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Interactive Bottle Recycler: A "Green" Senior Design Project Case Study

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Abstract

As sustainability and being “green” becomes more and more main stream by the end of the first decade of the 21st century, universities are also incorporating more sustainability into their curriculum. The purpose of this paper is to present an innovative “green” senior design project case study in which engineering students were asked to design an arcade style interactive bottle recycler at the University of North Carolina at Charlotte (UNC Charlotte).

This paper discusses a recycling project that was initiated by the SIFE (Students In Free Enterprise), a student organization in 2011, to create a fun and interactive recycling system for the university community. The project received sponsorship from the Charlotte Green Initiative (CGI) after winning the CGI Challenge (a green initiative proposal competition). Two interdisciplinary teams of engineering students from systems, mechanical, electrical and computer engineering were assembled to tackle this project during the 2011-12 academic year. Each team was led by systems engineering students, who acted as the principal engineer and the project manager, and mentored, by a systems engineering and an engineering management professor. After evaluating various design alternatives, both teams came up with very innovative bottle recycler designs. Both teams were selected as finalists (top 9 out of 50 projects) in the Best Senior Design Project Competition. In this paper, we will present the educational approach how these projects were conducted and assessed, and discuss the findings.

Introduction

“We do not inherit the Earth from our ancestors, we borrow it from our children.” This quote, often referred to as an ancient Native American Indian proverb, summarizes the principle of sustainability: meeting the needs of the present without compromising the ability of future generations to meet their own needs[1]. The importance of sustainability becomes clear as we try to meet the constantly increasing needs of our society with limited resources on Earth. Engineers can play a very important role in this, which is why, at the College of Engineering of UNC Charlotte, ways for incorporating sustainability into the curriculum are being sought.

In 2009, a UNC Charlotte “green fee” was established via a vote from university students. The mandate says that each student will pay $1 in student fees that will be used toward energy conservation and other environmentally beneficial projects on campus. Upon passage of the fee, the CGI committee was established. The committee is charged with identifying students / projects ideas on campus and potentially funding them. During the fall of 2010, CGI held their first annual “CGI Challenge” to promote the group and the objective. The winning proposal that led to the case study described here was submitted by a student organization, SIFE (Students In

Free Enterprise). The proposal was for two design teams to create “interactive” bottle recycling bins that would be used on campus testing the “fun theory”[2]. Behavior change is the cornerstone of sustainability. Therefore, the CGI committee has always been looking for ways motivate individuals to adopt diverse behaviors that support sustainability. Subsequently, the two projects were selected and were the first to be fully funded by UNC Charlotte students.

UNC Charlotte has a comprehensive engineering senior design program managed by a college senior design committee (SDC) and an Industry Solutions Lab (ISL) director. At the beginning of each semester, students are presented with various project options provided by companies, grants and national competitions. Each project description is carefully crafted through interactions with the project sponsor, which are then reviewed by the SDC to tag the project with the required engineering skills from different degree programs. Students are then assigned to projects to optimize success (skills matching). Student preference is also considered for project assignment, but is not a hard constraint. Interdisciplinary project teams can vary in size depending on the scope but typically averages about 4-5 people and mentored by a faculty advisor. The projects last for two consecutive semesters where the students do conceptual and detailed design during the first semester and build and test prototypes during the second semester. The final deliverable is a poster presentation at the Senior Design Expo with their prototype demonstration.

In this case, the design students and representatives of the Office of Waste Reduction and Recycling met on a weekly basis to discuss the project and ensure it met everyone’s objectives. Throughout the process, both groups realized that the value of such a partnership reaches into the core of their mission at the university.

This work will detail the execution of two capstone design projects with significant sustainability content. Project scope and deliverables will be discussed, along with project outcomes and lessons learned during the conduct of these projects. Project disposition and future work are also detailed. Links between sustainability and accreditation criteria are discussed.

Literature Review

While there are many papers that are worth mentioning in the literature for sustainability education for engineers, we have to limit this paper to a few highlights only. For a more comprehensive literature review the reader can refer to Galambosi and Ozelkan[3].

Sustainability has generally been the purview of chemical, civil and environmental programs, where teaching this concept is a well-established policy. These disciplines use of large amounts of natural raw materials makes them more connected to the idea of sustainability[4, 5, 6]. The challenges of integrating this subject into engineering curricula are ongoing[7].

In 2000, Crafton[8] posed the question about what kind of changes were needed in the curriculum to have adequately prepared engineers for the challenges of sustainable development and to increase the effectiveness of their solutions.

MacDonald[9] described how educating for sustainability is done in Manitoba including "policies that integrate sustainable development concepts into provincial curricula, establishing sustainability indicators and reporting on indicators, developing regulations and policies that work towards greening operations of educational institutions, and supporting educators in the field". They concluded that there is a need for "strategic, systemic, and concerted action to support educators as they work to develop students' knowledge, skills and values that contribute to a sustainable future". They also supported that the use of systems thinking as a practical and pedagogical framework would be a way to go in that direction as "the systems concept can help students to see how they are part of larger entities and how these larger entities include natural and manmade environments in a more encompassing whole", and "systems thinking can help students appreciate the complexity and tensions behind sustainability-related issues and provide frameworks and tools for developing and implementing solutions."

Boks and Diehl[10] described the challenge of integrating sustainability issues into a regular industrial design engineering product innovation course. Instead of just requiring students' assignments to show how sustainable product concepts can be incorporated into a traditional business, they tried to put sustainability into a bigger picture, where, for example, social issues such as safety play a role with the hope that this gives not only a better motivation and enthusiasm to students and teachers but the better motivation also leads to a better learning process.

Focusing more on sustainability in engineering and management, Porter & Cordoba[11] described three views of system theories and their implications for sustainability education to extend the notion of systems thinking as it pertains to sustainability pedagogy. The authors developed three broad approaches to systems thinking: functionalist, interpretive, and complex adaptive systems (CAS), which resulted in a practical set of ideas and pedagogical tools for immediate adoption by management educators in any field. Lynch-Cary and Sutherland[12] discussed how to integrate principles and practices of sustainability into the industrial engineering curriculum.

Kumar et al.[13] discussed infusing sustainability principles into manufacturing and mechanical engineering curriculum and describing challenges of the process and a benchmarking study at Michigan Technological University. They concluded that the three main barriers were lack of accreditation process improvement, conventional thinking of some faculty members and company expectations and recruiting trends.

"Fun Theory" is based on the simple hypothesis that “fun can change people's behavior for the better” [2, 14]. Games are often used in education as simulations and to create a fun-learning environment[15,16]. In 2009, Volkswagen (VW) asked a leading advertising and marketing services company, DDB (Doyle Dane Bernbach Worldwide Communications Group Inc.) to generate interest around its “BlueMotion Technologies”, aimed at reducing the environmental impact of their cars without compromising performance or the joy of driving[14,17]. Focusing on the “fun to drive” concept, DDB came up an advertising concept around “ The fun theory”. They conducted a number of social experiments to test how behaviors could be influenced through fun. There were two experiments related to the Senior Design Project described here: “Bottle Bank Arcade”, and “The World's Deepest Bin”. Their tests showed that 100 people used the Bottle Bank Arcade machine one evening, compared to 2 people who used a normal nearby recycling bin.

The literature review showed that there are multiple examples of sustainability courses and programs indifferent engineering and non-engineering fields, but examples of sustainability related projects in engineering senior design combining the “Fun Theory” seems limited. The authors believe that this paper will be a step showing how engineering programs can innovatively incorporate sustainability into their curriculum.

Green Initiatives at UNC Charlotte

UNC Charlotte Sustainability Progress

UNC Charlotte has been informally using the Sustainability Tracking, Assessment & Rating System (STARS) as a means to track progress in sustainability. STARS is a transparent, self-reporting framework for colleges and universities to measure their sustainability performance. STARS was developed by the Association of Advancement of Sustainability in Higher Education (AASHE) [18].

As stated by AASHE [18] “STARS is designed to:

- Provide a framework for understanding sustainability in all sectors of higher education.
- Enable meaningful comparisons over time and across institutions using a common set of measurements developed with broad participation from the campus sustainability community.
- Create incentives for continual improvement toward sustainability.
- Facilitate information sharing about higher education sustainability practices and performance.
- Build a stronger, more diverse campus sustainability community.

STARS is made up of a series credits. Each STARS credit assigned a type: Tier One or Tier Two. Tier One credits are worth one or more points each and are grouped in a subcategory (e.g. Curriculum) within a category (e.g. Education & Research). Tier Two credits are worth 0.25 points each, and many of the subcategories in STARS include Tier Two credits.

The progress of UNC Charlotte (red line) against the STARS Credits (blue line) is shown in Figure 1 below. As seen in this figure while the university is close to targets in certain categories such as diversity, coordination and planning, co-curricular education, waste, water and climate, there are other categories such as curriculum, research, buildings, energy, transportation, investment and engagement, which show improvement opportunities.

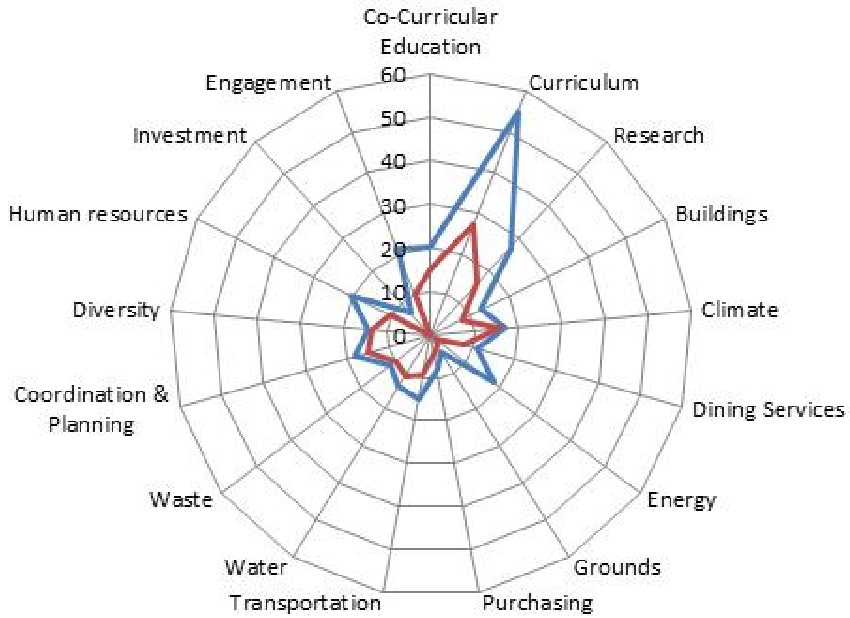

Figure 1. UNC Charlotte's estimated sustainability progress tracking using STARS (Legend: Blue Line STARS targets, RED Line: UNC Charlotte Progress)

UNC Charlotte Green Initiative

UNC Charlotte has tasked CGI to allocate funds from a student "Green Fee" to projects that will enable the university to use renewable energy, become energy efficient and operate in a sustainable manner. This committee is a student-led initiative to create campus-wide awareness, education, and consciousness of sustainability among students, faculty, staff, and visitors.

Each student enrolled in 12 or more credit hours contributes to the money allocated by the Green Initiative Committee through the Green Fee, which is currently set at $1 per student per semester. The Student Government Association (SGA) Student Affairs Committee worked with the Earth Club to pass legislation through the SGA Senate that placed a poll question to determine the willingness of students to pay the Green Fee on the fall 2007 SGA Election Ballot. Students voted overwhelmingly in favor of a fee increase starting fall 2008.

The committee chooses projects based on research, suggestions from students, and from the CGI Challenge, a student competition to propose and implement green projects on campus.

Senior Design Program

Overview:

UNC Charlotte has a capstone senior design course sequence that is implemented across departments for the entire college of engineering. This two semester course sequence features design challenges obtained from local and national industries, government agencies, non-profit groups and from faculty researchers. Projects are solicited that require cross functional teams for successful completion. ABET's recent move to unify the criteria for Engineering Science and Engineering Technology programs makes implementation of cross functional teams even more seamless.

Learning Objectives:

While the capstone design program is a college wide exercise, each individual department or program (Civil Engineering, Computer and Electrical Engineering, Systems Engineering, Mechanical Engineering, Motorsports Engineering, Mechanical Engineering Technology, Electrical Engineering Technology) uses the course for measurement of specific ABET metrics. Some examples include:

ABET Criterion	Criterion Description
3(b)	an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies
3(e)	an ability to function effectively as a member or leader on a technical team
3(g)	an ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and an ability to identify and use appropriate technical literature
3(k)	a commitment to quality, timeliness, and continuous improvement

Of particular interest in the context of this work are:

ABET Criterion	Criterion Description
3(h)	an understanding of the need for and an ability to engage in self-directed continuing professional development
3(i)	an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity
3(j)	a knowledge of the impact of engineering technology solutions in a societal and global context

Sustainability projects are excellent vehicles for reinforcing criteria 3(h) - 3(i). They provide an opportunity for self-directed study in an area where course work may not be common, reinforce ethical considerations and provide context for work in a global sense.

Student Groups:

The subject program uses three criteria when staffing students into project teams. Student interest is weighed along with student GPA and with project skill set requirements. A staffing algorithm has been implemented in software, with some human manipulation required for completion of the task. Projects typically consist of 4-5 students, with a mix of engineering science and engineering technology students as well as a mix of disciplines.

External Stakeholders:

Once student teams are selected they are introduced to their leadership team. This team consists of a grading instructor who will assess their work for both semesters, a faculty coach who supplies direction and oversight and an external stakeholder who acts as a technical point of contact and provides customer feedback. This interaction dynamic assures that the students are exposed to real world project execution and provides a realistic base of experience for transition into the workforce. All members of the student leadership team have input on student grades. Assignment rubrics are used to assure uniformity in assessment of student work.

Course Sequence Deliverables:

Table 1. Senior design course deliverables

Sequence	Course Deliverable	Description
1	Statement of Work	A document that describes the scope of the project and what is to be delivered.
2	Capabilities and Requirements Document	A project specification that defines acceptable performance and how it is to be verified.
3	Project Plan	A project schedule and work breakdown structure to illustrate understanding of the statement of work.
4	Conceptual Design Presentation	A design concept chosen for expanded development is presented along with other concepts considered. Rationale for the decisions made is discussed.
5	Design Package	A documentation package describing the student's design solution is submitted. This documentation package should be sufficient for implementation by a fabrication entity
6	Interim Report (1st Semester Final Report)	A narrative of the design process through the end of detail design, including calculations, research, design studies, simulations or modeling done in support of the project.
7	Public Presentation	A poster is prepared to illustrate the student's work during the first semester of the project. This poster is presented at a public event on campus.
8	Progress Report	Interim reports detailing work done over a certain reporting period (usually about 1 month).
9	Prototype Demonstration	Presentation of the realization of the student's design solution, demonstrating the capabilities detailed in the project specification.
10	Final Report (2nd Semester)	A narrative of the design and construction process through the end of the project, including calculations, research, design studies, simulations, modeling, fabrication, testing, redesign and final testing done in support of the project.
11	Exposition Presentation	The student group displays a poster of their project along with a working display of their project. This is done at a public event on campus. Student work is judged by a panel of academic and industry representatives

Interactive Bottle Recycler

In this section, a description of the design teams and their design concepts for the interactive bottle recycler project will be provided.

Objective:

The objective of the "Interactive Bottle Recycler" project was to design and build a recycling machine that recycles bottles and cans in the form of an arcade game. It was intended to make recycling fun, interactive, and to make students on campus want to recycle.

Teams:

The team structure is shown in Figure 2. Two senior design teams were tasked to work on this project (shortly called CGI_BOT1 and CGI_BOT2, where BOT was used short for Bottle Recycler). Both teams had the same mentor but the sponsor (CGI) designated two representatives to work with the teams independently. While multiple teams were initially intended to compete with each other initially, their scope differed such that CGI_BOT1 team was tasked to create a recycler for outdoors and the CGI_BOT2 team was tasked to create a recycler for indoors.

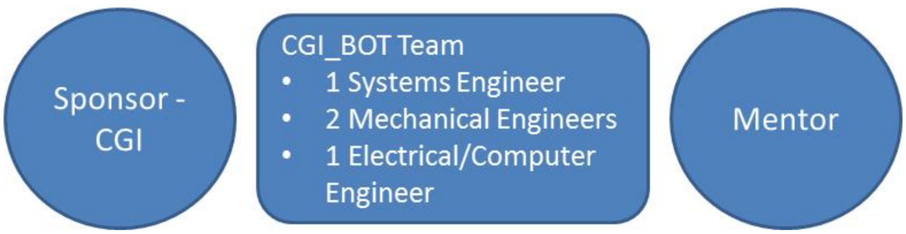

Figure 2. Team Structure

Responsibilities of the team members were determined as shown in Figure 3. The two mechanical engineers were tasked to complete the fabrication and assembly, quality control and the CAD design. The electrical and computer engineer was responsible for the sensor and computer system design. The systems engineer was responsible with project and budget management as well as ensuring that system is integrated well achieving desired functionality.

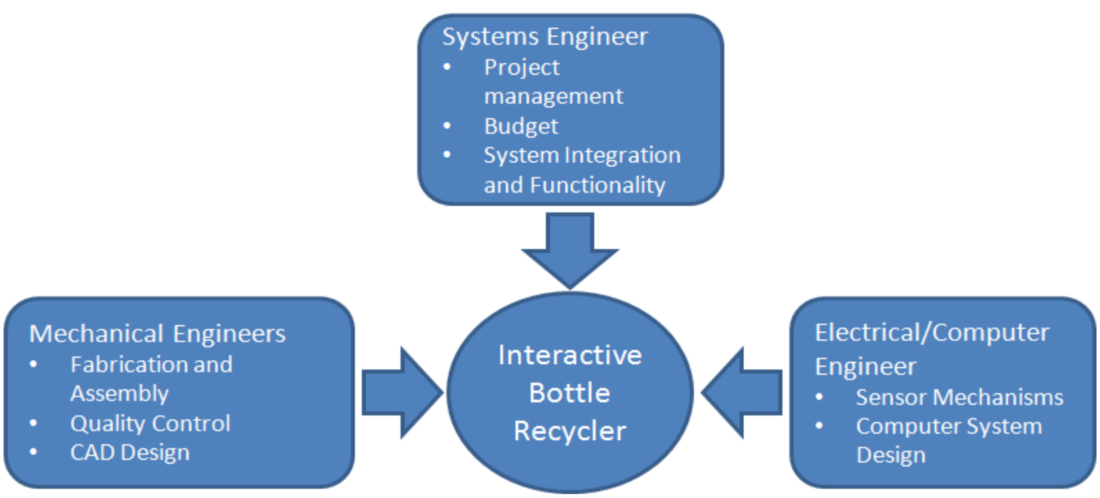

Figure 3. Team Responsibility Division

It was intended that each team would come up with their original designs independent from one another with the hope that the designs would be different. In case of a slim chance of coming up with a similar design, the mentor was tasked to moderate and resolve the conflict.

Project Capabilities, Requirements and Performance Goals

A sample of capabilities and requirements is shown in Table 2 below for the CGI_BOT1 team. As stated in the statement of work (SOW) templates distributed by the SDC, "it is of paramount importance to clearly, unambiguously and concisely identify all aspect of the project capabilities to be able to effectively identify what is required for successful project completion. Requirements serve as the rubric by which any independent party can verify that the end device has all the functionality the customer specified as the scope of the project."

Table 2. Capabilities, Requirements and Goals for CGI_BOT1

Capabilities

CAP001: The device must provide social incentive to recycle.
CAP002: The device must be deployable by one person.
CAP003: The device must contain storage for aluminum and plastic bottles.
CAP004: The device must process bottles to maximize available volume in the container.
CAP005: The device must be easily serviceable.
CAP006: The device must provide educational feedback.
CAP007: The device must have a drainage system.
CAP008: The device should consider "green" forms of energy.

Functional Requirements

REQF0001: The device shall operate under a minimal amount of power.
REQF0002: The device shall provide an entertaining game to spur interest in recycling.
REQF0003: The device shall provide credits, redeemable for novelty items.
REQF0004: The device shall be transportable by dolly.
REQF0005: The device shall be able to compact plastic bottles.
REQF0006: The device shall be able to compact aluminum cans.
REQF0007: The device shall have a bin to collect the excess liquid waste.
REQF0008: The device shall be modular in design such that assembly can be easily repaired.

Non-functional Requirements

REQN0001: The device shall have the CGI and UNC Charlotte logo present
REQN0002: The device should foster campus spirit and unity.

Performance Goals

REQG1: The device should be able to perform its functions without drawing any power from the power grid during days without sunlight.
REQG2: Volume of a crushed beverage container should be reduced by at least 20%.
REQG3: The weight of the device should be between 50-150lbs for deployment.

Project Plan:

Table 3 shows a sample project plan executed by one of the teams. The plan closely follows the general milestones and deliverables set by the SDC. As the teams are interdisciplinary with multiple deliverables throughout the project, superior project management plays a critical role for the success of these projects.

Table 3. Sample Team Project Plan.

Task Name	Duration	Start	Finish	Predecessors	Resource Names
Major Documents	**176 days**	**Fri 9/2/11**	**Fri 5/4/12**		
Project Capabilities & Requirements	6 days	Fri 9/2/11	Fri 9/9/11	14	Team
Statement of Work	2 days	Thu 9/22/11	Fri 9/23/11	2,14,15,16,17	Team
Project Plan	5 days	Mon 9/26/11	Fri 9/30/11	2,14,3	Brian,Chris
Progress Report #1	4 days	Tue 10/11/11	Fri 10/14/11	2,3,4,19	Team
Conceptual Design Review	3 days	Tue 10/25/11	Thu 10/27/11	20,2,3,4,5	Team
Progress Report #2	4 days	Tue 11/15/11	Fri 11/18/11	2,3,4,5,6,21	Team
Final Poster	3 days	Wed 12/7/11	Fri 12/9/11	2,3,4,5,6,7,31	Team
Final Design Package	7 days	Fri 12/2/11	Sat 12/10/11	2,3,4,5,6,7,8	Team
Project Status Review	3 days	Thu 2/23/12	Mon 2/27/12		Team
Final Senior Design Presentation	21 days	Fri 4/6/12	Fri 5/4/12	10	Mentor,Sponsor,Team
Product Design	**171 days**	**Fri 9/9/11**	**Fri 5/4/12**		
Sponsor Breakfast	3 hrs	Fri 9/9/11	Fri 9/9/11		Team,Mentor,Sponsor
Brainstorming/Idea Session	2 hrs	Fri 9/9/11	Fri 9/9/11	14	Team
Understand Customer Requirements	7.63 days	Fri 9/9/11	Tue 9/20/11	14	Team,Sponsor
Customer Meeting	1 hr	Wed 9/21/11	Wed 9/21/11	16	Team,Sponsor
Design Decision Matrix/Proposal	4 days	Thu 9/22/11	Tue 9/27/11	17,16	Team,Sponsor
Finalize Concept Drawing	9 days	Wed 9/28/11	Mon 10/10/11	16,17,18	Team
CAD Drawings	6 days	Mon 10/17/11	Mon 10/24/11		Chris,Josh,Keith
Material Selection	12 days	Fri 10/28/11	Mon 11/14/11		Team
Prototype Construction	35 days	Fri 1/13/12	Thu 3/1/12	20,21,33	Team
Protoype Demo (Customer)	1 day	Fri 3/2/12	Fri 3/2/12	22	Team,Customer,Sponsor
Design Review/Changes &Adjustments	5 days	Mon 3/5/12	Fri 3/9/12	23	Team,Mentor,Customer,Sponsor
Final Product Construction	31 days	Mon 3/12/12	Mon 4/23/12	22,24,23	Team
Testing/Implementation	9 days	Tue 4/24/12	Fri 5/4/12	25	Team,Sponsor
Financial	**171 days**	**Fri 9/9/11**	**Fri 5/4/12**		
Budget Assessment	35 days	Fri 9/9/11	Fri 10/28/11	14	Team,Mentor
Initial Bill of Materials	33 days	Mon 10/17/11	Wed 11/30/11	6,21	Team,Mentor
Initial Budget Review	4 days	Thu 12/1/11	Tue 12/6/11	30	Team,Mentor,Customer
Final Budget Review	4 days	Wed 12/7/11	Sat 12/10/11	31	Team,Mentor
Create Purchase Order	8 days	Tue 1/3/12	Thu 1/12/12	32	Mentor,Team

Monthly Budget Reviews	82 days	Thu 1/12/12	Fri 5/4/12		Brian,Customer,Mentor,Sponsor
General	**171 days**	**Fri 9/9/11**	**Fri 5/4/12**		
Weekly Team/Mentor Meetings	171 days	Fri 9/9/11	Fri 5/4/12		Team,Mentor
Bi-Weekly Sponsor Meetings	171 days	Fri 9/9/11	Fri 5/4/12		Team,Sponsor

<u>Conceptual Designs:</u>

Each team was tasked to come up with conceptual designs to achieve the project objective. It was interesting to see that the teams took different approaches as they developed conceptual alternatives. CGI BOT1 team quickly figured out that they want to develop a "plinko" game for the interaction and they came up with three variations of their design as shown below in Figure 4.

1. Plinko (Non-Automated)
2. Plinko (Fully-Automated)
3. Plinko (Alternate Non-Automated)

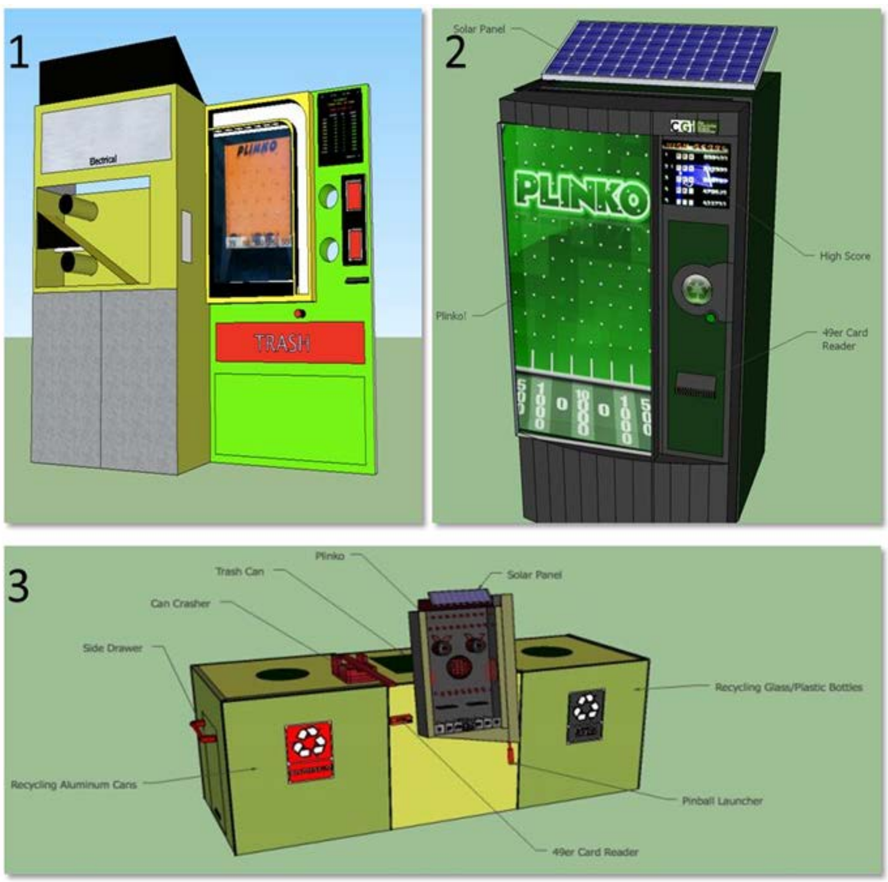

Figure 4. Conceptual Design by CGI_BOT1

The team did a decision analysis to compare each design alternative as shown in Table 4. While Design 1, which is Non-Automated Plinko came slightly ahead, the team ended up doing a combination of design alternatives 1 and 2 to leverage the benefits of both designs.

Table 4. CGI_BOT1 Decision Matrix for Selecting Best Design

Criteria	Weight	Design 1	Design 2	Design 3
Fun Factor	0.075	8	7	7
Portability	0.075	7	7	6
Self Powered	0.2	8	8	8
Capacity	0.075	7	8	9
Serviceability	0.2	9	8	10
Sorting	0.05	7	9	5
Recycled Materials	0.05	7	7	8
School Spirit/Branding	0.2	8	8	6
Resistance to Vandalism	0.075	8	8	5
Score		7.95	7.85	7.475

CGI_BOT2 team came up with four innovative designs as shown in Figure 5. It was interesting to see that both teams considered "plinko" game. It was suspected that both may select the plinko design but after each team evaluated their alternatives, it turned out that CGI_BOT2 team favored the "field post" design which resolved the potential conflict (Table 5).

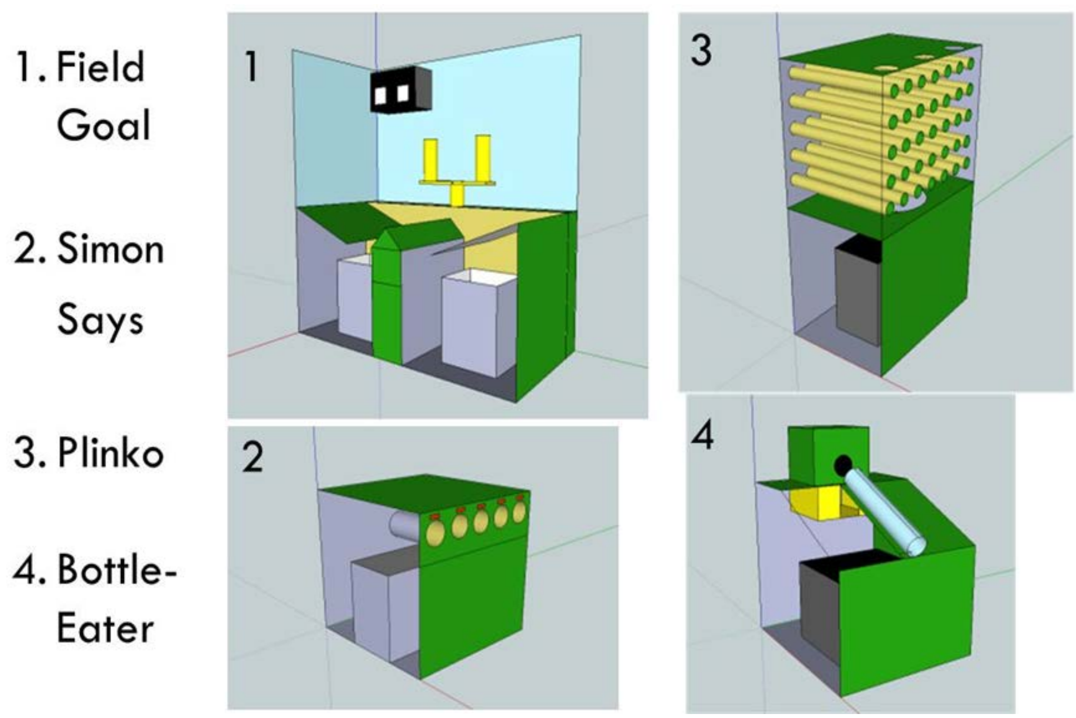

Figure 5. Conceptual Design by CGI_BOT2

Table 5. CGI_BOT2 Decision Matrix for Selecting Best Design

Design Requirement	Weight	Field Goal	Simon Says	Plinko	Bottle-Eating Face
Interactive	18%	5	4	2	3
Cost	18%	3	3	5	3
Capacity	14%	5	3	5	5
Location	11%	5	5	5	5
Portability	11%	3	3	4	3
Maintenance	14%	5	5	5	5
Mistake Proof	11%	4	3	3	1
Bottle Separation	4%	5	5	5	5
Total	100%	4.36	3.79	4.18	3.67

<u>Final Designs:</u>

The teams created prototypes for their design and demonstrated in the senior design expo at the end of Spring 2012 (Figures 6 and 7). Both teams were selected among the nine finalists (out of 53 teams) in the design competition.

Figure 6. Final Design by CGI_BOT1

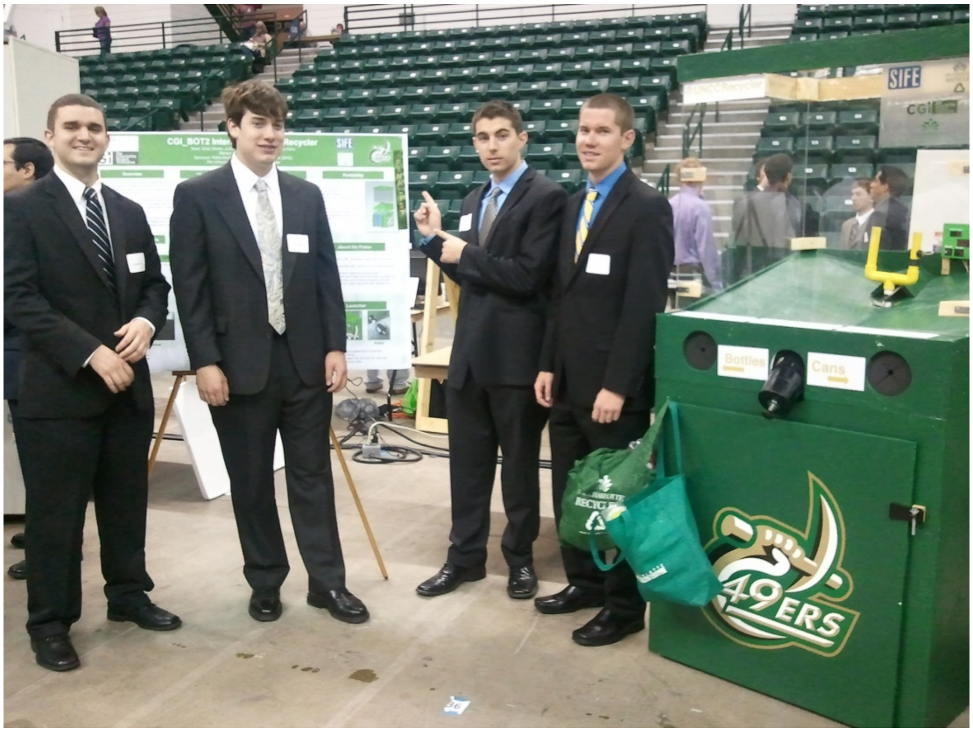

Figure 7. Final Design by CGI_BOT2

Summary & Conclusions

These projects were possible due to a confluence of organizations and programs in place at UNC Charlotte. An existing capstone design program was already in place, which provided a platform for project realization and student involvement in a structured way. A campus sustainability campaign and organization was also in place, providing a cultural impetus along with a funding source for support of the project. Perhaps most importantly, there were faculty in place who had the desire to do sustainability projects, the bandwidth to accommodate undergraduate research projects and the academic program in place to support this activity. Similar infrastructure should be in place if one seeks to implement sustainability projects into an existing curriculum.

Some of the major lessons learned are summarized below:

- Keep it simple: There was a big contrast between the two teams who participated in the "interactive bottle recycler" project. One of the teams wanted to satisfy all requirements for the customer (including lower priority requirements such as sorting of cans and bottles) which meant a more complex design. The other team focused on high priority items for the customer which resulted in a less complex design. Simplification brought benefits of reducing costs, decreasing design failure, and easier maintenance of the end product.

- Listen to your customer: Both teams listened to the customer really well but differed in the execution. Again one of the teams wanted to include all bells and whistles into their design to mainly showcase their engineering skills while satisfying all customer requirements. The other team did focus on high priority items. Both teams finished within budget but one team came up with a significantly lower cost design (almost 1/3rd of the cost of the other team).
- Conflicts: In this case the sponsor wanted each team to come up with different designs but there was a chance for them to select a similar concept during the conceptual design phase. In this case, each team initially considered "plinko" concept but selected different final designs. These two teams were not restricted initially but at the final selection phase an interference may be necessary to resolve potential conflicts if the end designs are desired to be different.
- Communication: It is very important for the mentors to emphasize the value of communication to each team constantly. One of the teams was superior in communication which showed in their success. The other team which did not communicate as effectively had difficulties to bring the end product together.
- Time management: Students often misjudge the amount of time necessary for building a realization of their project, resulting in insufficient time being allocated for testing and revision of the design concept to satisfy original requirements. Deadlines for hardware demonstration should be included that force the students to schedule their build to allow time for verification testing.

References

[1] Our Common Future, Report of the World Commission on Environment and Development, World Commission on Environment and Development, 1987. Published as Annex to General Assembly document A/42/427, Development and International Co-operation: Environment, August 2, 1987

[2] The Fun Theory, An Initiative of Volkswagen, Retrieved on 12/19/12 from URL: www.thefuntheory.com

[3] Galambosi, A. and Ozelkan, E. C.,, Integrating Sustainability into Systems Engineering Curriculum,, Proceedings of the American Society for Engineering Education (ASEE) Annual Conf. & Exposition, Vancouver, Canada, June 26-29, 2011.

[4] Lockette et. al., Research Experiences in Pollution Prevention and Sustainability, Proceedings of the American Society for Engineering Education (ASEE) Annual Conf. & Exposition, Chicago, Illinois, June 18-21, 2006.

[5] Burian, S., Teaching Sustainability and Sustainable Engineering Practice in the Civil Engineering Curriculum, Proceedings of the American Society for Engineering Education (ASEE) Annual Conf. & Exposition, Louisville, Kentucky, June 20-23, 2010.

[6] Ogden, K., Ogden, G., Incorporation of Sustainability Concepts into Traditional Chemical Engineering Education, Proceedings of the American Society for Engineering Education (ASEE) Annual Conf. & Exposition, Honolulu, Hawaii, June 24-27, 2007.

[7] Zhang, Q., Challenges for Integration of Sustainability, Engineering Education Proceedings of the American Society for Engineering Education (ASEE) Annual Conf. & Exposition, San Antonio, Texas, June 10-13, 2012.
[8] Crofton, F.S., (2000), Educating for sustainability: opportunities in undergraduate engineering Journal of Cleaner Production 8, 397–405
[9] McDonald, C., (2006), Moving forward on educating for sustainability in Manitoba, Journal of Cleaner Production 14.
[10] Boks, C. and J.C. Diehl, (2006), Integration of sustainability in regular courses: experiences in industrial design engineering, *Journal of Cleaner Production* 14, pp. 932–939.
[11] Porter, T. & Córdoba, J., (2009), Three Views of Systems Theories and their Implications for Sustainability Education, Journal of Management Education, Volume 33 Number 3, 323-347.
[12] Lynch-Caris, T, & Sutherland, J.,(2010), Industrial Engineering: Ideally Positioned to Address the Sustainability Challenge, American Society for Engineering Education,
[13] Kumar, V., Haapala, K.R., Rivera, J.L., Hutchins, M.J., Endres, W.J., Gershenson, J.K., Michalek, D.J., Sutherland, J.W. , (2005) Infusing Sustainability Principles into Manufacturing/Mechanical Engineering Curricula, Journal of Manufacturing Systems, 24(3).
[14] PR Newswire, DDB's Fun Theory for Volkswagen Takes Home Cannes Cyber Grand Prix, Retrieved on 12/19/12 from URL http://www.prnewswire.com/news-releases/ddbs-fun-theory-for-volkswagen-takes-home-cannes-cyber-grand-prix-97156119.html
[15] Ozelkan, E. C. and A. Galambosi, 2009, Lampshade Game for Lean Manufacturing, Production Planning and Control, 20(5), 385-402
[16] Koster, R. A Theory of Fun for Game Design, Paraglyph Press, 256 pp.
[17] DDB, Doyle Dane Bernbach Worldwide Communications Group Inc., www.ddb.com.
[18] AASHE, Association of Advancement of Sustainability in Higher Education, https://stars.aashe.org.