



Enabling Institute-wide Multidisciplinary Engineering Capstone Design Experiences

Dr. Amit Shashikant Jariwala, Georgia Institute of Technology

Dr. Jariwala is the Director of Design & Innovation for the School of Mechanical Engineering at Georgia Tech. He graduated with a Bachelors Degree in Production Engineering from the University of Mumbai, India with honors in 2005 and received Masters of Technology degree in Mechanical Engineering in 2007 from IIT Bombay, India. He was awarded a Ph.D. in Mechanical Engineering from Georgia Tech in 2013, with minors in Entrepreneurship. Dr. Jariwala has more than nine years of research experience in modeling, simulation, engineering design, and manufacturing process development, with research focus on design of polymer based micro additive manufacturing process. During his Ph.D. studies, he was also a participant of the innovative TI:GER® program (funded by NSF:IGERT), which prepares students to commercialize high impact scientific research results. Dr. Jariwala has participated and led several research projects from funded by NSF, the State of Georgia and Industry sponsors. At Georgia Tech, he is responsible for enhancing corporate support for design courses, managing design and fabrication/prototyping facilities, coordinating the design competitions/expo and teaching design courses, with a strong focus on creating and enabling multidisciplinary educational experiences.

Sarvagya Vaish, Computer Engineering, Georgia Institute of Technology

Dr. David W. Rosen, Georgia Institute of Technology

Enabling Institute-wide Multidisciplinary Engineering Capstone Design Experiences

Abstract

The final culminating Capstone Design course provides students the opportunity to work in teams and apply their knowledge to design, build and test prototypes for solving real-world, open-ended design challenges. Several research studies have shown both qualitative and quantitative advantages for students by working on multidisciplinary Capstone Design projects. All schools within various colleges of the Institute currently only offer the traditional mono-disciplinary Capstone Design course and hence there exists no formal channel for students to collaborate and work together on multidisciplinary Capstone Design projects.

In the absence of a common multidisciplinary Capstone Design course, the transition from traditional mono-disciplinary Capstone Design course raises issues of managing faculty teaching expectations, providing administrative support to faculty and student teams and forming multidisciplinary functional student teams. In order to assist with resolving these issues, an online portal was developed to support the implementation of multidisciplinary Capstone Design projects. Faculty and student feedback was solicited in order to conceptualize and develop the website to support the entire process of student team formation, sharing of multidisciplinary project ideas across schools and making student-team assignments. This paper presents the design of this web portal along with a discussion on the scope for further improvement.

Keywords

Multidisciplinary, capstone design, senior design, online portal

Introduction

Capstone Design Course is offered as a project based culminating course in many undergraduate engineering programs. It is an integrative course where senior-standing engineering students synthesize solutions to “real world,” open-ended engineering problems¹. Students taking Capstone Design course in various Schools within the College of Engineering (CoE) showcase their projects at the end-of-semester Institute wide Capstone Design Expo. Traditionally, at Georgia Institute of Technology, the course is offered mono-disciplinarily within each School with the exception for a special section comprising of few students who participate in the joint Capstone Design course offering between School of Mechanical Engineering (ME) and School of Industrial Design (ID).

Several past research studies²⁻⁴ have shown the positive impacts of multidisciplinary Capstone Design experiences. Most design challenges in industry are solved by multidisciplinary teams, and thus multidisciplinary projects provide a more realistic engineering experience for engineering students⁵. In order to enable multidisciplinary Capstone Design experiences, there are several logistical challenges to be overcome by faculty and students⁶. This paper presents a brief overview of the design of an online portal which assists with efficient information transfer between students and faculty and helps in enabling an Institute-wide Multidisciplinary Capstone Design.

Although unique for Georgia Tech, an online marketplace for multidisciplinary Capstone Design projects is not completely unique. A marketplace for multidisciplinary multi-university Systems Engineering Capstone projects has been presented earlier by Ardis et al.⁵. The authors clearly presented the need and requirements for a marketplace primarily for sharing information on project ideas to faculty and students. However, the marketplace did not assist in teams formation,

or making project-team assignments based on student interest. The design presented in this paper is the only known available design to the authors which truly alleviates the logistical burden of sharing information about projects, forming teams, accepting bids and awarding projects to the teams – all through one single website, with little to no faculty involvement.

Need for an online project portal

During Spring 2013, the Associate Dean for Academic Affairs at the College of Engineering (CoE) at Georgia Tech invited faculty and administrators from various schools within the College to collaboratively discuss possible pathways for developing a CoE or Institute-wide Capstone Design program. The faculty discussed several challenges, ranging from differences in curriculum requirements for individual schools, incompatibility between Schools having multi-semester Capstone Design sequence v/s a single semester, adequate scoping of projects, faculty load-sharing, etc. (some of which were similar to the ones already presented by Bannerot et al.⁶). Given the extremely large enrollments (around 800 students take Capstone Design every semester within CoE) and the other administrative challenges, it was decided that an Institute-wide Capstone Design Course (GT4823) be first offered by the School of Mechanical Engineering (ME) as a special topic substitute for traditional Capstone Design Course (ME4182) to a limited number of students. Other Schools could gradually “join-in” by allowing the GT4823 special topics course to be a substitute to their traditional Capstone Design or Senior Design course. In order to support the formation of multidisciplinary Capstone Design teams, it was found necessary to develop an online portal which would allow faculty and students to view and post project ideas.

Interestingly, there was yet another motivation within the School of ME, which provoked the development of an online project marketplace. The traditional Capstone Design course within ME is taught by 6-9 faculty members, each mentoring a section of around 30 students. For more than five years, the faculty teaching Capstone Design in ME has also been soliciting industry projects. Every semester, there were about 20 sponsored projects which have to be assigned to student teams. For the first week of class, students are under high pressure to form teams, look at project ideas and submit their ‘bids’, elaborating on the group’s skills and motivations to work on the project, to their respective faculty section instructor. The faculty team then compiles the priorities from each team and coordinates this information with other faculty to decide which team would be awarded the bid. This entire manual process of project-team assignment had the following drawbacks:

1. Too much burden on faculty to compile the necessary information from their students and share with other faculty (section instructors)
2. Narrow window of opportunity for students to learn about projects, form teams and submit their projects bids
3. Logistical issues involved with matching teams and projects. The process was cumbersome and not transparent to students. This would often lead to lack of motivation.

In order to aid the process of making project-team assignments and to support the realization of multidisciplinary Capstone Design projects from across schools, the Office of the Director of Design & Innovation (DDI) in the School of Mechanical Engineering launched an internal web portal development project. A multidisciplinary student team comprising of juniors and seniors

from the College of Computing, School of Electrical and Computer Engineering, School of Mechanical Engineering and the School of Industrial and Systems Engineering was assembled to develop the online portal.

Portal Concept and Design

The student team interviewed faculty and students to define the user needs for the two constituencies and conceptualized the work flow. The following requirements were identified:

1. Faculty, students and external users should be able to *submit* project ideas.
2. Faculty and students should be able to *view* all accepted projects for a particular semester along with information on which School's participation is necessary for any given project.
3. Faculty in-charge of a specific section should be able to *approve or reject* projects within their sections. For example, a faculty in a particular school was not keen on mentoring student teams working on multidisciplinary projects that would involve a specific discipline/school.
4. Students should be able to *form teams*, invite other students to their teams and *submit 'bids'* with priorities for projects of their choice.
5. Faculty should be able to view all teams within their section as well as their submitted bids
6. All students should be able to view how many bids have been submitted for a specific project. This would help them refine their 'bids' in case they believe that they deserve the project more than another team.



Figure 1 Screenshot of the homepage for the online portal

Since the site, (screenshot as shown in Fig. 1) and available online at <http://capstone.design.gatech.edu/>, was to cater towards a primarily Georgia Tech affiliated audience, the site's navigation and appearance was made consistent with other Institute's websites. The site was implemented using the Ruby-on-Rails web development framework. The overall portal design can be described into three major phases – project submission, team formation and making project-team assignments.

Project submission and approval

The portal needs to be first *activated* by the website administrator (currently the DDI) by creating semesters, sections and assigning faculty to each section. Once activated, the site starts building a database of users and projects as they are submitted.

An external sponsor can visit the site to learn about the course, review past projects, read about NDA/IP policy and submit project ideas. The project form asks for the typical design project problem, overall requirements, design constraints, and contact information. It also provides an option for the sponsor to check if they need an NDA (Non-Disclosure Agreement) to protect specific project related confidential details. As per the Institute's Intellectual Property (IP) policy, which is typical of most other engineering institutes, the students own the IP that they create during the course of working on their Capstone Design project. Students are free to negotiate their IP with the sponsors at the end of the project. This situation is not favorable for most entrepreneurial sponsors and they typically request to have their project offered to only those students who are willing to assign their IP to the sponsors. The students have to be made aware of such a requirement prior to them accepting to work on the project. When external users submit projects, they have an option to check if their project is only made open for students willing to negotiate IP assignment with the sponsor.

Several research faculty members consider Capstone Design course as a means to 'hire' a team of undergraduate designers for building automated systems to help advance their lab research. Often research faculty would offer design project ideas for the course which would help them advance their industry partnerships. At Georgia Tech students are also encouraged to utilize the course as a means to foster their own entrepreneurial spirit. Students have the freedom to work on an innovative project of their own choice, as long as it satisfies the course requirements (which are determined by the faculty instructor). Few students in the past have launched successful companies by further refining their Capstone Design course projects. To enable faculty and students to pitch their own ideas to the class, the website allows Institute affiliated users (faculty, staff and students) to submit their project ideas by simply logging into the site using their Institute official email credentials (which is based on Central Authentication Service – CAS). Using CAS eliminates the need for the users to reenter their contact information and makes it easier for other users of the site to quickly identify if the project is submitted by internal faculty/student or an external sponsor. Projects submitted by any user – external or internal arrive on the Projects' workflow for the site administrator.

The Capstone Design course (or Senior Design) is one of the most important elements for the development and assessment of student professional competencies for ABET accreditation. The overall project scope places heavy emphasis on whether or not the course project allows for satisfactory assessment of the student outcomes. Specifically, the project scope should be broad enough to allow students from the participating schools/disciplines to learn and demonstrate their knowledge to meet ABET Engineering Criterion 3⁷ – student outcome 3.a); identify discipline specific engineering requirements for design (to meet ABET Engineering criterion outcome 3.c) and provide opportunities to identify, formulate and solve engineering problems (to meet ABET Engineering criterion outcome 3.e) relevant to their specific disciplines. The rest of the students

outcomes are generic and not discipline specific within Engineering and hence do not significantly impact the project selection process.

Figure 2 shows the overview of the project submission and approval process for multidisciplinary projects. As mentioned earlier, project ideas can be initiated either from external sponsors (industry/entrepreneurs) or internal (faculty/students). Usually, external sponsors have specific requirements and expectations, which might not be within the scope of the Capstone Design course. Finding a good balance between solving a real-world industry need and meeting the curriculum requirements is necessary for successful industry-academia partnership for Capstone Design. The administrator (DDI), in consultation with faculty coordinators of relevant Engineering Schools review the submitted projects and revise the project scope to make sure that the project is of adequate scope. The administrator specifies the schools for which the project is most suitable for and the project then moves over to faculty and student users from the specified schools.

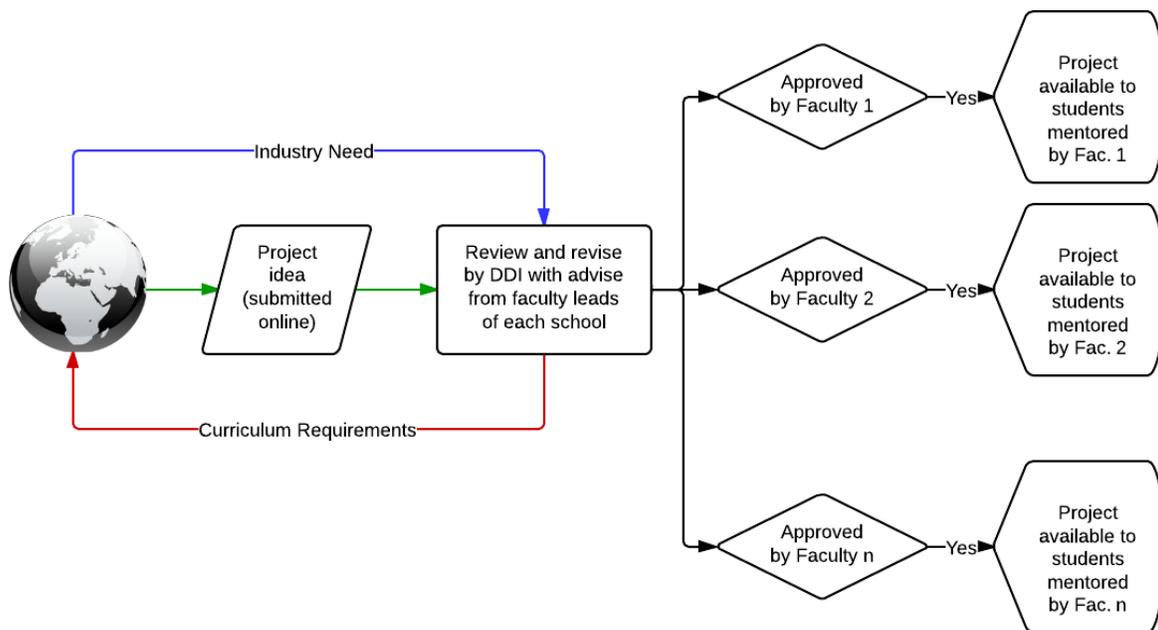


Figure 2 Overview of project submission and approval process

The project can be viewed by faculty and students associated with the schools that it has been made available for. The authors have experienced in the past that, especially for multidisciplinary Capstone Design projects, some faculty members are not comfortable in mentoring projects related to a specific industry or a school. Hence, faculty in-charge of a specific section has the option to *reject* projects within their sections. All projects accepted by the administrator are considered *approved* by default to eliminate additional workload on faculty. Figure 3 shows the view of the Project's page for a typical faculty. As shown, all projects accepted by the admin are approved by the faculty as default. They have the option to reject a specific project if they wish. Doing so would make the project unavailable to the students registered in the faculty's section, and hence they will be unable to bid for the project.

Welcome Ken Cunefare

PROJECTS

Viewing site details for: Spring 2014

All Available

QUICK LINKS

- Projects
- Groups
- My Profile

Note: If you are unable to view any projects, please switch to another semester and then switch back using the dropdown on the left.

Suggested School: Required School: *

Project Name	Available Schools								Status
	ECE	ID	ME	BME	ISyE	MSE	AE	CSE	Status of Bids
Wearable Bicycle Lock – Form meets Function meets Fashion			*						Approved
Washroom Trash Compactor			*						Approved
Bautamon			*						Approved
Floating Platform			*						Approved
Develop a novel application for the TANGO Autonomous Lawn Mower			*						Approved
Wine chiller, aerator & pourer			*						Reject
Novel Application for Dual Cool Jet Technology			*						Approved
IMF System			*						Approved

Figure 3 Projects' View for Faculty

Team Formation

When students login the site for the first time, they have to fill in their profile information which includes the semester in which they will be taking the Capstone Design course, their majors (school like ME, BME, AE, ECE, etc.) and the section of Capstone Design course that they have registered for. Students have options to view existing projects, submit their own project ideas, join existing groups and/or create their group. Only after they form a group, can they submit bids for any projects. If a particular student is interested in working on a project, he/she could form a single member team and submit a bid for a project. The bid can include details like their individual skills, expertise, co-op/internship experience and their interest to work on the project while ranking their interest levels. Figure 4 shows the typical view of the Project's page for a student. As shown, the student can view the projects that need his/her school's participation, as well as the number of submitted bids for the projects. The green icon shows that the student's team has submitted a bid for the project, whereas the yellow icon indicates that the student can submit a bid for the project on behalf of his/her group. A team can submit as many bids as they wish. All students, faculty and administrators can view the submitted bids and students can revise their submitted bids up until the deadline (typically by end of first week of the semester). This transparent view of the submitted bids allows students to learn from each other on how to submit stronger bids to enhance their chances to *win* the project.

Welcome Brian [REDACTED]
 Capstone Semester:
 Spring 2014
 Your Section: ME4182-F
 (Cunefare)
 Your Group: Test

PROJECTS

[Submit A New Project](#)

All Available

Viewing site details for:
 Spring 2014

Note: If you are unable to view any projects, please switch to another semester and then switch back using the dropdown on the left.

QUICK LINKS

- Projects
- Groups
- Project Bids
- My Profile

Suggested School: Required School: *

Project Name	Available Schools								Status
	ECE	ID	ME	BME	ISyE	MSE	AE	CSE	
Wearable Bicycle Lock – Form meets Function meets Fashion			*						0
Washroom Trash Compactor			*						1
Bautamon			*						0
Floating Platform			*						0
Develop a novel application for the TANGO Autonomous Lawn Mower			*						0
Wine chiller, aerator & pourer			*						0
Novel Application for Dual Cool Jet Technology			*						0

Submit new Bid

Figure 4 Projects' View for Students

One of the challenges in assembling an institute-wide multidisciplinary Capstone Design team, which spans across various schools, is that the students are unaware of the skills and expertise of the students from other schools. Given the time constraints of forming a team within the first week of the semester, students often do not have adequate time to know their potential team members. This problem can potentially be resolved by having a pre-capstone course or a common meeting. However, given the extremely large enrollments, an additional pre-capstone course is administratively challenging and having in-person meetings might not be productive.

The online portal also supports the formation of multidisciplinary teams. Figure 5 shows the typical view of the Group's page for a student. As shown, the student can view the existing groups and can choose to either join an existing group or create a new group. The screenshot shows the popup window showing the details of the submitted bid by the "test" group. Since, all students can view existing teams and the team bids, they can decide if they might be a good fit to join the group or not and send a request to join the group. Group members can also invite students into their group by entering their login username. Upon joining, the new student member can edit/update the submitted bid to reflect the renewed strength of the team to work on the project based on the addition of the new team member.

Welcome CapstoneTest_Student
 Capstone Semester: Spring 2014
 Your Section: GT4823-A(BME)

MANAGE GROUP SETTINGS

You are currently not a member of any group. You are viewing groups for Spring 2014

QUICK LINKS

- Projects
- Groups
- Project Bids
- My Profile

Join an existing group

Other Groups

- [Pcmkjb](#) Request Invite
- [Lub Dub](#) Request Invite
- [Test](#) Request Invite

Create a new group

name of group

Group Details

Name: **Test**

Members: Mark Trinquero

Bids: [Bid for Wearable Bicycle Lock – Form meets Function meets Fashion by Test](#)

Figure 5 Groups' View for Students

Project-team assignments

Once all the bids from all teams are received, they are sorted and presented in form of a matrix of team names and project titles indicating the priorities ranks specified by the teams as shown in partial Table 1 (from Fall 2013 data). The top row, E1, E2, etc. indicates the project code and the numbers indicate the team preferences. For instance, Team, 'Capston E' submitted their first choice to work on project, 'E8' followed by their second choice to work on project, 'E20' (not shown), then project 'E3' as third choice and 'E12' as their fourth choice.

Table 1 Compiled matrix showing the priorities as submitted by teams for projects

1 Team Names	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14
2 Capston E			3					1				4		
3 Dream Team			1											
4 G4						4		2						
5 G5									2					
6 G6				2		1		4						
7 K.I.D.S.	1								2					
8 Carnell4														
9 Star Tech														
10 Team 1														
11 Team 6														
12 The Best Group							8	1		7	6			
13 Yolo Jackets							2							
14 Absolute Zero							2	3						
15 Lunch Break			1					2						
16 Raising The Bar			3					2						
17 Team 4				6		3		7				4		
18 Aaa							4		2					
19 Bionic Glove	1													
20 Buzzed			6	2		1		3						5
21 Fft			4			3				5		6		
22 Go Jackets						1		2	6					5
23 Last Semester				1				3						4
24 Tbd				6		1		7						4
25 Tech Team 6			2	4		5		3						7
26 Ftw			1					2				3		

Table shows how student interest for few projects listed as E1-E8 (which were sponsored by large companies which are typical employers for undergraduates) was highly skewed compared to others. Interestingly, the team working on the most popular project, 'E8' also ended up winning the grand prize at the end of semester design expo.

The faculty will typically try to assign the project to the team that has listed a project as its top priority choice. In case of a conflict, the bids will be reviewed to compare the strengths and weaknesses of the competing team and appropriate assignments are made at a common meeting including all section instructors.

Experience and Outcomes

At the onset of the Fall 2013 semester, the beta version of this portal was made available to seniors taking Capstone Design in ME, ECE and BME. Three online presentations (on prezi.com) were designed and shared on the homepage to guide the users to easily navigate through the site and accomplish their task. During the first week of its launch, the site was actively used by around 300 students across campus, all of which were seniors interested in working on Capstone Design projects⁸.

A total of 34 sponsored projects and 19 student project ideas were accepted into the Capstone Design program using the site. 30 mono-disciplinary (mostly ME) and 10 multidisciplinary Capstone Design teams were assembled using the online portal. Most of the multidisciplinary projects were either between ME and ECE or ME and BME with an exception of one ME/BME/ECE team. In all a total of 49 students from the Schools of ME, BME and ECE were able to participate in a multidisciplinary Capstone Design experience in the Fall 2013 semester. A few of these exciting multidisciplinary projects included an assisting robotic system for the human hand, an autonomous lawn mower, a gesture-based automotive user interaction environment and a rapid yet accurate full-vehicle metrology system, most of which were sponsored by corporate partners or local entrepreneurs. Table 2 shows the matrix of multidisciplinary projects with participating student disciplines for each.

Table 2 Table showing the descriptions of multidisciplinary projects and the participating student disciplines

Project/Team Name	Project Description	Team Composition
Last Minute Guinea Pigs	During its manufacturing process, glass is heat treated then cooled. As the glass cools, differences in cooling rates can cause bowing in the glass. The project was to develop a new way to accurately measure the bow to a tolerance of 1/32 inch per linear foot of glass.	3 ME, 2 ECE
Team FFT	Designed and prototyped an edger system for the John Deere TANGO autonomous lawn mower	3 ME, 2 ECE
Team AAA	Designed and built a measurement system to measure the outer dimensions of golf cart sized vehicles.	3 ME, 1 ECE
Team Buzzed	Project was to design and prototype an automated, self-contained, and user-friendly brewing device that accurately controls the temperature of the fermenting process, creating a high quality home-brewed lager at low cost.	5 ME, 1 ECE
License to Chill	A rapid refrigeration system to cool beverage drinks within a minute using forced convection cooling.	4 ME, 2 ECE

Electric Drive Team	Designed an electric drive control system for a multi-motor vehicle with independently driven wheels that can be used as a platform to test an electric car's differential drive function.	2 ME, 3 ECE
Inovein	Our device aids nurses in placing needles into neonatal infants for IV line installation and blood draws.	1 ME, 1 ECE, 3 BME
K.I.D.S. (two sub-teams)	Design and prototyping of cybernetic exoskeleton to assist injured and disabled patients (with muscle atrophy) to perform normal functions while still being able to utilize their partially functioning arm	5 ME, 3 BME, 1 ECE
Infotainment I/O	Design of a system to reduce driver distraction while providing the flexibility to operate a tablet/navigational system. Simulation of car interior, dashboard, windshield and steering wheel.	2 ME, 2 ECE

Industry sponsors provided tremendous support (financial and technical mentorship) for the initiative and were hugely appreciative of the student results. Such positive experiences certainly help the participating schools to continue to build stronger support and potentially receive more projects for future semesters. Students and faculty overwhelmingly appreciated the simple, minimalistic and clutter-free design of the portal. Few students suggested embedding more in-depth team formation tools within the site. With the growth of social networking and online collaboration and profile sharing platforms like Facebook, Google+, LinkedIn, etc. it is unlikely that adding team forming tools would remain a frequently requested feature. Of interest is the recently released online portfolio network, Seelio.com. This platform allows students to easily and beautifully document their skills, work experience, projects, and passions⁹. The Seelio.com platform seems to be tightly integrated with commonly known social networking websites. Students can potentially use such a platform to find potential team members, learn about their background, expertise and form multidisciplinary teams.

Future Features

Currently, the web portal is managed and operated by the School of ME. A single administrator approves all external projects ideas with consultation and coordination from faculty in all participating schools. This burden of coordination among different schools can be distributed by creating a *capstone coordinator* role within the site, for each School (within Engineering and outside like Industrial Design, Computer Science, etc.). Assigning such a role to at least one faculty from each school would allow them to accept suitable projects directly from the web-portal. Although the back-end design of the site is quite developed and robust, the front end views need to be made more user-friendly. The above mentioned features are slated to be added as part of a Capstone Design project for students in the College of Computing within Georgia Tech in future semesters.

Conclusions

Despite its well-known advantages for student learning, enabling multidisciplinary Capstone Design experiences across traditionally divided silos of Engineering is difficult and quite challenging. One of the challenges arises from the additional logistical burden on supervising faculty for sharing project ideas, forming teams between students across schools and making team assignments. An online portal, which enables open and transparent sharing of project information, makes the process simpler. An easy to use interface, minimalistic, yet functional design and helpful online presentations for different user groups are keys to successful

implementation of an online project management portal. We hope that the simple to use online platform continues to encourage students and faculty from different disciplines within Georgia Tech to work together on real-world true multidisciplinary Capstone Design projects. The design team is continually working on improving the user experience for all the three user groups – external sponsor, faculty and students to reduce the logistical burden.

Acknowledgements

The creation and development of the institute-wide portal would not have been possible without the help of the student web developers: Sarvagya Vaish (BS CMPE'13), Jasmine Lawrence (BS CS'13), Mark Trinquero (BS ISyE'13), Eli Cooper (Computational Media Senior) and Lindsay Dady (ME Senior). Thanks also to the helpful staff from the Office of Information Technology (OIT) at Georgia Tech, Jason Belford, Jimmy Lummis, Peter White and IT staff from the School of ME and Georgia Tech OIT: Asu Ogork, Marlena Frank, Mark Juliano and Kurt Nelson. The portal development project was funded by the Office of the Director of Design & Innovation at Georgia Tech with additional support from our generous corporate sponsors: John Deere, Ford, Caterpillar, Lockheed Martin, Bechtel, NCR, Rolls Royce, Whirlpool, Eaton's Cooper Lighting, National Instruments, Integrated Environmental Services, E-Z-Go, Textron, Jacobsen, Coca-Cola, Formetco, Delta, Michelin, Autodesk, Angelica, Southern States, Medtronic, TriVantage, Boeing, Pratt & Whitney, Viracon, Weyerhaeuser, Shell, BP, Panasonic, DKF Investments, CyborFusion, VinoSpout, HarrellNut Company, General Motors, General Electric, and American Fiber Packaging.

References

- [1] C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering Design Thinking, Teaching, and Learning," *Journal of Engineering Education*, vol. 94, no. 1, pp. 103-120, 2005.
- [2] N. Hotaling, B. B. Fasse, L. F. Bost, C. D. Hermann, and C. R. Forest, "A Quantitative Analysis of the Effects of a Multidisciplinary Engineering Capstone Design Course," *Journal of Engineering Education*, vol. 101, no. 4, pp. 630-656, 2012.
- [3] R. L. Miller, and B. M. Olds, "A Model Curriculum for a Capstone Course in Multidisciplinary Engineering Design," *Journal of Engineering Education*, vol. 83, no. 4, pp. 311-316, 1994.
- [4] J. T. Allenstein, B. Rhoads, P. Rogers, and C. A. Whitfield, "Examining the Impacts of a Multidisciplinary Engineering Capstone Design," in 120th ASEE Annual Conference and Exposition, Atlanta, GA, 2013.
- [5] M. Ardis, E. Hole, and J. Manfredonia, "Creating a Marketplace for Multidisciplinary Multi-university Systems Engineering Capstone Projects," *Procedia Computer Science*, vol. 16, pp. 1036-1042, 2013.
- [6] R. Bannerot, R. Kastor, P. Ruchhoeft, and J. Terry, "Challenges and Solutions in Developing a Three Department Interdisciplinary, Capstone Design Course at the University of Houston," in International Conference on Engineering Education, Gainesville, Florida, 2004.
- [7] "Criteria for Accrediting Engineering Programs," last accessed 12/31/2013, 2013; http://www.abet.org/uploadedFiles/Accreditation/Accreditation_Process/Accreditation_Documents/Current/eac-criteria-2012-2013.pdf
- [8] A. Chandak. "Tech student body integrates for capstone," 12/31/2013, 2013; <http://niquie.net/life/2013/09/12/tech-student-body-integrates-for-capstone/>.
- [9] "What is Seelio?," 12/31/2013, 2013; <https://seelio.com/about-us>.