and growth of technical skills such as implementing the engineering design process were reported as improving over the course of the project by the University X students in the reflection questions. Reported from the SWEET modules were improved team dynamics in regards to equitable discussion and decision making, but lacking were improvements in the sharing of work types. For example, team members BB and CC did not extensively learn machine shop skills to prototype despite having expressed this desire, and members AA and DD did not seek to improve their technical writing skills by taking on more writing tasks. Students cited the pressure of deadlines and workload as the primary reasons why they did not leave their comfort zones to try new things. Other reasons given were that, for example, they are not "good writers" and therefore left the bulk of documenting the project to those with more experience. These actions directly contrast their stated desires to expand their strengths in technical writing, as evidenced in their asset maps and self-reflection essays. The advisors strongly believe that direct intervention is needed to pair students off to teach and learn new skills. This was attempted in group meetings for many tasks, but the students cited the pending deadline of the project as why they would stick with the tasks aligning with their assets identified at the project start. Pairing students was successful in some cases, for example CC paired with AA to learn laser-cutting, and BB contributed to final construction by painting and finishing.

Recommendations for instructors and advisors of multidisciplinary teams to improve outcomes for all students to align with curricular goals, based on this project, follow. As always, adjust to suit specific project needs.

- Assign some form of equity training prompting students to examine implicit bias and stereotyping. This can take the form of the full assignment of SWEET modules, or a lighter version by simply asset mapping and discussing as a group, then revisiting partway through the project and at the end.
- Assign some form of reflection activity to focus attention on specific aspects (effectiveness of methods, changes to expectations, goal shifting, satisfactions, frustrations, etc.) or simply discuss in meetings. If more reflection appears to be needed for low functioning teams, increase the frequency or adjust the method of intervention.
- Attend weekly meetings to review assigned tasks, with a focus on the equitable distribution of work. Let students lead the meetings, and recommend that tasks be rotated. Reassign tasks if the workload appears unequal or inequitable.
- Pair students in twos or threes (depending on project size) to engage them in peer learning: one student with a strength can teach another student with that desired area of growth.

Appendix: Self-reflection questions based on the 40 Reflection Questions from Edutopia [1] used at the end of each term

1st Term Questions:

Backward-looking (before you started the project):

1. Share what you thought this project was going to be like before you started. What did you assume? What were your initial expectations?
2. What experiences did you have that brought strength to this project?
3. In what areas were you looking to build stronger skills?

Inward-looking (how you feel about it right now):

4. How do you feel about the current state of your project? Can you give examples to explain these feelings?
5. Did you have a specific goal to have completed by now? If you met the goal, have you exceeded your expectations? If you did not meet the goal, what happened?
6. Are there any ideas you had about this project that have changed, either a little or a lot? If so, how have these idea changes influenced your work?

Outward-looking (how you think others feel about it right now):

7. In what ways do you work differently, and in what ways do you work the same as your other team members?
8. How would you assess the work you and your team have completed so far? What metrics come to mind when you self-assess your work?
9. Does your work convey anything about your personality? If someone outside your organization were to look at it, what would they learn about you?

Forward-looking (what your thoughts are about the future):

10. What aspects of the project do you want to improve upon? These can be self-improvement, team improvement, work improvement, advisor improvement, etc.
11. Is there a process, design idea, or methodology you want to bring into this project to try out?
12. What is the most important think that you want a future colleague (teammate, advisor, teacher, employer, etc.) to know about this project?

2nd Term Questions:

Backward-looking (before you started the project):

13. In what type of work have you gotten better at through working on this project? What has contributed to this improvement?
14. In what ways do you think you need to improve? What do you think could help you achieve this, either within your group or outside your group?
15. What resources did you use while working on this project? Which ones were especially helpful? Which ones would you use again? Conversely, what has not been helpful and why?

Inward-looking (how you feel about it right now):

16. What was especially satisfying to you about either (1) the process you have undertaken so far, or (2) the product you have so far made, or (3) your project team?

17. What did/do you find frustrating about either (1) the process you have undertaken so far, or (2) the product you have so far made, or (3) your project team?
18. In what way can you transform these feelings into action items or plans for your team?

Outward-looking (how you think others feel about it right now):

19. Did you do your work the same way other people did theirs? In what ways do you work differently or the same as your other team members?
20. Imagine you are the teacher for this project: What comments would you make about this project? Would you consider making these comments to your group?
21. What is the one thing you particularly want people to notice when they look at your project? How you can think to take this desire and turn it into a component of your project?

Forward-looking (what your thoughts are about the future):

22. What would you change if you had a chance to do this project over again? What is stopping you from making that change now?
23. What's the one thing that you have seen another team member do that you would like to try?
24. What things you might want more help with? Is there a team member, advisor, or other person who can help you with those things?

3rd Term Questions:

Backward-looking (before you started the project):

25. What process did you go through to produce this piece?
26. Does this work tell a story?
27. What area(s) of growth are you most proud of?

Inward-looking (how you feel about it right now):

28. What were your standards for this piece of work? Do you feel you met those standards?
29. What does this piece of work reveal about you as a learner, or about how you learn?
30. What did you learn about yourself as you worked on this piece?

Outward-looking (how you think others feel about it right now):

31. What grade would you give yourself for this work?
32. If you were the teacher, what comments would you make about this work?
33. What is one thing your classmates notice about your work?

Forward-looking (what your thoughts are about the future):

34. As you look at your work, what is one thing you want to change
35. What is one goal you would set for yourself the next time you undertake a project like this?
36. From your experience on this project, what would you like to spend more time on in school?

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