An integrated Service Project for Junior and Senior Students

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Abstract

Project-Based Service-Learning (PBSL) offers a unique and rich educational experience for engineering students. The present work highlights some of its aspects through the discussion of a multi-level design and build project. A service project was assigned to two teams of junior and senior students. The project was to design and build a bubble tower for the local children's museum. The tower was completed in two phases. In the first phase, it was assigned as a final project in a junior level course. In the second phase, another team of seniors was added to lead the design optimization and building of the tower as their capstone experience. The Service-Learning (SL) nature of the project and having two teams at different academic levels added challenges and benefits to the students. The details of this unique experience are discussed and samples from the students' work are presented. The project was completed successfully with positive feedback from the students, the customer and the local community. Reflections about this project and recommendations for future use of similar SL are also presented.

Introduction

Theory and application is a challenge in engineering education. Instructors always seek real life examples to support the theoretical foundation of the engineering curriculum. Engineering educators have been using course projects through nearly all levels of courses to increase the students' interest in the course and help them to build this bridge between theory and application. Pacella et al.[1] and Mokhtar[2] introduced design projects in the freshman year. In both cases, although the students have limited technical skills at this level, the studies showed positive results in terms of both technical and soft skills. In a sophomore statics course, Chaphalkar et al.[3] used successfully a reverse engineering project to introduce design kills. Duesing et al.[4] and Mokhtar[5] used Project-Based Learning (PBL) in teaching software-based courses and showed success. Design projects were also used in senior level heat transfer courses to support the theoretical foundation, Newell et al.[6] and Fleischmann et al.[7]. References [8-12] show more examples of the successful use of projects in courses of all levels. Mokhtar et al.[13] and Hadim et al.[14] discussed the use of projects in a sequence of courses. Their work showed that a planned use of projects with the suitable level of open-ended problems and challenges can introduce the students to design skills and support the theoretical foundation of the engineering program.

Capstone senior project is another example where students work in teams to design and build a product and apply many of the subjects they learn. Beside technical skills, in capstone projects, students develop soft skills such as: project management, team working, communication, and budget managements. Interaction with a customer is another unique experience of capstone projects. Hasan[15] discussed the effect of using small course projects on the success of the capstone senior projects. Mokhtar[16,17] presented the balance between students' mentoring and creativity in capstone and small course projects respectively.

Service-Learning (SL)

Service-Learning (SL) presents another level of challenge where the customers, most of the time, do not have the technical background to interact with students and budget is always a major constraint. Singh[18] introduced renewable energy design projects for humanitarian engineering. He presented several examples of successful projects where the students designed products that suitable for developing countries. Pearce[19] outlined the need for Service-Learning (SL) projects to both the students and the products users. Thomas et al.[20] presented two case studies for SL where the students designed and implemented a project in developing countries, Rwanda and Peru. Service learning through the partnership between a university and the surrounding community was discussed by Hembroff et al.[21]. They presented the benefits of SL to both the students and the community and the challenges in these types of projects. In the freshman year, Tsang et al.[22] and Bottomley et al.[23] introduced SL where the students designed instructional tools for teachers. Kasarda et al.[24] also introduced SL in capstone project to develop tools to help high school teachers who are supervising FIRST Robotics teams. A survey that was done nearly a decade ago showed the use of SL in many universities in the US, Duffy et al.[25]. In addition they showed some of the guidelines for successfully implementing SL in engineering courses. Narayanan[26] provided further guidelines for a successful SL capstone senior project. Javadpour[27] worked with one of the local non-profit organizations to develop projects where the students designed and built several household projects to help handicap persons. Duffy et al.[28] showed the expansion of introducing SL to 35 core engineering courses. Both technical and soft skills benefits were presented in the study. Assessment method for SL projects was presented by Bielefeldt et al.[29] and Narayanan[30]. Zoltowski et al.[31] discussed the challenges in the success of introducing SL where a multidisciplinary teams of students worked with the local communities and developed “human centred product”. The faculty response to SL projects was presented by Paterson et al.[32] They discussed a recent survey where they indicated that 40% of the responses received from universities confirmed the use of SL. Zarske et al.[33] discussed the students attitude toward SL in the freshman year. They compared between conventional and Project-Based Service-Learning (PBSL) approaches. They indicated that there was a significant gain from introducing PBSL. In a junior level course, Rockenbaugh et al.[34] also compared between conventional projects and PBSL. Through before and after survey they showed the changes in the students' motivation.

It can be seen that PBSL combines the advantage of open-ended problems with a unique set design requirements. The main features can summarized as follow:

- Unique design: The design challenge is for a unique product with unconventional constraints.
- Students' motivation: The level of creativity needed to complete the project increases the students' interest in the project.
- Human face of engineering: It offers the students a chance to get in touch with an important aspect of the role of engineers.
- Learning outcomes and assessment: It offers a very rich learning environment for instructors to address both technical and soft skills.
- Customer/client: Service-Learning (SL) allows the students to interact with a wide range of customers/clients with all levels of technical background.

In the present work, two teams of students completed a service project for the local children's museum. The project was completed in two phases. The first part was assigned as a course project in a junior level Finite Element (FE) course. The second part was completed by another team during the capstone senior project. The project details and the interaction between the two teams are the focus of this paper.

Project overview

The local children's museum approached the school of engineering to design a bubble tower. According to the museum staff, over 1500 visitors come to the museum every year and the bubble tower is one of the main stops for nearly all the visitors. The museum used to have a bubble tower that was 10 years old with long list of usage and maintenance concerns. The two main challenges for this design were the limited budget and the high safety requirement. The project was completed in two phases. In the first phase, a team of two students was assigned to the project in a junior level FE course. The main tasks of this team were to define the project requirements, assess the current design and develop an initial design to meet the basic requirements. In the second phase, a team of two senior students optimized this design and completed the construction and delivery of the final bubble tower. Figure 1 shows the completed bubble tower that was designed and built by the students at the end of this project.

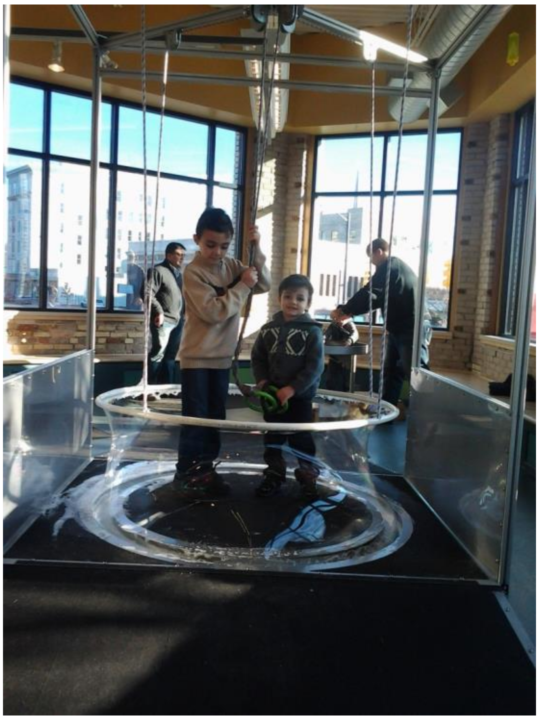


Figure 1: A photo of the designed bubble tower in the children's museum.

First phase: Specifications and initial design (junior team)

The junior team completed three main tasks: project specifications, evaluation of the old bubble tower and proposing a new design. Details of each step is presented in the following sections

Project specifications (junior team):

Project definition is one of the challenges for any design team. Being at the junior level also added to these challenges. The starting point was a list of basic project requirements that was developed by the customer. The team held a set of meetings with the museum staff to generate and enhance this initial list. The team also researched similar designs in other children's museums to add more to this list. Figure 2 shows the results of this part of the study. It can be seen that this list is more qualitative than quantitative. It was an important educational experience for the students. As they collected their design information from the product user and they had to use non-engineering terms and ask the right question to get their data.

Reaching this point of information, it was time for the team to move to the second stage of problem definition. They had to translate this initial list of project requirements to engineering specifications. Being in an FEA course, the design aspects of the project was a natural focus of the team. Dimensions, sizes, stability of the structure and durability of the tower were among the list. The team advisor role here was important where he raised more questions about functional specifications of the bubble tower. Table 1 shows a further detailed list that was developed by the junior team.

From educational point of view, it is important to evaluate the team's progress between these two sets of project information. Comparing the two lists, the team did four main tasks:

1. Turn some of the requirements into numbers, (Examples: height, width, side panels, etc...).
2. Detailed some of the qualitative requirements, (Examples: stability, non-slip coating, and pulley systems).
3. Kept some qualitative requirements, (Example: visually pleasing).
4. Added new specifications, (Examples: ability to move the tower, interlocking surfaces and ramps).

For a junior team to collect information from the customer, complete research and list reasonably detailed set of specification was a good achievement in the project progress. They also kept open-items as "TBD" which is another design skill where a designer sometimes delays some decisions to the right stage of the product development. The following task for the team was to evaluate the old tower design and add these notes to the list of specifications for the new design. In engineering terms, they were reverse-engineering the old product for bench marking.

Figure 2: List of basic bubble tower specifications, junior team.

Table 1: Detailed bubble tower specifications, junior team

- Approx. total height 7' (Light grid 9')
- Width 64" (will verify paediatric wheelchair size)
- Structurally stable (able to withstand the force of many children!)
- Visually pleasing
- Two solid side panels approx. 23' x 60" that are an appropriate distance from the ring as to not pop the bubble
- Inside platform approx.55" (will verify paediatric wheelchair size)
- Platform surface removable for easy cleaning with smooth underside surface
- On and off ramp approx. size 60" x 24" possibly with hand rail
- Ability to remove the ramps for cleaning (designed to minimize the amount of liquid they might travel in the joints
- Non-slip coating on surfaces where people will walk
- Non-slip coating that can be easily reapplied when it wears off
- Tray for bubble solution 3" wide and 3" deep
- Ability to move the entire unit to clean the floor underneath (not mandatory but this would be nice)
- Simple pulley system to raise and lower the ring
- Ability to replace the pulleys easily when they wear out
- Hub at the top of the structure which directs the ropes designed so ropes do not fray as they move up and down
- All interlocking surfaces designed to minimize the amount of liquid that might be trapped or move over the surface causing rust
- Circumference of ring TBD
- All materials used TBD

Old bubble tower evaluations (junior team):

As a part of the problem definition, the junior team evaluated the old bubble tower design. The objective of this step was to collect more design specifications and technical constraints. Figure 3 shows photos of the old bubble tower and some of the failure points. Figure 4 shows the CAD and part of the FEA of the old bubble tower completed by the junior team.
Concerns in the old tower design can be categorized into set tracks:

- Usage issues.
- Maintenance.
- Structural failure.

The list of specifications that was developed by the team in the previous stage of the project addressed well the first and second concerns, for this phase of the project. The team focused in this part on the structural analysis and mechanical failure. This was a direct application for the FEA course they were taking. The educational part here was defining the loading and failure scenarios. Unlike a traditional text book problem, the team had to collect dimensions from an un-assembled structure, as shown Figure 3, and collect the loading information from the user. Since the focus of this paper is the educational experience of the team, detailed of this study will not be presented. The author sees this part of the project as an expanded FEA exercise and the students did not have difficulty completing it at a satisfactory level.

Figure 3: Photos of the old bubble tower and some of the failure point, junior team.

New proposed design (junior team):

After collecting all of this information, the junior team was ready to develop their own design. This design should meet the list of specifications and overcomes deficiencies in the old bubble tower. Figure 5 shows the proposed design and its bill of material. When comparing the team design to the old design, it can be seen that the team developed a totally new geometry with a different mechanical structure. In the author view, this design did not meet many of the items in the list specifications. The team even felt that in their presentation as they included a list of improvements with the final design, which is not a typical tradition in design processes.

The author sees three reasons for that:

- Being a final project in a course, the team did not have enough time to complete this stage properly.
- Students at this level, junior class, tend to loose big picture and focus on details.
- They still did not have the necessary advanced design skills such as fatigue analysis and design optimization that are taught in the senior level courses.

Junior team outcome

The main outcome of the first team was to define the project requirements and take some steps toward the final design. They spent a significant time interacting with the museum staff and researching similar designs. The proposed new design shows a lot of improvements compared to the old one. The tool they used at this level was FEA and basic design skills. Manufacturability, fatigue analysis and design optimization were beyond their skills set at the junior level. These steps are the task of the senior team as will be presented in the following sections.

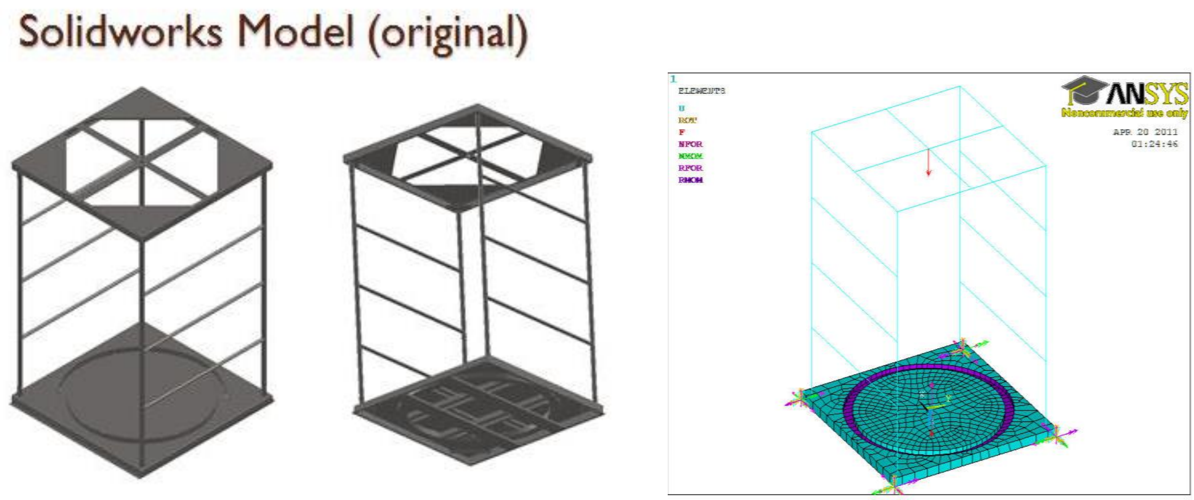
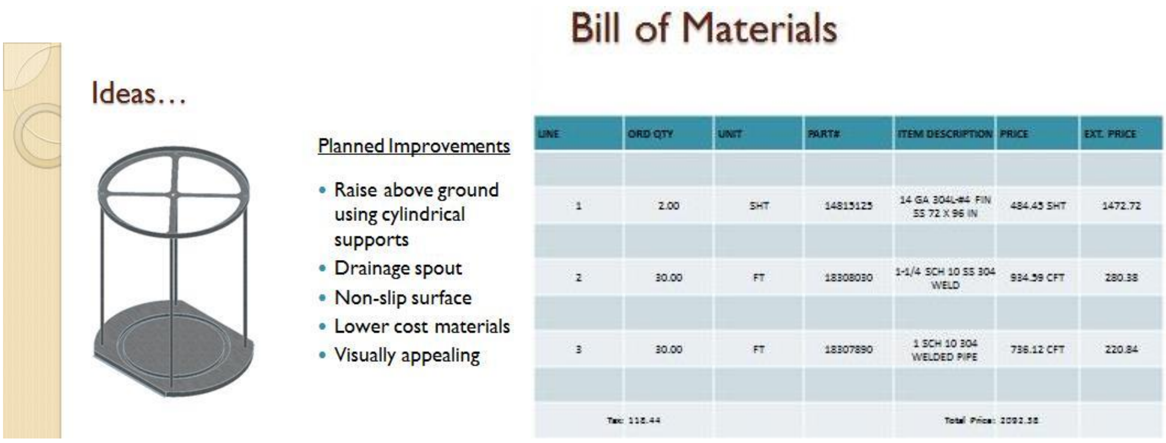


Figure 4: CAD and FEA of the old bubble tower, junior team.



LINE	ORD QTY	UNIT	PART#	ITEM DESCRIPTION	PRICE	EXT. PRICE
1	2.00	SHT	14815125	14 GA 304L-#4 FIN SS 72 X 96 IN	484.45 SHT	1472.72
2	30.00	FT	18308030	1-1/4 SCH 10 SS 304 WELD	934.59 CFT	280.38
3	30.00	FT	18307890	1 SCH 10 304 WELDED PIPE	736.12 CFT	220.84
Tax: 118.44				Total Price: 2092.38		

Figure 5: Proposed design and the bill of material, junior team.

Second phase: Final design and build (senior team)

In the senior year, students complete a capstone project over two semesters. The first semester is for design and the second semester is for building, testing and delivery. The bubble tower project did not follow this traditional sequence. The junior team completed a good part of the design process (problem definition, technical specifications, benchmarking and initial design). Two senior students took the project for the second semester to complete the rest of the design process and finish the building and delivery of the project. The details of the senior team contributions to the project is discussed in this section with further reflection on the interaction and cooperative learning experience between the two teams.

Transition from junior to (senior team):

The junior team completed their part of the project and finished the FEA course. The senior team was assigned between the two semesters to carry out the rest of the project and finish it. All the project details including the results from junior team were passed to the second team. The two teams held a couple of meetings with tours to the children's museum to introduce the new team to the museum staff. Although the junior team had no further obligations toward the project, they kept involved in the project till the end of the second semester. They got to see the evolving of their ideas though the senior team and learn a lot about advanced design tools.

The author noticed that in this stage of the project, the senior team was not full confident in the junior team work. They started by verifying the project specifications and collecting information from the customers again. They found that the junior team work at defining the project was reasonably reliable to use. That was a good learning experience for both teams. Engineers need to learn to received and report information with people of a wide variety of technical level and judge the limit of accuracy in this information. The same applied to the old design analysis; it was found that it was also accurate. The tower design that was proposed by the junior team lacked some required characteristics as was discussed before.

Initial design evaluation (senior team):

After finalizing/reviewing the project specifications, the senior team performed a comprehensive evaluation for the design that was proposed by the first team. Figure 6 shows the junior team design evaluation and the new design. The main points they found in that design were related to some functional requirements that were missing and concerns about manufacturability of some parts within the available budget. Comparing Figures 5 and 6, it can be noticed that the junior team identified some of these concerns and presented them as suggested improvements. As indicated before, the junior team was involved in this evaluation which enriched the cooperative learning process for both teams.

Figure 6 also shows the new designed proposed by the senior team. Being a Service-Learning (SL) project, the budget controlled many of the decisions such as: material, manufacturing and required level of maintenance after delivery. Also, at this stage the senior team started answering many of the open items in the project specifications that was listed as “TBD” by the junior team such as material, ring dimensions, drain system, etc…

Design iterations (senior team):

The senior team had all the designs skills to complete the project. Having the full specifications opened the door for the team to finish the project in weeks, as they thought. The high level of safety requirements was the real challenge for this team. A toy that is located in a public museum with users from all ages needed a long list of safety requirement. For example, no sharp edges, no small opening that can fit a child finger, no ladder-like structure where kids would try to climb, non-slip surfaces which were hard with the bubble solution, etc… This part of the project needed a set of meetings between the team and the museum staff. Also the team performed research for safety standards especially with the fact that the bubble tower was also designed to accommodate a child with a wheel chair. This part of the design process was an important aspect of the learning experience for the students. The human side of engineering is a major part of SL projects that is hard to do inside classrooms.

Figure 7 shows one of the design iterations and the list of concerns that was found during the discussion with the customers and researching safety requirements. After a couple of design iterations, the team reached the final design, shown also in Figure 7. It can be seen that the major components of the structure were not significantly changed during the iteration process. The improvement focused on certain areas such as the ramps, pinch points, and accessibility for cleaning.

From the technical point of view, the team completed a details structure analysis using FEA, Figure 8. Fatigue analysis was another critical part of the mechanical design that the team also completed. They performed an experimental analysis to study the surface tension for the bubble formation. These are some examples of advanced tools that were used by the senior team beyond the technical level of the junior team.

Senior team outcome

The senior team finalized the project specifications, optimized the design and built the bubble tower. The team completed all its work in one semester. Challenges faced the team included two main factors: project budget and safety requirements. The mechanical design of the bubble tower would not be a challenge for them without these two factors. Having a junior team before them that went through most of the problem definition gave them more time to focus on these challenges and successfully complete the project. The members of the junior team were voluntarily contributing to the project after completing their phase. Table 2 shows the bill of material of the final design that was developed by the senior team. It is clear that the level of details in this design is way higher that the junior team. Figure 9 shows the final project and the two team teams during the end of the semester design day. Traditionally, this day is for seniors only. The senior team invited the junior team to present the final design with them as they value their contribution to the project.

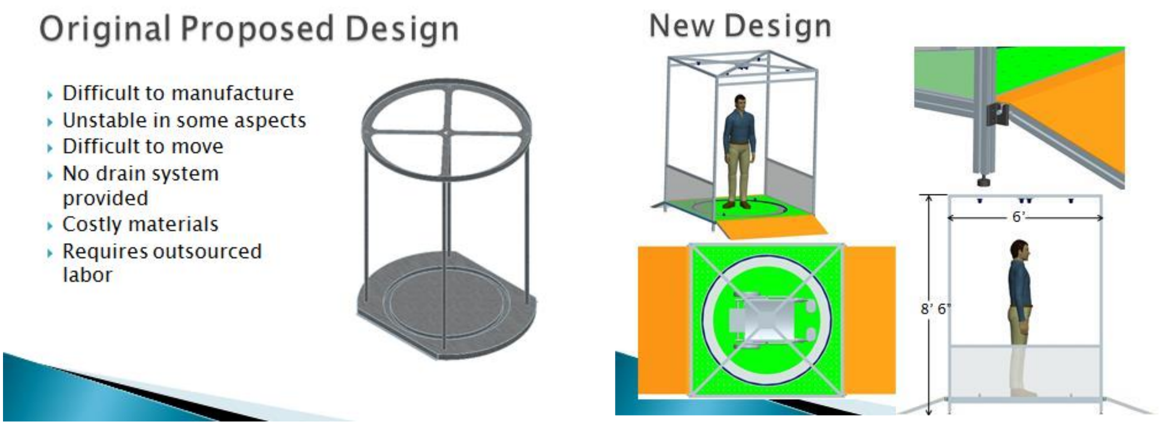


Figure 6: Evaluation of the junior team design and one of the new design iterations, senior team.

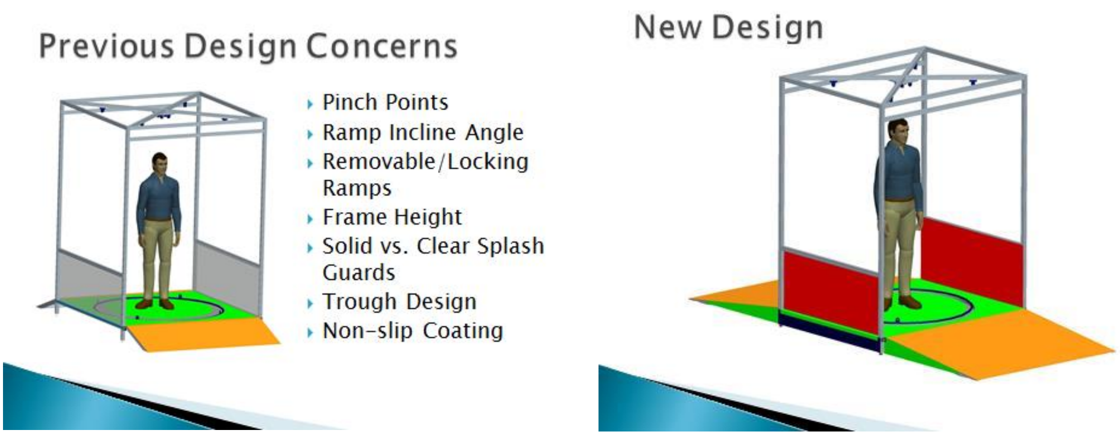


Figure 7: Some of the concerns for one of the design iterations and the final design, senior team.

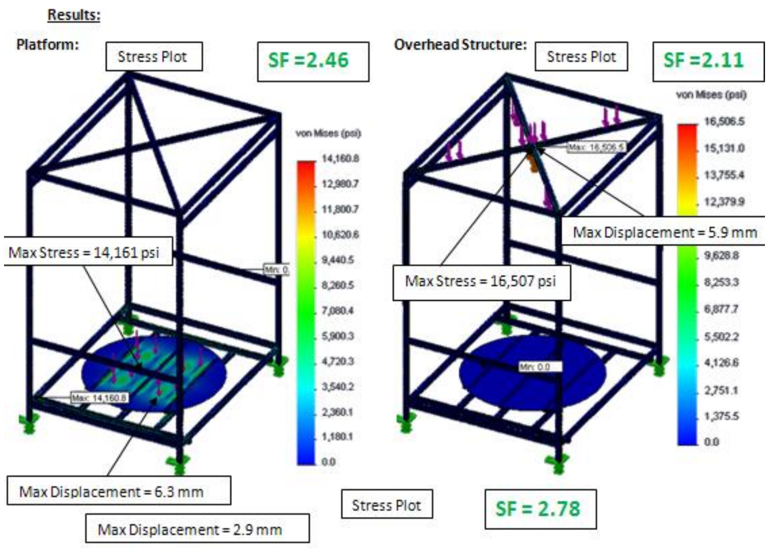


Figure 8: Part of the FEA of the final design, senior team.

Table 2: Bill of material, senior team.

Item	Quantity	Supplier	Part No.	Cost	Line Cost
Aluminum Extrusion Package (See PO)	1	Shupan Aluminum		$ 980.00	$ 980.00
Inside Gusset	40	Grainger	5JRV5	$ 6.58	$ 263.20
Joining Plate	4	Grainger	2RCX4	$ 10.88	$ 43.52
Laser Cut Ramp, Bubble Tray (See PO)	1	Lakeshore Cutting Solutions		$ 2,179.49	$ 2,179.49
Pulleys	8	McMaster-Carr	3087T42	$ 28.72	$ 229.76
3/4" x 20' SCH40 PVC Pipe (bubble ring)	1	Etna		$ 20.00	$ 20.00
Low Stretch Polyester Rope	1	McMaster-Carr	3828T13	$ 39.72	$ 39.72
Splash Shields, Frame Skirts, Delet Panels (See PO)	1	Alro Steel		$ 979.18	$ 979.18
12" x 24" Diamond Tread Aluminum	1	Lowes		$ 24.95	$ 24.95
Leveling Feet	8	McMaster-Carr	1942K73	$ 5.77	$ 46.16
Grip Tape	6	Grainger	2TUY8	$ 45.95	$ 275.70
SS Surface Mount Hinge	2	McMaster-Carr	1488A120	$ 5.26	$ 10.52

Water Hose w/ Brass Swivel	1	McMaster-Carr	5722T694	$ 15.62	$ 15.62
Brass Ball Valve 1/2" NPT	1	McMaster-Carr	47865K43	$ 10.04	$ 10.04
316SS Weld-on Tank Fitting 1/2" Pipe	1	McMaster-Carr	1145K53	$ 27.64	$ 27.64
3 1/2" x 50' Sill Seal - Insulation	2	Lowes		$ 7.00	$ 14.00
5/16"-18 1-1/2" SHCS 316SS	1	McMaster-Carr	92185A587	$ 120.00	$ 120.00
5/16"-18 3/4" SHCS 316SS	1	McMaster-Carr	92185A581	$ 120.00	$ 120.00
5/16"-18 1/2" SHCS Button Head SS	12	McMaster-Carr	92949A578	$ 6.04	$ 72.48
80/20 Economy T-nuts 5/16"-18	300	Bond Fluidaire		$ 0.27	$ 81.00
				Total	**$ 5,552.98**

Figure 9: The completed bubble tower and the two teams during the end of the semester design day.

Further discussions

Looking at the final product, it is not that easy to judge how much each team contributed. The junior team worked on the project as a course assignment which put a limit on the number of hours they could put in. Their technical skills and experience also put another limit. They were successful to complete the list of specifications and requirements through interaction with the customer and researching similar designs. The FEA analysis of the old bubble tower was a traditional assignment for their course. They got the credit in developing the CAD and identifying the weak points in the design.

The senior team had more time since it was assigned as a capstone project and they had more technical skills and experience. By the time they started working on this project they had completed three semesters of cooperative engineering courses where they worked full time in local companies. They were very familiar with interacting with venders; they participated in more sophisticated industrial projects. However, in this project they had more control as they completed it from beginning to end. The senior team used the information from the junior team in terms of problem definition, specifications, and analysis of the old design. From the author observations, they were not confortable to rely on the design proposed by the junior team. They did a fair evaluation for it as a starting point and then developed their own. Fatigue analysis, surface tension calculations for the bubbles, and manufacturability were some of the tasks that the senior team had to finish without the junior team because of the needed technical skills. Design optimization, budget management and safety requirements were among the challenges for the senior team. The junior team continued to participate in the project even after finishing their part.

The Service-Learning (SL) component of the project was a major part in the tasks for both teams. They were designing a unique product that was totally custom made for the children's museum. The interaction with the museum staff on weekly bases for nearly most of the project time was a valuable experience for the students. The limited budget controlled a lot of the design decisions. Easy to maintain with minimal cost, was another design constraint that the students needed to meet. Finally, safety was a major challenge that the students had to meet.

Cooperative learning between the two teams was another educational experience for the students. From the author point of view, this could be the most important parameter of this project. The junior team got to see their design being evolved by the senior team using advanced tools. Although the senior team had some doubts in the junior team results, they ended up using most of the junior team specifications which was an important team-building skill (team members' interdependency) for both teams.

Evaluation and feedback

Designing the bubble tower for the children's museum was really a rewarding experience. The users are children and both teams were very proud for participating in this project. From the author point of view, the level of motivation and the sense of ownership of the project were outstanding. Some of the students continued to help in improving the design even after their graduation.

As an advisor for this project, it offered a challenging design for the students especially with the high safety requirements and budget constraints. The interaction between two teams with different level of skill sets was another learning experience for both teams. The technical constraints, budget, customer background, safety requirements were some of the challenges that encouraged the students to use creative ideas to complete the project.

A feedback survey was collected from the students after the project. Having four students, two in each team, makes the traditional presentation of the statistical results of the survey pointless. Instead, the discussion in this section will be focusing more on reflecting on the students' feedback. Over all, the responses from the students were all positive. Figure 10 shows a sample of the students' responses. Figure 11 shows a note written by one of the junior students highlighting the value of having a junior and senior team in this SL project. His words show the success of the project from educational point of view.

Another advantage of SL project is that it gets the attention of the news. A local newspaper and one of the local news channels presented coverage for the bubble tower, Figure 12. The students and the faculty advisor were interviewed in this news coverage. In addition to publicity of the engineering program, having a product in the public children's museum that carries the name of the engineering school was another achievement to introduce the name of engineering to children in their early ages.

Another view of the SL projects is that they offer opportunities to help local community. The project cost and the quality of the final product would not be achieved if the museum outsourced it to one of the local manufacturing facility. The museum approached the engineering school in the following year for another project and it was also completed as a course project. This is expected to be a long term relation between the university and the museum.

This is a technical evaluation of the project. Please put a score for each item.

You worked in this project as a:
- course project ☑
- senior project ☐

1. How interesting was the tower project?

1 (Poor)	2	3	4	5	6	7	8	9	10 (Excellent)
☐	☐	☐	☐	☐	☐	☐	☑	☐	☐

2. Rate technical challenges of the project

1 (Poor)	2	3	4	5	6	7	8	9	10 (Excellent)
☐	☐	☐	☐	☐	☐	☐	☐	☑	☐

3. Rate the technical benefits to work in a service-project

1 (Poor)	2	3	4	5	6	7	8	9	10 (Excellent)
☐	☐	☐	☐	☐	☐	☐	☐	☑	☐

4. Rate the personal benefits to work in a service-project

1 (Poor)	2	3	4	5	6	7	8	9	10 (Excellent)
☐	☐	☐	☐	☐	☐	☐	☐	☐	☑

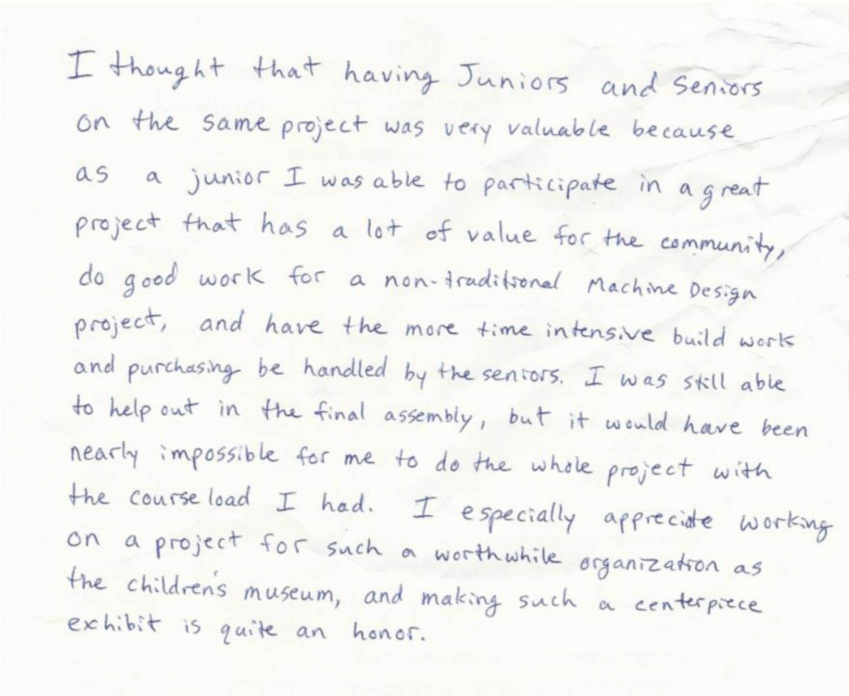
5. Rate the value of using service-project in engineering programs

1 (Poor)	2	3	4	5	6	7	8	9	10 (Excellent)
☐	☐	☐	☐	☐	☐	☐	☐	☐	☑

6. Rate the value having two teams in the project (juniors and seniors)

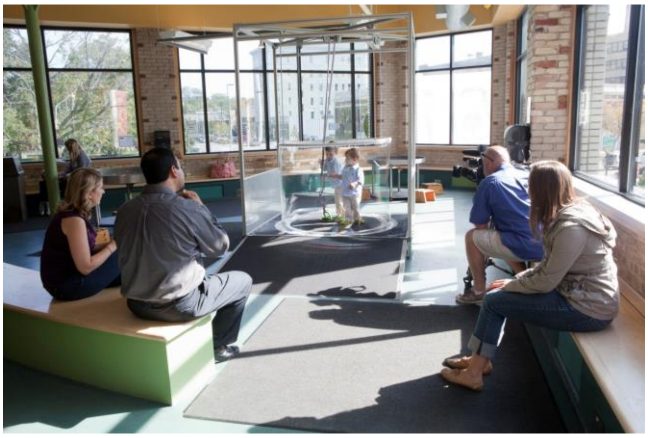
1 (Poor)	2	3	4	5	6	7	8	9	10 (Excellent)
☐	☐	☐	☐	☐	☐	☐	☐	☑	☐

Figure 10: Sample for the students' feedback.



I thought that having Juniors and Seniors on the same project was very valuable because as a junior I was able to participate in a great project that has a lot of value for the community, do good work for a non-traditional Machine Design project, and have the more time intensive build work and purchasing be handled by the seniors. I was still able to help out in the final assembly, but it would have been nearly impossible for me to do the whole project with the course load I had. I especially appreciate working on a project for such a worthwhile organization as the children's museum, and making such a centerpiece exhibit is quite an honor.

Figure 11: One of the students' feedback about the project.



A6 THURSDAY, OCTOBER 13, 2011

Museum unveils bubble tower

GVSU students build machine to delight kids

BY ERIN ALBANESE
THE GRAND RAPIDS PRESS

PRESS PHOTO/KATY BATDORFF

Inside job: Grand Rapids Children's Museum worker Jake Bouck is encircled by the facility's new bubble tower, which is large enough to be wheelchair accessible.

GRAND RAPIDS — "Show me your mad bubble skills," Alyssa Wagner told Parker Sanford, 4, and his brother, Drew, 2, at the Grand Rapids Children's Museum on Wednesday.

The two boys soon discovered how easy it was to make enormous bubbles with the new bubble tower unveiled at the museum. With the bubbles big enought to stand in, they remained entranced, creating bubble after bubble after bubble.

The new bubble tower replaces a 10-year-old one, which was so popular it was "loved to death," said Jan Stone, museum exhibits manager.

Museum staff turned to the engineering department at Grand Valley State University for help replacing it. Engineering students Jonathan D'Anna, Michael Ritsema, Matt VanSlooten and Andrew Geelhoed, under the direction of Wael Mokhtar, GVSU assistant professor of engineering, built the new and improved tower by adding to the original design's key features.

D'Anna, 21, said the changes included using aluminum, which holds up in water better than steel, increasing the circle's diameter and entry and adding a drain to allow better cleaning.

The new bubble tower has larger pulleys, which enhance the learning experience.

Stone said. "Now a child interested in how the mechanics work can follow the whole process," Stone said.

D'Anna, who is studying mechanical engineering, said major concerns were safety and handicapped accessibility.

"The last one seemed to pop more because the smaller diameter ring would not hold enough solution," D'Anna said.

Stone said the students' design should hold up for another 10 years of play by the nearly 150,000 museum visitors each year.

For D'Anna, it was great to see the tower in use.

"The best thing was seeing the smiles on the kids' faces," he said.

Email: localnews@grpress.com

Figure 12: The bubble tower in the local news.

Conclusions

A junior level team and a senior level team worked in the design and build of a bubble tower for the local children's museum. The first team completed the initial stages of the project, technical specifications, requirements and benchmarking. The senior team completed the advanced analysis, optimization and building. The interaction between the two teams in a Service-Learning (SL) project enhanced the experience for both teams. Having teams with different technical level add a cooperative learning environment in the project between the seniors and juniors. However, the senior team was, to some extent, hesitant to rely on the junior team. This by itself is another experience that students usually do not see till they start working.

The project was well received by the customer, provided the students with a unique learning experience, and allowed the university to help a local non-profit organization. From the author point of view, regardless of the challenges in managing a SL project, it is a very rewarding experience to all participants and engineering schools should continue seeking these opportunities.

The project was completed with small groups of students in both teams. The feedback and evaluation indicated positive educational results. The question is still open on whether this model of sequential completing of a project through teams of different academic level would work with larger numbers of students or not.

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