12-2015

A Retrospective Study of the Motivations and Perceptions of Industry Sponsors and Academia Regarding Mechanical Engineering Capstone Design Program

Varun Rawal
Clemson University

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A RETROSPECTIVE STUDY OF THE MOTIVATIONS AND
PERCEPTIONS OF INDUSTRY SPONSORS AND ACADEMIA
REGARDING MECHANICAL ENGINEERING CAPSTONE DESIGN
PROGRAM

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Mechanical Engineering

by
Varun Rawal
December 2015

Accepted by:
Joshua D. Summers, Committee Co-Chair
Gregory Mocko, Co-Chair
Oliver Myers, Co-Chair
ABSTRACT

The overall goal of this research is to understand and explore the motivation and value that industry gains from sponsoring senior year capstone design projects in the Department of Mechanical Engineering at Clemson University. Further, this research compares the true value as defined by the sponsoring companies against the perceived value of the faculty recruiting these projects. It compares the thoughts between the faculty members of the capstone program for the Department of Mechanical Engineering at Clemson University and the company sponsoring those projects. This can help the faculty in dealing with the company sponsors when soliciting new projects.

Capstone design program is a bridge that improves the industry-academia relations. It is important to understand the requirements of the industries and what they expect from the undergraduate students as the companies are important customers of the academia. While sponsoring the projects companies have certain expectations, in order to improve the capstone design program it important to know these needs and try implementing in later years. The thesis also investigates the faculty members in the Department of Mechanical Engineering at Clemson University in order to discern the perceptions of faculty that recruit the project for the senior year undergraduate program.

This research uses interviewing as a method of data gathering to explore the perceptions of the faculty and company sponsors regarding the capstone design program. There are three research questions used as a basis to conduct the interviews. Ultimately, the thesis presents a retrospective view of the impact of capstone design projects in
Department of Mechanical Engineering at Clemson University since 2004. The thesis concludes with suggestions to improve the capstone design program.
DEDICATION

This thesis is dedicated to my parents, Neela Rawal and Bhavesh Rawal, and my sister, Heli Rawal. Their support and love has provided me the motivation needed to finish this thesis. Without my family, I would not have had this wonderful opportunity for higher education.
ACKNOWLEDGEMENT

I would like to thank my advisor Dr. Joshua Summers and my co-advisors, Dr. Gregory Mocko and Dr. Oliver Myers. Their patience, advice, and criticism have helped me mature not only as a student but also in life. They believed in my ability when I often doubted myself. They have taught me to be creative, think deeper, and strive to understand engineering subjects at a deeper level. People often say that they would change something in hindsight, but looking back I know that I could not have made a better choice in advisors. I can say without a doubt that Dr. Mocko and Dr. Myers truly care about their students.

I would like to thank all members of the CEDAR lab. Discussions and collaboration with the member of CEDAR helped me further advance my education outside of the classed, and helped me form the basis for my research.

I would also like to thank all of the interviewees who spent time from their schedule.
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Chapter One  
CAPSTONE DESIGN PROGRAM

The overall goal of this research is to understand and explore the motivation and value that industry gains from sponsoring senior year capstone design projects in the Department of Mechanical department at Clemson University. Further, this research compares the true value as defined by the sponsoring companies against the perceived value of the faculty recruiting these projects. The paper also highlights suggestions from the company sponsors that can benefit the mechanical department of Clemson University.

1.1 Mechanical Department Capstone Design Program at Clemson University

The Mechanical Engineering capstone design program at Clemson University is divided into a two semester program. The ME 4010 is the pre-capstone program where the students learn the role of analysis, synthesis and evaluation in design. The students are taught to utilize the engineering design tools with the influence of economics and optimization, concurrent development, integration of design and manufacturing and systems creation. This prepares the students for ME 4020, the second semester senior year design course, called internship in engineering design. It should be noted, prior to 2012 there was a single yearlong ME 4020 course.

Table 1 shows the list of student projects for ME 4020 from 2004 until 2014 including the source of sponsorship and the year. As this study was initiated in 2014, the sponsors for 2015 were not considered. It can be seen that out of ninety projects only seven are department sponsored which shows that the ME 4020 is heavily funded by the companies making it necessary to investigate.
<table>
<thead>
<tr>
<th>Year</th>
<th>Deliverables</th>
<th>Sponsors</th>
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<tr>
<td>2004</td>
<td>Evaluation of the replacement alternatives for current pre-heat systems and</td>
<td>Fuji Film</td>
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<tr>
<td></td>
<td>Modeling the mechanical and thermal performance of current pre-heat system to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>compare with the potential alternatives</td>
<td></td>
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<tr>
<td>2004</td>
<td>Designing new type of stabilized, flexible tire clamping system to accommodate</td>
<td>Michelin</td>
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<td></td>
<td>a wide range of tire with a desire of a clean and quality cut.</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>Design an injection molding machine to perform at least one operation in one</td>
<td>CETL</td>
</tr>
<tr>
<td></td>
<td>hour following the complete cycle.</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>Designing a brake spoiler</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>Re-designing or modifying the gaging system to improve the Gage reproducibility</td>
<td>Jacobs Chuck manufacturing</td>
</tr>
<tr>
<td></td>
<td>and repeatability with best performance and low cost.</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>Design a paint application fixture for hang on parts.</td>
<td>BMW</td>
</tr>
<tr>
<td>2005</td>
<td>Designing an attachment that will allow usage of a CETL MIG gun into 3 axis</td>
<td>CETL</td>
</tr>
<tr>
<td></td>
<td>milling machine, also selecting an appropriate laser and attachment in order</td>
<td></td>
</tr>
<tr>
<td></td>
<td>to permit heat treatment and thermal deposition of printed parts.</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>An engineering estimate of full expansion cost with all materials necessary</td>
<td>Michelin</td>
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<tr>
<td></td>
<td>and estimated time table of implementation.</td>
<td></td>
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<tr>
<td>2005</td>
<td>Feasibility and concept development for the integration of electrical</td>
<td>BMW</td>
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<td></td>
<td>components in automotive structural components.</td>
<td></td>
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<tr>
<td>2005</td>
<td>SAV under hood Assembly Assistance</td>
<td>BMW</td>
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<tr>
<td>2005</td>
<td>Sav rearhatch assembly assistance</td>
<td>BMW</td>
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<tr>
<td>2005</td>
<td>Door Setting fixture of paint shop</td>
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<td>2005</td>
<td>Drag Racing Tread Grip Tester with varying Surface</td>
<td>Michelin</td>
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<tr>
<td>2005</td>
<td>Design and construction of Hardware to integrate a Multi pole gas analyzer</td>
<td>Department of physics and</td>
</tr>
<tr>
<td></td>
<td>in a NASA sounding rocket payload.</td>
<td>astronomy</td>
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<tr>
<td>2006</td>
<td>Development of a lunar wheel for use in possible future land/rover system.</td>
<td>JPL</td>
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<tr>
<td>2006</td>
<td>To develop a prototype for a fixture required during the paint process of</td>
<td>BMW</td>
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<td></td>
<td>hang on parts</td>
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<tr>
<td>2006</td>
<td>Redesign of clutch and switching Mechanisms for hand drills</td>
<td>Techtronic Industries</td>
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<td>2006</td>
<td>Greenhouse shipment box design.</td>
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<td></td>
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<td>2006</td>
<td>Design of Armor Tape Curling Fixture</td>
<td>Corning Cable systems</td>
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<td>2006</td>
<td>Method to Measure Surface Marking of In-door Tires</td>
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<td>2006</td>
<td>Universal Robotic Welding Work cell.</td>
<td>Wright Metal Products</td>
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<td>2007</td>
<td>Design of Tail Light Assembly Fixture</td>
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<td>2007</td>
<td>Design of fiber cement siding cutting tool</td>
<td>Techtronic Industries</td>
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<td>2007</td>
<td>Design of Automated Trans lube Application</td>
<td>Eaton Corporation(Toccoa</td>
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<td></td>
<td></td>
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<td>2007</td>
<td>Design and Build a heat transfer solution for an electric motor</td>
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<td>2007</td>
<td>Design and Analyze improved nose gear assembly</td>
<td>Raytheon</td>
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<td>2007</td>
<td>Design of Tweel for in-line Skated</td>
<td>Michelin</td>
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<td>2007</td>
<td>Design of headrest system for manual wheelchairs</td>
<td>Automotive Safety Research</td>
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<td>Year</td>
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<td>2008</td>
<td>Design of biodiesel production facility</td>
<td>Agricultural and Biological Engineering</td>
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<td></td>
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<td>2008</td>
<td>Design of an Automatic Film Splicer</td>
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<td>2008</td>
<td>Design of a method for testing and calibrating Plastic Fastening</td>
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<td>Design and validation of an I-Beam Coupon Test Fixture System</td>
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<td>Design of Polyurethane and Rubber Interface</td>
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<td>Design and prototype of a system for measuring heat dissipation in Electrical</td>
<td>Square D/Schneider Electric</td>
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<td>Timken US Corporation</td>
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<td>2008</td>
<td>Heat treatment Distortion of Flatness</td>
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<td>Development of a working prototype of a high-heel shoe, based on Tweel Shear</td>
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<td>Increasing the life cycle of Torx Bits used by the Automotive Industry</td>
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<td>2008</td>
<td>Design of test surface Burnishing System</td>
<td>South Carolina Institute for Energy Studies</td>
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<td>2008</td>
<td>Design of renewable energy power systems for South Carolina Markets</td>
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<td>2008</td>
<td>Design of test system for Lawn mower blade performance study.</td>
<td>Duramatic Company</td>
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<td>Design of pneumatic hammer combined with rolling forming crimper</td>
<td>Automation Engineering Corporation</td>
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<td>2008</td>
<td>Design an improvement for tension control and web guiding for packaging system</td>
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<td>2008</td>
<td>Design of tire-wheel assembly handler</td>
<td>Michelin</td>
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<td>2009</td>
<td>Investigating Tube-to-Header Leaks in Aluminum Automotive Radiators</td>
<td>Bell South</td>
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<td>Application development for Scrapped Material Reuse</td>
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<td>Impact driver noise reduction</td>
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<td>Scrap Metallic Tissue Reduction or Recycling</td>
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<td>Vtg high temperature wear tester</td>
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<td>Design of Rivnut Remover</td>
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<td>Hydrogen engine conversion</td>
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<td>Passenger Car Kinematics and Compliance Sensor Upgrade</td>
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<td>Jigwas tracking improvement</td>
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<td>Sound Dampening for Benchtop Systems</td>
<td>Techtronic Industries</td>
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<td>2010</td>
<td>Design of Borehole Extensometer</td>
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<td>Determination of Airflow Patterns and Particle Motion During Grass Mowing and</td>
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<td></td>
<td>Mulching Process</td>
<td></td>
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<td>2010</td>
<td>Freezer Door easy open</td>
<td>Electrolux</td>
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<tr>
<td>2010</td>
<td>Drum machine road surface cleaning system</td>
<td>Michelin</td>
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<td>2010</td>
<td>Water depth gauge for Michelin Laurens providing ground</td>
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<td>2010</td>
<td>Geothermal sealing Back up system</td>
<td>Parker Hannifin Corp.</td>
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<td>Year</td>
<td>Deliverables</td>
<td>Sponsors</td>
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<td>2010</td>
<td>Stream Bed flow meter</td>
<td>Geology Department at Clemson University</td>
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<td>2011</td>
<td>Design of saw testing fixture</td>
<td>TTI</td>
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<td>2011</td>
<td>Flexible Product Guide for Beef Sub-Primals</td>
<td>Cryovac</td>
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<td>2011</td>
<td>Design of Ergonomic Plug Installation Tool</td>
<td>BMW</td>
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<td>2011</td>
<td>Design of robot gripper Device</td>
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<td>2011</td>
<td>Water Dispenser flow rate improvement</td>
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<td>Wind turbine blade transportation redesign</td>
<td>GE</td>
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<td>2011</td>
<td>Capacitor Dip mixing Mechanism</td>
<td>Kemet Electronics corp</td>
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<td>2011</td>
<td>Reinventing the CNC machine Tool way cover design</td>
<td>Okuma America Corp</td>
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<td>2011</td>
<td>Automated seal spicing system</td>
<td>Parker Hannifin Corp</td>
</tr>
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<td>2011</td>
<td>Determination of Air Flow Patterns and Particle Motion During Grass Mowing and Mulching Processes</td>
<td>MSN</td>
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<td>2012</td>
<td>Adjustable shelves for consumer refrigerator interior</td>
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<td>2012</td>
<td>French Door closure and seal improvement</td>
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<td>2012</td>
<td>Screw Sorter and Magnetic Wrist Band Clip for loading screws into a Battery Gun</td>
<td>BMW</td>
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<td>2012</td>
<td>Electronically controlled gas powertrain for utility vehicle</td>
<td>Textron</td>
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<td>2012</td>
<td>Tube inside out assist</td>
<td>Parker</td>
</tr>
<tr>
<td>2012</td>
<td>Automated tube grinding</td>
<td>Parker Hannifin Corp</td>
</tr>
<tr>
<td>2012</td>
<td>Develop stylish comfortable low cost seating</td>
<td>Textron</td>
</tr>
<tr>
<td>2012</td>
<td>Fly wheel motor Design and analysis</td>
<td>Carolina Motors</td>
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<tr>
<td>2012</td>
<td>Automated rubber banding design</td>
<td>Parker Hannifin Corp</td>
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<tr>
<td>2012</td>
<td>Refrigerator door-to-cabinet seal design</td>
<td>Electrolux</td>
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<td>2013</td>
<td>Design of multi-blade mower deck fixture</td>
<td>Rotary Corp.</td>
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<td>2013</td>
<td>MWB vibration dampening centralizer design</td>
<td>Parker</td>
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<td>2013</td>
<td>Self-feeding nailer</td>
<td>TTI</td>
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<td>2013</td>
<td>Magnet storage carts</td>
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<td>2014</td>
<td>Cushman ambulance</td>
<td>Textron</td>
</tr>
<tr>
<td>2014</td>
<td>Design of low cost AGV</td>
<td>BMW</td>
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<tr>
<td>2014</td>
<td>Designing an automated madrel removal system</td>
<td>Parker</td>
</tr>
<tr>
<td>2014</td>
<td>ARF power stick</td>
<td>AmstedRail Fairveley</td>
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Figure 1 shows how the interaction take place between the three stake holders namely the students, company and faculty. The three relationships that can be identified from the table are: Student – Sponsor, Student- Faculty and Faculty – Sponsor.

ME 4010 is where the faculty and students interact and the students are prepared to solve the real world problems for customers, while ME 4020 is where all of the three major
stake holders interact with each other. In ME 4010 there is a more push from faculty members to the students while in ME 4020 there is more push from the students to the capstone design program. The relationship between these three are discussed below.

Company sponsor-student team: The tasks between the company liaison and the student teams are exchanging required information necessary for the project completion. There should be a considerable support from the company liaison which drives the student teams to obtain required outcome from the project.

Student teams-Faculty: Faculty advisors in the project check the progress of student teams and provide necessary support and guidance in the student projects.

Company sponsor- Faculty: This interaction is based more on deciding the scope of the project, paper work, and student’s project evaluation.

After project completion, it is necessary to take feedback from the students, faculty and industry regarding the program outcome in order to improve the academia-industry relations.
Figure 1 Capstone Program Outline

Figure 1 describes that the faculties train the students for real world problems dealing with customers in the ME 4010 class where the students get more push from the faculty side. The ME 4020 is where all of the three interact with each other regarding the student projects. The sponsor and the customer is same for the ME 4020 projects, whereas sometime they can be different as well.

The Clemson Design Applications and Research (CEDAR) group within the Department of Mechanical Engineering has been working under Engineering design education research. Summers[1] explains how they successfully integrate education practice, and the research in the CEDAR group within the Engineering Design research field. In 2010 Shraddha et al. [2] analyzed the Senior Design Capstone Projects for a case study to investigate information loss in collaborative design, Beshoy et al. [3] discussed the difficulties that were encountered when a team of Mechanical Engineering students attempt to elicit requirements during their capstone design program and discussed on using personas as a design tool for requirement elicitation.
1.2 Motivation

Ninety two percentage of the ME 4020 projects are sponsored by the companies. The companies are the primary customers of the Mechanical Engineering Department at Clemson University. In order to build and improve the existing relationships with local companies which will be further discussed later in the thesis, it is necessary to know what the companies perceive about the program. Moreover, the feedback can be useful for the department to implement changes in the ME 4010 class. Figure 2 shows the goal of the thesis, which is to understand, if the incentive that the companies get in sponsoring the projects are same as what the faculty members of the ME 4020 perceive. If the benefits in sponsoring the ME 4020 projects as mentioned by the company sponsors are different from the faculty members’ perception, then there is an opportunity for the faculty members to improve their pitches while approaching industry for new projects. These include both previous, current, and future industry sponsors. Also, if there are certain benefits that companies get in sponsoring the projects, are the only ones that are stated by the faculties and not company sponsors than those can be side benefits which are not the main focus of the companies. Moreover if the some of the benefits perceived by both are same, then it certainly shows that the faculties of the ME 4020 are selling what the companies want. Also, the perceptions of both regarding the value as a student in pursuing the ME 4020 projects is also discussed in this thesis.
1.3 Prior Research in Capstone Design

There is an extensive list of work done under design education and specifically for the capstone design program. A literature review was conducted for relevant papers assessing the capstone design program as shown in Table 2, different factors that were looked at are described below.

- Is the paper assessing the program or written to inform about different features of the program?
- The impact of the senior design program on students, faculty and company
- Is the paper querying: students, faculty or the company sponsor?
- Description of the school and the deliverables of the paper.

### Table 2 Prior work under Capstone Design Program

<table>
<thead>
<tr>
<th>Reference</th>
<th>Research motivation(Information/Assessment)</th>
<th>Impact on</th>
<th>Investigated by Querying</th>
<th>School</th>
<th>Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>Research motivation (Information/Assessment)</td>
<td>Impact on</td>
<td>Investigated by Querying</td>
<td>School</td>
<td>Deliverables</td>
</tr>
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</tr>
<tr>
<td>[5]</td>
<td>Assessment</td>
<td>S</td>
<td>FC</td>
<td>Seattle University</td>
<td>Describes the program and includes assessment conducted for the sponsoring agencies.</td>
</tr>
<tr>
<td>[6]</td>
<td>Assessment</td>
<td>SFC</td>
<td>SFC</td>
<td>Smith College</td>
<td>Describes survey results related to course management, students’ deliverables, project funding and perceived success.</td>
</tr>
<tr>
<td>[7]</td>
<td>Assessment</td>
<td>S</td>
<td></td>
<td>University of Detroit Mercy</td>
<td>Explains a competition motivated senior design course</td>
</tr>
<tr>
<td>[8]</td>
<td>Assessment</td>
<td>S</td>
<td>C</td>
<td>University of Fulton</td>
<td>Assesses the industry perception of the capstone program.</td>
</tr>
<tr>
<td>[9]</td>
<td>Assessment</td>
<td>S</td>
<td></td>
<td>Purdue University</td>
<td>Describes instruments developed for a mechanism for systematic and quantitative evaluation of outcomes</td>
</tr>
<tr>
<td>[10]</td>
<td>Assessment</td>
<td>S</td>
<td>S</td>
<td>Rose Hulman Institute of Technology</td>
<td>Discusses the data collected during the assessment process comparing the students taking international and domestic projects</td>
</tr>
<tr>
<td>[11]</td>
<td>Assessment</td>
<td>SFC</td>
<td>S</td>
<td>United States Military Academy</td>
<td>Talks about three key elements for a successful capstone design program</td>
</tr>
<tr>
<td>Reference</td>
<td>Research motivation (Information/Assessment)</td>
<td>Impact on</td>
<td>Investigated by Querying</td>
<td>School</td>
<td>Deliverables</td>
</tr>
<tr>
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<td>-------------------------------------------</td>
<td>-----------</td>
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<td>-------</td>
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</tr>
<tr>
<td>[12]</td>
<td>Assessment</td>
<td>SFC</td>
<td></td>
<td>Brigham University</td>
<td>Describes standard practice and current state in the capstone design program by reviewing 100 papers.</td>
</tr>
<tr>
<td>[13]</td>
<td>Assessment</td>
<td>SFC</td>
<td>S</td>
<td>Brigham University</td>
<td>Survey of the capstone program in north America</td>
</tr>
<tr>
<td>[14]</td>
<td>Information</td>
<td>SF</td>
<td></td>
<td>Wisconsin University</td>
<td>Describes how a robust real world project should be for the capstone project.</td>
</tr>
<tr>
<td>[15]</td>
<td>Information and assessment</td>
<td>SFC</td>
<td>SF</td>
<td>Brigham University</td>
<td>Describes an ideal program that satisfies industry customers</td>
</tr>
<tr>
<td>[16]</td>
<td>Information</td>
<td>C</td>
<td></td>
<td>Indiana University Purdue University</td>
<td>Challenges and benefits of the startup firms sponsoring the capstone projects.</td>
</tr>
<tr>
<td>[17]</td>
<td>Information and assessment</td>
<td>S</td>
<td>S</td>
<td>Mississippi State University</td>
<td>Describes the design of an industrial tied program.</td>
</tr>
<tr>
<td>[18]</td>
<td>Information</td>
<td>S</td>
<td></td>
<td>University of Texas</td>
<td>Information on integrating professional responsibility in capstone projects</td>
</tr>
<tr>
<td>[19]</td>
<td>Information</td>
<td>SFC</td>
<td>-</td>
<td>-</td>
<td>Investigates the assessment framework used in capstone program.</td>
</tr>
<tr>
<td>[20]</td>
<td>Information</td>
<td>SC</td>
<td></td>
<td>University of South Florida</td>
<td>Discusses different aspects of partnering with industries</td>
</tr>
<tr>
<td>[21]</td>
<td>Assessment</td>
<td>SF</td>
<td></td>
<td>Brigham University</td>
<td>Guidelines in selecting the industry projects</td>
</tr>
<tr>
<td>[22]</td>
<td>Assessment</td>
<td>SFC</td>
<td></td>
<td>Penn State University</td>
<td>Describes the industry based capstone design program</td>
</tr>
<tr>
<td>Reference</td>
<td>Research motivation(Information/Assessment)</td>
<td>Impact on</td>
<td>Investigated by Querying</td>
<td>School</td>
<td>Deliverables</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------</td>
<td>-----------</td>
<td>--------------------------</td>
<td>--------</td>
<td>--------------</td>
</tr>
<tr>
<td>[2]</td>
<td>Assessment</td>
<td>S</td>
<td>Clemson</td>
<td></td>
<td>Investigates the type of information lost during the capstone design program.</td>
</tr>
<tr>
<td>[23]</td>
<td>Assessment</td>
<td>S</td>
<td>S</td>
<td>Clemson</td>
<td>Describes a coding scheme to analyze the capstone design projects</td>
</tr>
</tbody>
</table>

Legend: S -Student, F-Faculty, C-Sponsor

As seen in Table 2, prior work is mainly focused on explaining the development of capstone design course, explaining the structure of the course, aspects of team oriented design projects, work on the assessment framework used. However, out of twenty one papers only four of them are using the view points of the sponsors as an assessment tool. Additionally, the thesis also compares the faculty perception and the companies’ perception about the ME 4020.
Chapter Two
RESEARCH APPROACH

The main objective of the thesis is to explore the viewpoint of the faculty and the sponsors with respect to the value of sponsoring the project. The objective forms the basis for the three research questions. Interviewing is used as the method of data gathering using two set of semi-structured set of questions prepared separately for faculty and sponsors and triangulated within in order to answer the three research questions.

| Research Questions | • Three main research questions  
                      • Triangulated questions for faculty and company sponsor |
|---------------------|------------------------------------------------------------------|
| Research method     | • Interview  
                      • Face to Face and telephone conference. |
| Data gathering      | • Interview transcripts and summaries  
                      • Students project abstract |
| Findings            | • Patterns in the answers.  
                      • Answers to research questions and discussion between the ME 4020 faculty and sponsors |

**Figure 3 Research Approach**

Figure 3 shows the research approach undertaken to answer the three research questions as discussed below.
Question 1: What impact do academic projects have on the companies? What is the perception (value and motivation) of the industry about sponsoring the projects for ME 4020?

Question 2: What is the perception (value the faculty think they deliver to the industry) of academia for the program ME 4020?

Question 3: Do the perceptions of faculty and company sponsors match?

2.1 Research Questions

The research questions were finalized based on the objective of the research. The objective is to understand the faculty members and company sponsors insights regarding ME 4020 this helped to divide the objective into three questions.

First is to talk about the impact that the projects have on industry and ask them about necessary changes or implementation of the students’ solutions.

Second is to ask the industry about what motivates them to sponsor the projects. Their perceptions on working with the undergraduate students, professional aspects of the students, team dynamics. Finally, talking to the professors involved in advising the capstone design program about their perceptions: the value they deliver via the program, learning outcomes, team dynamics.

2.2 Interviewing as a method of data gathering

Interviewing is a widely accepted method in qualitative research, this can be seen in [24] which describes a list of 30 papers that used interview for educational design research. In addition, it is used in fields other than engineering like psychology, law, arts,
biology as a qualitative data gathering method. Gable [25] suggests that interviewing can help ask penetrating questions which helps in querying the interviewee with leading questions and get his thoughts out regarding the Capstone Design Program. In addition asking penetrating questions leads to more elaborated answers for a given set of questions.

The other surety that comes along interviewing is the time and place agreed upon by the interviewee’s comfort which increase the data quality. The reading of facial expressions and body language, making eye contact or hearing the voice tones while in telephone interviews are some essential visual or nonverbal cues that work in benefit for interviews as suggested by Lokman in [26]. This helps the interviewer in knowing the attitude of the interviewee while answering questions and can ask questions based on the threads leading to interviewees’ perceptions more deep.

In order to be as objective as possible and increase credibility of the findings a systematic interview process is followed.
Figure 4 Interview Process

Figure 4 shows the steps followed in the interview process, these steps are explained in the below sub sections.

2.2.1 Training

It was made sure that the interviewer was well trained before interviewing. The interviewer was trained by the faculty advisor who has a significant experience in qualitative research methods and also the interviewer has practice on conducting interviews from a prior coursework in the Research Methods in Collaborative Design. Lastly, before starting the interviews, there were mock interviews practiced by the interviewer.
2.2.2 Design of interviews

For the interviews, a semi-structured set of questions is prepared based on the three research questions. Three iterations were conducted to properly frame the flow of questions and properly design triangulation method within the questions.

2.2.3 Selecting subjects

The subjects for the interview process are from two separate fields. One is academia and another is the company. The faculty members were selected using the criteria that they either were or currently the head of their respective capstone design program.

For the company sponsors, students’ abstracts were collected from 2004 until 2014 and a list of all company sponsored project is made with contact information of all the sponsors and the respected liaison for the project as well. This list along with the prior experience and knowledge of the faculty advisor and corresponding company liaisons were selected and approached for the research interviews.

2.2.4 Initial contact

A prior email was sent to a selected professors in the Mechanical, Industrial and Bioengineering Department of Clemson University, one faculty from the Department of Mechanical Engineering at Colorado School of Mines and one faculty from the Department of Mechanical Engineering at Mississippi State University. The faculty member from other department and schools were queried in order to see if the other department/schools perceive the same value as the ME 4020 faculty. The same process was done for the company sponsors’ interviews. The interviews were conducted on the preference of the
interviewee. It should be noted that the subjects were asked to select the time and place of their convenience.

2.2.5 Conducting interviews

After initial contact, the interviews were conducted, which either were face-to-face or telephone interviews. The face-to-face interviews were conducted in the interviewee’s office and two of them were conducted in a cafeteria with a silent ambience. A silent conference room was used by the interviewer to conduct the telephone interviews. The location of the telephone interviewee was undetermined but according to the interviewer’s knowledge the subjects were in a silent location.

A notification email was also sent to the interviewees well before the interview time and date so that they can prepare if they needed to. Hand written notes and recordings were used as tools to gather the interview data. The importance of recording the conversation is that the respondent talks confidently after being aware of the conversations being recorded [27]. The interviewee’s consent was asked before taking notes and recording the conversation. If the interviewee consented to the request of recording and taking notes, transcripts were written after that.

2.2.6 Post contact

At the end of every interview a thank you note was sent and the interviewee was asked about any questions or concerns regarding the interview. Sending a post thank you note helped to maintain a structured approach to the interview process and it benefited in approaching the interviewee again for cross verifications.
2.2.7 Transcription

The interview recordings and the notes were used to make a brief transcript of the interview. It is used to summarize the interviews and findings were based on the transcripts and the summaries. Listening to the interview recordings and converting those in a written readable format makes the transcript part most time consuming. It should be noted that certain expressions in transcript are colloquial and semi-formal which are not changed in order to maintain the objectivity and quality of the data.

2.2.8 Summary

The transcripts and the notes were used to summarize the interview which includes all the information on the interviewee, his thoughts about the program, the motivation for investing time and money for the program, the value of the senior design program to the company sponsoring the projects, student taking the course and the department offering it and suggestion to better the program.

2.2.9 Analysis

There are certain generalized patterns that can be found in the answers of the respondents, these patterns will be discussed later in this thesis.

2.3 Interview overview

Table 3 shows a checklist that is used for every interview conducted [24].
<table>
<thead>
<tr>
<th>Context of study</th>
<th>Understanding/change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
<td>Academia</td>
</tr>
<tr>
<td>Relationship of the interviewee and the interviewer</td>
<td>To ensure a non-bias and objective answer</td>
</tr>
<tr>
<td>Information on Interviewee</td>
<td>Important for credibility purpose</td>
</tr>
<tr>
<td>Information on interviewer</td>
<td>Helps further researcher in replication studies and information given on the training of the interviewer adds benefit to the reader about a smooth and unbiased process</td>
</tr>
<tr>
<td>Interview location</td>
<td>Adds credibility in the interview process conducted when the location is exposed</td>
</tr>
<tr>
<td>Type of interview</td>
<td>Explains the general structure</td>
</tr>
<tr>
<td>Supplement material or recording</td>
<td>Helps in transcription of the interview and critical for repeating the interview</td>
</tr>
<tr>
<td>Duration of the interview</td>
<td>Supports in replicating and repeating the interviews</td>
</tr>
<tr>
<td>Questions reported</td>
<td>Exposing the questions can add credibility of the researcher from the reader perspective</td>
</tr>
<tr>
<td>Context of study</td>
<td>Understanding/change</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>Answers reported</td>
<td>Exposing the questions can add credibility of the researcher from the reader perspective</td>
</tr>
<tr>
<td>Summary of the interview</td>
<td>Gives an objective view of the data collected before the inference.</td>
</tr>
</tbody>
</table>
Chapter Three
INTERVIEW DESIGN

The semi-structured interview process as discussed in Chapter Two, was followed to interview six professors and eleven company sponsors as seen in Table 4. These subjects were selected based on the discussions presented in subsection 2.2.3 in Chapter 2. Below table presents the experience of the respondents in their corresponding fields. All of the professors have more than seven years of experience and ten of the company liaisons have more than nineteen years of experience while one has eight years of experience, in their respective fields. The interview type is either Face-to-Face or Virtual and the locations of the interviews include conference rooms, personal offices or cafeterias. The interview location is categorized as public or private. Locations such as a cafeteria or conference room are considered to be public (as they are accessible by anyone), while a personal office is considered to be a private location. With that said, the interview location is disclosed in the following table for the sake of transparency/repeatability and to be as objective and unbiased as possible.

Table 4 Interviewee list

<table>
<thead>
<tr>
<th>Interviewee name</th>
<th>Interviewee code</th>
<th>Background</th>
<th>Company/school name</th>
<th>Experience (years)</th>
<th>Interview Date</th>
<th>Interview type</th>
<th>Interview place</th>
<th>Interview duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Joshua Summers</td>
<td>Fa1</td>
<td>Fa,M</td>
<td>Clemson</td>
<td>&gt;12</td>
<td>7/10/2014</td>
<td>P,F</td>
<td>Dr. Summers office</td>
<td>43:58</td>
</tr>
<tr>
<td>Dr. Gregory Mocko</td>
<td>Fa2</td>
<td>Fa,M</td>
<td>Clemson</td>
<td>10</td>
<td>7/15/2014</td>
<td>P,F</td>
<td>Dr. Mockos office</td>
<td>24:58</td>
</tr>
<tr>
<td>Dr. John DesJardins</td>
<td>Fa3</td>
<td>Fa,B</td>
<td>Clemson</td>
<td>&gt;7</td>
<td>08/04/2014</td>
<td>P,F</td>
<td>Dr. DesJardins office</td>
<td>49:46</td>
</tr>
<tr>
<td>Interviewee name</td>
<td>Interviewee code</td>
<td>Background</td>
<td>Company/ School name</td>
<td>Experience (years)</td>
<td>Interview Date</td>
<td>Interview type</td>
<td>Interview place</td>
<td>Interview duration (min)</td>
</tr>
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<td>--------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Dr. Oliver Myers</td>
<td>Fa4</td>
<td>Fa,M</td>
<td>Mississippi State</td>
<td>NA</td>
<td>05/07/2015</td>
<td>P,F</td>
<td>Dr. Myers office</td>
<td>26:49</td>
</tr>
<tr>
<td>Dr. Scott Mason</td>
<td>Fa5</td>
<td>Fa,I</td>
<td>Clemson</td>
<td>15</td>
<td>07/30/2014</td>
<td>Pu F</td>
<td>Conference room</td>
<td>32:48</td>
</tr>
<tr>
<td>Dr. Cameron Turner</td>
<td>Fa6</td>
<td>Fa,M</td>
<td>Colorado School of mines</td>
<td>&gt;18</td>
<td>08/09/2014</td>
<td>Pu,F</td>
<td>Cafeteria</td>
<td>53:57</td>
</tr>
<tr>
<td>Mr. Mason Morehead</td>
<td>Co1</td>
<td>Co, M</td>
<td>Parker Hannifin</td>
<td>15</td>
<td>04/02/2015</td>
<td>Pu,V</td>
<td>Conference call–EIB 135</td>
<td>20:22</td>
</tr>
<tr>
<td>Mr. Gary Carpenter</td>
<td>Co2</td>
<td>Co, A</td>
<td>Parker Hannifin</td>
<td>30</td>
<td>05/01/2015</td>
<td>P,F</td>
<td>Parker Hannifin.</td>
<td>22:08</td>
</tr>
<tr>
<td>Mr. Johnson Stephen</td>
<td>Co3</td>
<td>Co, M</td>
<td>General Electric</td>
<td>32</td>
<td>04/06/2015</td>
<td>Pu,V</td>
<td>Conference call–EIB 135</td>
<td>19:05</td>
</tr>
<tr>
<td>Mr. Micheal Lail</td>
<td>Co4</td>
<td>Co, M</td>
<td>Okuma America Corp.</td>
<td>NA</td>
<td>04/07/2015</td>
<td>Pu,V</td>
<td>Conference call–EIB 135</td>
<td>14:29</td>
</tr>
<tr>
<td>Mr. Siva Chavali</td>
<td>Co5</td>
<td>Co, M</td>
<td>Schneider Electric</td>
<td>8</td>
<td>05/10/2015</td>
<td>Pu,V</td>
<td>Conference call–EIB 135</td>
<td>18:38</td>
</tr>
<tr>
<td>Mr. Porter Whitmire</td>
<td>Co6</td>
<td>Co, M</td>
<td>TTI</td>
<td>NA</td>
<td>11/13/2014</td>
<td>Pu,F</td>
<td>TTI</td>
<td>24:58</td>
</tr>
<tr>
<td>Mr. Warren McAlpine</td>
<td>Co7</td>
<td>Co, M</td>
<td>Corning Cables</td>
<td>21</td>
<td>02/24/2015</td>
<td>Pu,V</td>
<td>Conference call–EIB 135</td>
<td>29:53</td>
</tr>
<tr>
<td>Mr. Bob McCracken</td>
<td>Co8</td>
<td>Co, M</td>
<td>TTI</td>
<td>NA</td>
<td>11/13/2014</td>
<td>P,F</td>
<td>TTI</td>
<td>24:58</td>
</tr>
<tr>
<td>Mr. Joerg Schulte</td>
<td>Co9</td>
<td>Co, M</td>
<td>BMW</td>
<td>&gt;19</td>
<td>05/13/2015</td>
<td>P,F</td>
<td>BMW</td>
<td>22:39</td>
</tr>
<tr>
<td>Mr. Ralph Hulsmen</td>
<td>Co10</td>
<td>Co, M</td>
<td>Michelin</td>
<td>34</td>
<td>05/08/2015</td>
<td>P,F</td>
<td>Conference room</td>
<td>20:36</td>
</tr>
<tr>
<td>Mr. Tracy Crews</td>
<td>Co7</td>
<td>Co, M</td>
<td>Michelin</td>
<td>NA</td>
<td>10/7/2014</td>
<td>Pu,V</td>
<td>Conference call</td>
<td>20:03</td>
</tr>
</tbody>
</table>
Table 5 describes a semi–structured questions used to interview the professors. It is not necessary that all questions are used while conducting the interview in order to follow the structure since the interview questions should be asked according to the answer of the
respondent [27]. The questions fall into three categories; how, why and what and can be seen below.

**Table 5 Semi-Structured Interview Questions for Faculty**

<table>
<thead>
<tr>
<th>Question number</th>
<th>Faculty Interview Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>How many years have you taught a design course?</td>
</tr>
<tr>
<td>Q2</td>
<td>How many years have you taken a part in student projects?</td>
</tr>
<tr>
<td>Q3</td>
<td>How many undergraduate projects have you been a part of?</td>
</tr>
<tr>
<td>Q4</td>
<td>What is your role generally, is it to advise, mentor, or collaborate with the teams?</td>
</tr>
<tr>
<td>Q5</td>
<td>How critical/central is the capstone course to your undergraduate program? Why is it so?</td>
</tr>
</tbody>
</table>
| Q6              | Can you please explain the structure of your capstone program?  
Types of projects  
Size of teams  
Duration of the project  
Advisor students  
Structure of the course(Lecture+projects;projects only)  
Solicitation of projects.  
Industry involvement. |
| Q7              | What are the student benefits for projects in your program? |
| Q8              | How is the program/project viewed in your department?  
Are there clear learning objectives? Why?  
Is it treated as an exit exam? Why? |
<p>| Q9              | Do the faculty use these projects as a way to evaluate the effectiveness of the rest of the undergraduate program? If so, how? |
| Q10             | What are the types of projects students can do in a capstone program? Are they self-defined? Industry sponsored? Faculty research driven? Faculty defined? Competition? |
| Q11             | What makes a good project in your opinion? Are you interested in student-defined deliverables or the impact of them in the company or sponsor? Why? |
| Q12             | Must there be a sponsor for a project to be good? |
| Q13             | What are the learning objectives or expectation differences between undergraduate company sponsored project, research project or faculty defined project? |
| Q14             | Why should a student participate in a company sponsored project? |
| Q15             | How do you approach a company when looking for program projects |
| Q16             | Why do you think companies choose to sponsor projects? Why do you think this? Have companies communicated this to you? |</p>
<table>
<thead>
<tr>
<th>Question number</th>
<th>Faculty Interview Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q17</td>
<td>Has any company approached to you looking to sponsor projects? How often? Why do you think this is?</td>
</tr>
<tr>
<td>Q18</td>
<td>Do any companies continue sponsoring projects? Do they continue their past projects or sponsor new ones? Can you describe some examples? What brings them back again?</td>
</tr>
<tr>
<td>Q19</td>
<td>What does the program do to seek out new company sponsors?</td>
</tr>
<tr>
<td>Q20</td>
<td>Is there a limit to how many projects you can offer in a given semester or year? Is this a hard constraint or a pragmatic limitation?</td>
</tr>
<tr>
<td>Q21</td>
<td>How satisfied are the companies with their experiences in sponsoring capstone design projects? What makes you think this? Can you give some specifics?</td>
</tr>
<tr>
<td>Q22</td>
<td>General speaking, where are the companies that sponsor the projects located? Are they in the local area (less than an hour drive) or are they further? Are there company projects from other states? Any example you would like to add? What is the incentive for a company to sponsor projects from so far? What is the value to students in participating in long distance projects? Is there any benefit to the faculty or the department for long distance projects? Can you provide an example?</td>
</tr>
<tr>
<td>Q23</td>
<td>Why should a company continue providing projects to the same course?</td>
</tr>
<tr>
<td>Q24</td>
<td>Do the companies provide any resources to the students for the projects?</td>
</tr>
<tr>
<td>Q25</td>
<td>Is there a sponsorship fee? How was the value defined? When was the last time that it was adjusted?</td>
</tr>
<tr>
<td>Q26</td>
<td>What is the role of the company sponsor? Is it only as a customer or also a mentor, manager, advisor? How frequently does the team meet with the industry sponsor? How explicit are these roles defined?</td>
</tr>
<tr>
<td>Q27</td>
<td>Apart from the previous questions, can you provide any additional information about projects or challenges faced?</td>
</tr>
</tbody>
</table>

Table 6 shows the triangulation of the above mentioned questions with respect to four categories which are described below:

- **Motivation** – The perception of the professors regarding the purpose of a company/sponsor to undergo senior year design projects for the capstone design program. For instance, it leads to why type of questions, asking as to why a company sponsors a capstone design senior year project.
• Value – The perception of the professors regarding the importance and benefits (as a faculty member and student) to organize and undergo company sponsored senior year capstone design projects.

• Project aspects – These questions are related to different aspects of the various projects such as structure of the program, project scope duration of the projects, and multiple team/field dynamics.

• Retrospective – These type of questions are memory based questions which are related to the respondent’s memory of the events.

Table 6 Triangulation Table for Faculty Interview Questions.

| Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 | Q23 | Q24 | Q25 | Q26 | Q27 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  | x  |

The triangulation table shows the related questions marked with a symbol ‘x’. The relation of the categories is determined to get a cross checking on the answers related to
the questions. For instance, Q1, Q2, Q3, Q4, Q10, Q15, Q17, Q19, Q20 and Q27 are considered to be retrospective, which are related to the memory of the respondent. This means that it is anticipated to get answers related to the memory of the respondent regarding the students’ project upon asking those questions.

Similarly, the questions Q12, Q14, Q16, Q18 and Q23 are related in terms of the answers possible, upon asking those questions. It is projected to get answers that relate to the benefits as a company in sponsoring the projects after asking those set of questions.

3.2 Company interviews

The selection of company liaisons for interviews is made from a list of eighty three company sponsored projects from 2004 until 2014. This list along with the prior experience and knowledge of the faculty advisor, was used to select and approach company liaisons for the research interviews. As seen in Table 7, there are eight sponsors who have sponsored a combined forty six projects between 2004 and 2014. This information suggests that industry is a primary customer for mechanical engineering capstone design projects. The table also shows that there are four companies that have sponsored at least six projects, one company that has sponsored two projects and three companies that have sponsored one project. This difference is considered as to find a reason for the companies sponsoring multiple projects to the same department.
Table 7 Interviewed Company List

<table>
<thead>
<tr>
<th>Company</th>
<th>Sponsored projects</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMW</td>
<td>16</td>
<td>2004-2014</td>
</tr>
<tr>
<td>Michelin</td>
<td>13</td>
<td>2004-2010</td>
</tr>
<tr>
<td>Parker Hannifin</td>
<td>6</td>
<td>2010-2014</td>
</tr>
<tr>
<td>Techtronic Industries</td>
<td>6</td>
<td>2006-2013</td>
</tr>
<tr>
<td>Okuma Americas Corp.</td>
<td>1</td>
<td>2011</td>
</tr>
<tr>
<td>Corning Cables</td>
<td>1</td>
<td>2006</td>
</tr>
<tr>
<td>General Electric</td>
<td>2</td>
<td>2011,2013</td>
</tr>
<tr>
<td>Square D/Schneider</td>
<td>1</td>
<td>2008</td>
</tr>
<tr>
<td><strong>Total projects</strong></td>
<td><strong>46</strong></td>
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</tbody>
</table>

In order to get an idea about the sponsoring companies, an introduction about the corresponding companies are given below.

3.2.1 Michelin North America¹

Michelin North America is a $10.76 billion dollar a year company operating nineteen plants in sixteen different locations. There are six locations in South Carolina namely Greenville, Spartanburg, Lexington, Sandy Springs, Starr, and Duncan where car, truck and bus tires as well as earthmover and semi-finished products are manufactured. Michelin has sponsored thirteen projects from 2004 until 2010.

3.2.2 BMW of North America²

BMW of North America is an automotive OEM facility. Its North America headquarters’ is in New Jersey with a facility located in Spartanburg, South Carolina. Moreover, it is part of the BMW Group’s global manufacturing network and it exclusively manufactures X5 and X6 Sports Activity Vehicles. BMW is also a sponsor for the capstone

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² BMW of North America - http://www.bmwusa.com/
design program for the Department of Mechanical Engineering, it has sponsored sixteen projects from 2004 until 2014.

3.2.3 Parker Hannifin³

Parker Hannifin is the global leader in motion and control technologies. It provides precision-engineering solutions to a wide variety of mobile, industrial and aerospace markets. Hannifin is a division of Parker situate near Spartanburg, SC. The company has sponsored six projects between 2010 and 2014.

3.2.4 Techtronic Industry⁴

Techtronic Industry (TTI) North America manufactures power tools, outdoor power equipment, and floor care and appliances for consumers, professionals and industrial use in home improvement, repair and construction industries. TTI has a facility located near Anderson, SC that designs electronics and electrical products and sponsored six projects from 2006 to 2013.

3.2.5 Okuma Corporation⁵

Okuma Corporation is a US based world leader in Computer Numeric Control machine tools and machining process optimization. The facility located in Charlotte, North Carolina is Okuma America Corporation which is a U.S based sales and service affiliate of Okuma Corporation. It sponsored a project in 2011.

³ Parker Hannifin - http://www.parker.com/
⁴ Techtronic Industry - http://www.ttiinc.com/
⁵ Okuma Corporation - http://www.okuma.com/americas
3.2.6 Corning Cable Systems⁶

Corning is one of the world’s leaders in materials science. It manufactures advanced optics, ceramics, and glass. In 2014 it had approximately $10 billion in sales and is a Fortune 500 company. Moreover, Corning cable is a facility located in NC and sponsored a project in 2006.

3.2.7 General Electric Power and Water⁷

General Electric Power and Water has more than 700 locations globally and is a broad array of power generation, energy delivery and water process technologies. It is headquartered in Schenectady, New York, with more than $27 billion in revenue in 2014. GE sponsored a project in 2011 and 2013.

3.2.8 Schneider Electric⁸

Square D/Schneider electric is an integration of Square D and Schneider in North America. Schneider electric is a global specialist in energy management systems. The facility is located in Seneca, SC where circuit breakers and switches are produced and distributed. It sponsored a project in 2008.

Table 8 shows questions that were used to interview the company sponsors. The questions are divided into three categories namely: memory, motivation and program outcomes.

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⁶ Corning Cables Systems - https://www.corning.com/
⁷ General Electric Power and Water - https://www.gepower.com/
• Memory and experience: This type of question is based on memory and is based to the recollection of the respondent for the project. These questions also query into the background and experience of the respondent.

• Project aspects: This type of question is related to the different aspects of the projects (such as structure of the program, duration of the projects, and multiple team/field dynamic).

• Project outcomes – The project outcomes discuss the final solutions of the projects, and impact of the project in the corresponding company.

• Motivation: The perception of the company liaison regarding the purpose of a company to sponsor senior year design projects for the capstone design program.

<table>
<thead>
<tr>
<th>Question number</th>
<th>Company Liaison Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>How many years have you worked in industry? How many years have you been with this company?</td>
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<tr>
<td>Q2</td>
<td>How many academic projects have you been a part of?</td>
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<tr>
<td>Q3</td>
<td>How do you feel about working with the undergraduate students in the projects? What are the challenges or benefits? Why is this?</td>
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<tr>
<td>Q4</td>
<td>What do you think about the ability of the undergraduate students to deal with open ended problems?</td>
</tr>
<tr>
<td>Q5</td>
<td>What is the incentive behind sponsoring the projects to undergraduate students? Is it to prepare the students for current industrial needs?</td>
</tr>
<tr>
<td>Q6</td>
<td>What about the student’s professionalism during the projects? How do you find their professionalism during the projects?</td>
</tr>
<tr>
<td>Q7</td>
<td>What are your thoughts on the students’ presentation skills?</td>
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<tr>
<td>Q8</td>
<td>Can you provide some improvements for academia to more efficiently carry out the projects? Why is it so? Were this suggestions motivated by past experience with the projects?</td>
</tr>
<tr>
<td>Q9</td>
<td>Have you approached universities for projects? What is the incentive/reasoning behind approaching a university to sponsor a project?</td>
</tr>
<tr>
<td>Question number</td>
<td>Company Liaison Questions</td>
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<tr>
<td>Q10</td>
<td>Is there a reason to continue in the same program for sponsoring projects? Do the past projects add value? If so, is this a factor in a companies continued involvement?</td>
</tr>
<tr>
<td>Q11</td>
<td>Can you recall any particular student or a team? If yes, what was it that made the member or team memorable?</td>
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<tr>
<td>Q12</td>
<td>What expectations did you and your company have for the projects? Of students? Of solutions?</td>
</tr>
<tr>
<td>Q13</td>
<td>Did the projects meet your expectations?</td>
</tr>
<tr>
<td>Q14</td>
<td>Would you sponsor the same project again? If so, what would be your motivation?</td>
</tr>
<tr>
<td>Q15</td>
<td>What effect did the sponsored project(s) have? Was it on a product, process, or tool? If a positive effect, did you use any of the provided suggestions in your company?</td>
</tr>
<tr>
<td>Q16</td>
<td>Were there multiple teams involved in the project? Are their benefits to multiple teams?</td>
</tr>
<tr>
<td>Q17</td>
<td>Do you still have the documentation provided by the students?</td>
</tr>
<tr>
<td>Q18</td>
<td>What other group evaluated the project (R&amp;D)? Was there any necessary change on the system or process after the project?</td>
</tr>
<tr>
<td>Q19</td>
<td>What about your confidence in sponsoring research and development projects to the program after the capstone project? Why do you think it did? Was that because of the effectiveness of the project/program?</td>
</tr>
<tr>
<td>Q20</td>
<td>What are your thoughts about the mechanical engineering Capstone design program at Clemson University?</td>
</tr>
<tr>
<td>Q21</td>
<td>As a liaison was your time and sponsorship well spent during the projects you conducted with the students?</td>
</tr>
</tbody>
</table>

Table 9 shows the triangulation table for the company sponsors questions, the questions are triangulated based on the four categories discussed above.
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<th>Q1</th>
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<th>Q16</th>
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</table>

The interviews were converted into a transcript which can be found in APPENDIX A. The transcripts are used to develop summaries and generate patterns which will be discussed in the later chapters.

It should be noted that only ME 4020 project sponsors are interviewed in this thesis, as the motivation is to understand the viewpoint of the sponsors and faculty members related to the capstone design program of the Mechanical Department at Clemson University. However, the faculty members from different department and schools are interviewed to get to understand the viewpoints of other faculty members and understand the similarity or dissimilarity between department/school.
Chapter Four
INTERVIEW RESULTS

The summary of an interview data is a condensed version of the transcript that is generated from the interview recordings. It recapitulates the interviews conducted for seven professors and eleven company liaisons as discussed in Table 4. It should be noted that the summaries are based on what the interviewee has said or expressed his/her thoughts about the topic. Some of the summaries may not include answers to all the listed questions in Table 5 for the faculty members and Table 8 for the company sponsors.

4.1 Summary

The summaries for all the interviewees comprise of the information on the interviewee, information on the interviewees perceptions regarding the students projects and suggestions that they have from the challenges faced while undertaking the capstone design projects. It should be noted that the interviewee codes are used for the ease of writing.

4.2 Summaries for Sponsor Interviews

This section details the summaries for the interviews conducted with the external sponsors of the capstone design projects. It is based on these summaries and the transcripts of the interviews as found in Appendix A that the patterns are discovered. These will be discussed in Chapter Five. The summaries include a small table that describes the projects in which the sponsors were involved. Table 4 can be referred to find more information on the interview.
4.2.1 Parker-Co1

<table>
<thead>
<tr>
<th>Year</th>
<th>Projects description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Automated Rubber Banding</td>
</tr>
<tr>
<td>2013</td>
<td>MWB Vibration dampening centralizer</td>
</tr>
</tbody>
</table>

Information: Co1, has thirty years of experience in automotive field and has been with Parker since a year. The company sponsored two projects as shown in the table above. The first project was a piece of a bigger project, that the sponsor was trying to solve, and got interesting solutions out of it. The teams were well balanced in the first project than the second project. Because the company has lot of variations in their products, the student’s team have a great opportunity for a real world exposure. The company sponsor was impressed with the documentations with necessary prototype, USB sticks, and reports provided by the student teams of the second project. The sponsor is working on one team’s prototype to build an actual machine using the ideas of the team. The liaison had a great experience working with the teams on the projects.

Suggestions: From the experience with past projects, the liaison feels that the documentation procedure should be improved. The justifications given by the students regarding the usefulness of their prototype for a customer were a bit vague, which the sponsor feels is an area for students to improve on.
4.2.2 Parker-Co2

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Geothermal sealing system</td>
</tr>
<tr>
<td>2011</td>
<td>Automated seal splicing system</td>
</tr>
<tr>
<td>2012</td>
<td>Automated rubber banding system</td>
</tr>
<tr>
<td>2013</td>
<td>MWB vibration dampening system</td>
</tr>
<tr>
<td>2014</td>
<td>Automated mandrel removal</td>
</tr>
</tbody>
</table>

Information: The following company sponsor has done five ME 4020 projects consecutively as a company liaison. The experience with all the projects was mostly positive and they have used three of the project’s solutions in bits and pieces. Also, the concept of multiple team is interesting which helps to combine ideas of different groups for a final solution. The sponsor is positive regarding the experience with ME 4020 and sees as a good publicity for parker. Other divisions of Parker located in other areas, have shown interest towards the capstone design program after looking the impact of ME 4020 on Parkers Anderson division.

Suggestions: The students should do site visits more often and see what they are creating or modifying which results into better project outcomes.

4.2.3 General Electric-Co3

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Wind turbine blade transportation redesign</td>
</tr>
</tbody>
</table>

Information: The interviewee has thirty two years of experience and is in the supply chain department of General Electric. According the liaison the teams had creative solutions and considering their expertise in the field, the liaison was satisfied with their work. The incentive of sponsoring the project was to get new ideas from an outsider
unknown of the company’s internal problems with the equipment. The liaison still had the reports from the students and on how well the reports were written. The liaison had schedule conflicts and that is why the project was unable to move forward. The liaison also mentioned about his spending less time with the student teams and also mentioned that the project could have been better if the liaison would have spent more time interacting with the student teams and has shown interest to sponsor project relating to his field in future.

Suggestions: The project with a good challenge should be related to the course work of the students. Also, there should be a periodic dialogue between the involved faculty member and the company liaison on the projects progress concluding with a feedback on the project scope, which the company liaison felt missing in this project.

4.2.4 Okuma-Co4

<table>
<thead>
<tr>
<th>Interviewee: Michael Lail(Co4)</th>
<th>Interviewer: Varun Rawal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Project Description</td>
</tr>
<tr>
<td>2011</td>
<td>Reinventing the Computer Numeric Control tool way cover.</td>
</tr>
</tbody>
</table>

Information: This company liaison has sponsored one project in 2011 and the transcript is not provided for confidentiality purpose. The company sponsored the project with an intention to get better design by improving the existing machine. The presentations and professionalism of the students were good. The solutions of different teams were conceptual, but the liaison was disappointed with the solutions as they were not manufacturable at all.

Suggestions: The liaison felt that the students should spent more time investigating the feasibility of their solutions rather than developing concepts. The multiple teams doing
a project can be done in way that, initially three months all the teams should work individually for a same project then the later three months they should work together combining different solutions that they came up initially, this way the final results can be achieved faster.

4.2.5 Schneider/SquareD-Co5

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Designing measurement system for heat dissipation in electrical equipment</td>
</tr>
</tbody>
</table>

Information: Co5 has eight years of working experience and was not directly related to the project discussed in the above table. The four teams submitted final prototypes to the company for testing - out of which three groups came with different proposal and ideas. Moreover, according to the liaison sponsoring of the projects depend upon the company policies and management, and the company sponsored the project because the management at that time wanted to have more interaction with the next generation in order to absorb it to the company. The presentations were also good and convincing according to the liaison.

Suggestions: The students should have interpersonal skills in order to gain necessary information and data from the company for their projects.
4.2.6 Techtronic-Co6

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Jigsaw tracking improvement</td>
</tr>
<tr>
<td>2013</td>
<td>Self-feeding nailer.</td>
</tr>
</tbody>
</table>

Information: This company liaison has been guiding the ME 4020 students in the sponsored projects shown in the above table. The company liaison thinks highly regarding the students’ deliverables and the most important incentive as a company to sponsor the projects is to get return on investment for. The company has got return on investment as it has sponsored ten projects to the ME 4020. The liaison has a strong requirement of prototypes at the end of the projects, which helps the company in knowing and understanding the solutions more clearly. There is a patent bought by the company from a past ME 4020 project.

Suggestions: In order for the projects to have better outputs the involvement of the company liaison is necessary. The presentation skills and time management of the undergraduate students are a little bit off the line as said by the liaison.

4.2.7 Corning-Co7

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Design of armor tape curling fixture</td>
</tr>
</tbody>
</table>

Information: The company liaison has thirty one years of experience in his relevant field. The company tested one of the solutions which was unique out of four solutions provided. The presentation skills of the teams were very well expect one team. The liaison
feels that motivation as a company comes from someone in the company, who is convinced by the value that comes out of the capstone design program.

Suggestions: The project scope should be appropriate which should not include the students delivering something that is a huge breakthrough to the company.

4.2.8 Techtronic-Co8

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Impact driver noise reduction</td>
</tr>
<tr>
<td>2010</td>
<td>Jigsaw tracking improvement</td>
</tr>
</tbody>
</table>

Information: The liaison has done several project consecutively for five years with ME 4020, and they have used bits of the several projects. There is a patent bought by the company from a past ME 4020 project. The impression that the past projects have created a positive impression and motivated the liaison in sponsoring projects in later years.

Suggestions: The projects should have prototypes as a necessary deliverable, as a proof of their concept. The time management is another aspect that the student need to learn while undergoing sponsored projects.

4.2.9 BMW-Co9

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Plug installation tool</td>
</tr>
<tr>
<td>2014</td>
<td>Design of low cost Automated Guided Vehicle (AGV)</td>
</tr>
</tbody>
</table>

Information: The company liaison has nineteen years of experience working with BMW and has done four projects with the ME 4020. The liaison is impressed with the presentation skills of the ME 4020. There were prototypes provided by the teams in AGV
project, however they still want to continue getting new ideas to reduce the cost of AGV and Technical College in Greenville with continue building those.

Suggestions: Multidisciplinary projects are more relative to the real world experience for the students and the company can sponsor more projects if there are multiple fields involved in the ME 4020. Also the idea of a design expo from the ME 4020 projects is worth considering, which can be a good visibility to other company sponsors about the value coming out of the capstone design program.

4.2.10 Michelin-Co10

<table>
<thead>
<tr>
<th>Year</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Development of a lunar wheel</td>
</tr>
<tr>
<td>2007</td>
<td>Design of tweel for inline skate</td>
</tr>
<tr>
<td>2008</td>
<td>Design of polyurethane and rubber interface</td>
</tr>
</tbody>
</table>

Information: The liaison has thirty four years of experience and is involved in multiple projects with multiple universities. The projects yielded new ideas and creative solutions which impressed the liaison. One of the project related to the cutting sections of the tires had teams working on different aspects and this worked out well. The lunar wheel project that the company did had three patents filed and Michelin is working with NASA and has actually developed it. Out of all the projects. The liaison is less impressed with fancy presentations and more by the technical results.

Suggestions: The project scope should be small meaning that it is challenging for the undergraduate students to deal with a project that requires them to design a fully functional final product and install in a manufacturing run. The student are less adapt in
using heavy and sensitive machineries and should be given projects having safe environment.

4.2.11 Michelin-Co11

<table>
<thead>
<tr>
<th>Interviewee: Tracy Crews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviewer: Varun Rawal</td>
</tr>
<tr>
<td>Year</td>
</tr>
<tr>
<td>2004</td>
</tr>
</tbody>
</table>

The following interviewee has done a single project as discussed above. The interviewee is working in Michelin since 24 years and has done this project in order to seek creative solutions to the problem. The interviewee is satisfied with the efforts and creativity implemented by the students. The ideas given by the team were not too concise to implement them into an industry, though the creativeness of the project was efficient. This project was challenging to achieve and hence the company did not implement the solutions.

4.3 Summaries for faculty members’ interview

This section provides the summaries for the six faculty interviews. It is based on these summaries and the transcripts of the interviews as found in Appendix A that the patterns are discovered. These will be discussed in Chapter Five.

4.3.1 Clemson-Mechanical-Fa1

Information: The faculty member Fa1, has a teaching experience of 12 years in Clemson University and has advised 35 capstone design projects. The faculty member was a head of the ME 4020. The faculty thinks highly about the capstone design program considering it as a last gate for the faculty member to check the application of students learning. The students get exposure to the companies and develop skills such as
communication and managing the project resulting. Most of the students get coops and internships because of the projects. With multiple teams involved in a project, the companies can get to know and interview twenty undergraduates at a time and they can have multiple solutions to the projects they sponsor. The far distance projects are somewhat challenging to handle logistically and there is a difficulty in communication. The faculties have a benefit of learning the company culture, eventually help them to get research projects. The worth point noting is that the companies keep coming back because of the impact of the past ME 4020 projects.

The biggest constraint that the interviewee described was the lack of faculty participation for the ME 4020 projects. The overall experience of the capstone program serves beneficial to the company, faculty and students. The synchronization is also pretty good between them, which make the projects successful.

4.3.2 Clemson-Mechanical-Fa2

The faculty member is teaching a design course since 2005. The faculty member is the current head of the ME 4020. The capstone program is very critical, which enables the students to apply all their previous course work and gives them an opportunity to address open ended problems. For a project to be good, there should be a champion who cares and has got a proper project scope regardless of whether the project is company sponsored or a student defined. There has been instances where the faculty member reduced the sponsorship fee because of the fact that the project was good. Multiple teams working on a same project mitigates risk and increases chance of successfully coming up with the solutions. The overall experience with the capstone design program is great and there is a
huge value to the companies as they keep coming back. The other motivation as a company to sponsor the projects is in developing strategic partnership with the universities.

The access to working spaces and resources are a challenge in terms of the infrastructure, moreover the faculty members sees a challenges with student being less adapt with mechatronics and electronic aspects of the projects.

4.3.3 Clemson-Bio Engineering (BioE)-Fa3

The following interviewee is a professor in Bio-Engineering (BioE) Department of Clemson University and is teaching since 2009. The faculty member is in the advisory group for the capstone design program in BioE. The structure of the course in BioE is a yearlong format, where students have to go through six gated namely; needs finding, proposal to validate the need, deep dive into prior research, prototype production plan, verification and validation and results. The students also should give justifications for their project funds spent. The idea of company sponsoring a project is not satiable for the BioE department as students want to come up with their own needs and do their own projects, while company projects limit their entrepreneur potential as well. There was one group in 2012 who designed shoulder brace device and started their own company. Moreover, there is a time sink for faculties to find companies with appropriate project scope and marinating documentation. The faculties use this program to iterate the class structure and have often developed research projects from their capstone projects. They have also got patents out from the projects.

The BioE department acts as a bridge between the companies and doctors in terms of finding needs, because of the conflictive interests the companies are not allowed to
communicate directly with doctors regarding the needs. Overall, the faculty member is satisfied with the program being less company sponsored and more student oriented.

4.3.4 Mississippi State-Mechanical-Fa4

The following faculty member has a three years of experience with design course in the Department of Mechanical Engineering at Mississippi State University. The faculty has done at least twenty five projects. The faculty has served as the facilitator for the capstone program which includes working with companies, other faculty members and the students. The capstone program is an opportunity for students to experience a real world problems in a relatively safe environment. The faculty member developed the course as a corporate setting and students were required to perform professionally while communicating and presenting their solutions to the program managers. The relationship between University and Companies should be symbiotic for a project to be successful. The motivation for a company to sponsor the project is to look for potential hires and get creative solutions to their problem.

As being facilitator, the faculty members feels there was a less amount of participation by the other faculties because of conflictive schedules with their researches. This less participation hinder the iterative loop of getting feedback regarding the students learning. There were couple of successful projects and a paper mill project was actually implemented by the sponsoring company. The faculty also expresses a great support for the students doing the projects and has defended them against the company sponsors on multiple occasions because of their level of efforts put in the projects.
Overall, the faculty member is satisfied with the student’s projects and feels the same about the companies that sponsors the projects, however the faculty is quite disappointed with other faculty members’ participation in the capstone design projects because of schedule conflicts.

4.3.5 Clemson-Industrial-Fa5

The faculty has a fifteen year of experience in teaching students and has undergone capstone projects since 2000. According to the faculty, capstone program is a visible demonstration to the company regarding the potential of the university and students. The student projects should be correctly scoped and large enough to offer challenge to the students. The faculties use the projects to evaluate their curriculum and have made necessary changes in their curriculums as well. The department gets sponsorship for the projects from local companies and Greenville hospital. They also did a successful project with Greenville hospital regarding patients waiting time. The companies keep coming back for more projects because of the value they get from the sponsored projects.

The faculty is content with the student’s outcome and strongly believes that the projects should have a real sponsor in order to have real world implications. However, the faculty is very cautious with the project selections and finds it unnecessary to take projects that are easy for the students to undergo.

4.3.6 Colorado-Mechanical-Fa6

The following faculty member is a professor in the Department of Mechanical Engineering at Colorado School of Mines and has been involved in capstone design
programs since 1997. The faculty also headed the program at Colorado School of Mines for three years. The department has sixty percent of multi filed projects, which replicate the real world more closely and students can learn from other disciplines.

According to the faculty, the students should learn from the real world experience they are getting by doing the capstone projects. The students should learn from their mistakes as it is their last chance to fail in a controlled environment. There was a far distance project done in Antarctica which went well and shows that a well selected project with a responsible company sponsor are the main reason for a successful project.

The faculty member perceives that the companies’ sponsors project because capstone design program is an economical engineering and as a professional responsibility. The faculty believes, the projects that companies sponsor, should be back burners which are not in their critical paths. The students cannot create a product that saves the company as the main reason of a capstone project is training the students for a greater good.
After analyzing the transcripts and summaries of the interviewees, it was observed that a close relationship exists between answers obtained from different respondents and answers from the same respondent (found through triangulation). These topics were defined as patterns, and described below. It should be noted that the patterns were based on the responses of the interviewed faculty members and company liaisons. Moreover, the responses of the faculty members were based on the experiences obtained from projects that they have advised thus far, while the responses from the company liaisons were based on the ME 4020 capstone design projects with which they have been involved.

5.1 Project Outcome (P1)

This set of patterns takes into account answers from the faculty interviewee regarding the program outcomes. This following set of patterns are related to the research question.

5.1.1 Pattern 1a

The response regarding the expectations of the interviewed faculty members on the deliverables of the students from the project is included in this pattern. This can show what the faculties think the student should deliver from the projects and can be compared with the company sponsors responses about those deliverables. It eventually helps the faculty members in determining the effectiveness of the ME 4020 program. This effectiveness can help as a visual proof to show to the potential sponsors, about how well the students perform in the program and the results the companies can get after sponsoring.
5.1.2 Pattern 1b

The response of the faculty interviewees regarding the benefits that students get in participating in the ME 4020 project are discussed in this pattern. This helps in answering the faculty members’ view on the motivation as a student to undertake the capstone design program. This can be compared with the company sponsors view on the students’ benefits and it helps to show the students the value that can get in doing capstone project.

5.1.3 Pattern 1c

The following pattern includes the responses of the interviewed faculty members regarding the motivation as a company to sponsor senior year design projects. This pattern is useful to understand the faculty members’ perception on the motivation of companies to sponsor the projects. This is a cumulative perception of all the faculty members interviewed, which helps in comparing with the company sponsors perception on the motivation side of the capstone program, eventually helps in showing the alignment and which helps the reader understand the alignment between the responses. If there are new motivation found that are specified only by the company sponsors, than the faculty members can understand the real motivation and market their program based on that.

5.1.4 Pattern 1d

This pattern is based on the faculty member’s perception about the value of the capstone program for academia/faculty. This pattern makes the faculty members understand the value that they can get with the capstone program and eventually motivating the other faculty members to participate more in the program.
5.2 Project Impact (P2)

This set of patterns includes the responses of the interviewed company sponsors on the deliverables by the students and impact of the student projects with the benefits as a students in doing the company sponsored capstone projects.

5.2.1 Pattern 2a

The viewpoints of the sponsors regarding ME 4020 projects and its value as a student were encompassed in this pattern. This pattern is a cross checking on the responses of the faculty members on the student benefits. Owing to this the faculty members can understand the real benefits the students can get from the capstone design program. It can help in motivating the potential student undergoing the capstone program.

5.2.2 Pattern 2b

This pattern includes the impact of the capstone program in a company, the company sponsors responses on the student deliverables of the ME 4020 projects. This is again used to compare with the faculty members responses on the student deliverables and show the real effectiveness of the student projects in the companies. This is considered to show the overall effect of the ME 4020 program on the companies. This can help the faculty to show a written proof of the results got by the selected companies and use this as a factor in marketing for potential sponsors.

5.3 Motivation for Sponsorship (P3)

This pattern is aligned to the company sponsor’s responses relative to the motivation as a company to sponsor projects in the capstone design program. It is used to
show the alignment between the faculty members’ responses on the motivation that the companies have in sponsoring the projects. It will lead to make the faculty members understand the real reason as to why the companies sponsor the projects. This pattern is related to the Research Question 1 which is based on the perceptions of the company sponsors on the capstone design program.

5.4 Professionalism (P4)

This pattern includes the responses of interviewed faculty members and company sponsors on the level of professionalism they have observed in the teams through the past projects. These include the students’ presentation skills and how teams work together to successfully complete a project. This pattern helps in showing the company sponsors, the level of professionalism the students have. It also helps the faculty members to confirm if the students are developing professionally by comparing it with the interviewed company sponsors response on the professionalism of the ME 4020 project students.

5.5 Program Features (P5)

The following set of patterns consists of responses from all the interviewees on the project selection for a capstone design program and other features of capstone design projects. This pattern directly relates to the third research question which is about the alignment of the faculty and company sponsors perception on the capstone design program.

5.5.1 Pattern 5a

The scope of the projects (i.e. project latitude and dynamics) is discussed in this sub pattern. Selecting an appropriate project is a crucial part in the capstone program and
this pattern helps in identifying the responses of the faculty members and the company sponsors regarding the project selection for capstone. This can help the faculty members identify the types of projects that are looked upon by the company sponsors.

5.5.2 Pattern 5b

The multi-team project inclusion is discussed in this pattern. This helps in understanding the feasibility of multiple team projects that are undergone in the ME 4020 program.

5.5.3 Pattern 5c

This pattern discusses the aspect of long distance project sponsorship. This is useful to know the feasibility of far distance project, helping the reader/faculty understand the factors that come along with far distance projects and eventually make decision on taking up far distance projects.

5.5.4 Pattern 5d

The following sub pattern is based on the responses of the interviewees on the interdisciplinary project dynamics. This is included in order to highlight the responses on the interdisciplinary projects.
5.6 Corroborations

There are three types of corroborations identified for the responses in the patterns: the internal corroboration, external corroboration and cross corroboration.

![Diagram of corroboration types]

**Figure 5 Corroborations of pattern**

As shown in Figure 5, when two or more professor’s responses related to the same topic in a pattern it was considered an external corroboration for the faculty members. When two or more interviewed company liaisons responded related for a same topic in a pattern, it was considered an external corroboration. If the same pattern was observed two or more times for a single faculty member’s answer then it was considered an internal corroboration for that pattern. Similarly if an interviewed company liaison responded to a single response to a pattern twice or more, it was considered as an internal corroboration. Cross corroboration was defined when a company sponsor and a faculty member responses
were the same, relating to a pattern. However, internal corroborations are not considered in the pattern discussions. The responses which have at least three external corroborations from faculty members and company sponsors were considered to be a strong response. This is because if a cross pattern/cross response that counters the already considered strong response, is found in a transcript from any interviewee then it is mentioned exclusively.

5.7 Pattern Findings

Transcripts of six faculty members and eleven company sponsors were used for constructing the table below and the respective faculty and company sponsored codes can be found from Table 4. In Table 10, patterns 1a, 1b, 1c and 1d are constructed based on the transcripts of faculty members responses, while patterns 2a, 2b and 3 are constructed based on the transcripts of company sponsors responses. The patterns 4, 5a, 5b, 5c, 5d are common and are constructed using the transcripts of faculty members and company sponsors.

The number of unique responses from the interviewee for a particular pattern are counted and shown for all the interviewees and all the patterns. For instance, the cell Fa1:1a shows that the interviewed faculty member 1 has responded for the pattern 1a twice during his interview and each response is a unique answer. It should be noted that the two answers are unique and multiple instances of each answer in the transcript were not counted in this table. Similarly the remaining cells were constructed using responses from all the interviewees. It should be noted that all the unique responses given by an individual interview regarding a pattern are not given. The responses that have a significant external corroborations are discussed in the later pattern discussions.
Table 10 Pattern Summary

<table>
<thead>
<tr>
<th>P</th>
<th>Fa 1</th>
<th>Fa 2</th>
<th>Fa 3</th>
<th>Fa 4</th>
<th>Fa 5</th>
<th>Co 1</th>
<th>Co 2</th>
<th>Co 3</th>
<th>Co 4</th>
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Legend: F – Frequency of the responses for a single pattern, P – Pattern

5.7.1 ME 4020 Program Discussion

The following discussion is based on the responses of the ME 4020 faculty members Fa1, Fa2 and the eleven company sponsors for the ME 4020 projects. It will show the faculty views for the benefits as a company in sponsoring the projects and the company sponsors view for the benefits as a company in sponsoring the projects. This benefits are what the company sponsors respond, they can get from sponsoring the projects.
5.7.1.1 Faculty members responses on the benefit as a company sponsor

Table 11 is the faculty members’ response on the company sponsor benefits in sponsoring the projects.

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Fa1</th>
<th>Fa2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies getting new ideas and getting their problems solved for economy</td>
<td>Companies benefit from multiple solutions for their problems and the multiple solutions offer up new ideas</td>
<td>Get new ideas and economically solve open ended problems</td>
</tr>
<tr>
<td>Building the relationship with academia</td>
<td>Reputation in terms of building relationship with the university and the companies can know available resources and research done in the university</td>
<td>Companies benefits from building strategic partnership with university</td>
</tr>
<tr>
<td>Building employment pipeline</td>
<td>Benefits of interviewing twenty engineers with a single project</td>
<td></td>
</tr>
</tbody>
</table>

According to Fa1, companies get multiple solutions for their problems and the multiple solutions offer up new ideas. It helps companies to market them in the department. After the capstone course, industries get new and professional engineers to work for their company. The students doing the projects might consider the companies as a possible option for them to work. Local companies can know the quality of the students in Clemson University and they have a chance of interviewing twenty engineers at a time by sponsoring a single project.

Companies can also know different available resources and research being done on campus, which eventually helps in giving out research projects that are long in duration and eventually developing long term relationship with the university.
The faculty Fa2 sees the benefits as a company in sponsoring the project in terms of getting new ideas and economically getting their open ended problems solved. The companies benefit from sponsoring multiple teams in terms of getting to interact with more students and successfully achieving the final solution with less risks.

5.7.1.2 Company sponsors responses on benefits as a company sponsor

The company sponsor views regarding benefits in sponsoring the program were found a lot more specific, the benefits are categorized as shown in Table 12. The benefits are divided into three main sections: quality output, saving company money and time and company publicity.

Quality output is a generalized term in which the output can have different aspects. It includes the output in terms of new ideas and creative solutions, solving small problems which are linked to a big problem within the company. It helps the company get outside thinking when they run out of ideas and do not want to recycle the old ones. It is a faster way to solve problems that are not time sensitive. The company can link this to their continuous improvement policies.
<table>
<thead>
<tr>
<th>Benefits</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality output</td>
<td>C01,C02,C03,C04,C05,C06,C07,C08,C09,C10,C11</td>
</tr>
<tr>
<td>Quality output from multiple teams</td>
<td>C01,C02,C03,C04,C05,C06,C07,C09,C10</td>
</tr>
<tr>
<td>Company visibility (publicity)</td>
<td>C01, C04,C05, C06, C07, C08, C09, C10</td>
</tr>
<tr>
<td>Saves money from outsourcing</td>
<td>C01, C09, C04</td>
</tr>
<tr>
<td>Saves money from hiring full time engineers</td>
<td>C01, C011</td>
</tr>
<tr>
<td>Saves money and time from allocating research group for small projects</td>
<td>C02, C010</td>
</tr>
</tbody>
</table>

The quality output that the companies get in sponsoring multiple team projects are multiple creative ideas for their problems and it also increases the likelihood of a usable output.

The other benefits that the sponsors see are saving their time and cost in outsourcing or hiring full time engineers to solve their problems. There are certain problems that are very small for research group to deal in terms of their time, these types of projects are conducive for the capstone program.

Furthermore, company visibility is another incentive that the company sponsors get in terms of publicizing their company in the university. The benefits can be, searching for potential hires within the teams doing the projects or an overall visibility in the school which spreads because of word of mouth from different students. This eventually help the companies, as there is an increase in the level of confidence as a student to work for the company.
The discussion comparing the responses of faculty members and company sponsors regarding the benefits the companies can get from the capstone program is shown below. It can be seen that, the faculty members Fa1 and Fa2 are having an alignment of thoughts with the company sponsors in the quality output and the company publicity that a company gets in sponsoring the projects. Fa2 has not responded about the companies’ benefits in searching for potential hires from the capstone program.

However, faculty members see benefits for company in sponsoring the projects in a general way. The company sponsors responses on the benefits are more focused, which are not mentioned by the ME 4020 faculty are discussed below.

The company time and cost that they save from sponsoring the projects are specified only by the company sponsors. This explains that economically getting new ideas is by saving time and cost from hiring full time engineers, outsourcing the projects or allocating the projects to research and development group. The other benefits of sponsoring the project as a company are the promotion of the companies’ continuous improvement policy. The companies that sponsor their projects to the capstone program, can either solve their problem or can save their time in determining why the problem cannot be solved. Also, there is benefit in terms of investing for multiple teams doing a project, either working on the same concept or working on different approaches to a problem. The incentives that the company sponsors get are more than one creative ideas and if the teams are working on different approaches, it can also lead to a final solution faster.

The faculty members for ME 4020 should also consider the benefits to solve the back burner projects for the companies. The projects that are important but are not in the
critical path of a company. The projects that are not time sensitive are conducive for the undergraduate students to work on because this reduces the baggage of the company to depend solely on the student team solutions.

Other benefit is saving the company sponsors time in proving the difficulty of a problem, as some problems are challenging to solve and undergraduate students can prove that with a minimal investment and a minimal time of six months.

On company visibility, they get output in terms of quality engineers to hire for their company. Checking for potential hire is a generalized term, in a sense that the companies either check the students that are working on the projects or they can also be checking the department as a whole, and the students in the department. They expect to spread their reputation by word of mouth from the students doing the projects.

Allocating multiple teams for a same project is an important aspect that comes out from this discussion. It depends upon the company sponsors requirement, if the requirement is to come up with a final solution and if the problem can be broken down into different aspects, then the teams working on different aspects in parallel will yield a final solution with less risks. For instance the project that was sponsored by Co3 dealt with improving the shipping of their turbine blades, which different teams looked at different aspects of the shipping. Figure 6 shows how teams are divided to solve the project for a final solution. It shows the first team looked the improvement of the shipping fixture on the rail, team two looked at road transport as a resource, and team three looked at improving the shipping fixture related to marine transportation. The final solution was in terms of the best fixture possible for shipping the turbine blades.
If the companies want to get multiple novel thoughts on a problem, then different teams working on a same project with same approach which can yield creative solutions faster, For an example Figure 7 shows when the team 1, 2 and 3 work on a same project they yield different creative solutions such as Solution 1, 2 and 3.

The other fact that is understood from the responses is that there should be someone in the company seeing a value in doing projects with the capstone program, which makes it is easy in terms of getting projects for the capstone program. The value of the program that a liaison sees depends on the relationship of the company and academia or the result from the past project. The value is a generalized term which can be the quality of output from the projects. The sponsor knowing the importance of the program as a company can

**Figure 6 Multiple team working in parallel**

**Figure 7 Multiple teams working for same concept**
be an alumina of the university and know what the program can deliver, as is the case with Co1, Co6. The liaison could be impressed with the overall visibility of the program and the efforts put by the faculty members in approaching for the projects.

The aforementioned benefits are the benefits from quality output and company publicity. However, the value in terms the financial output is not focused in this thesis. The financial output is the return on investment that the companies get in terms of money.

Table 7 shows that three companies have sponsored a single project, the reason about the companies not coming back to sponsor the project are vague. It shows that there can be a reason from the faculty members’ side in re approaching the companies because of already getting sufficient companies related the intake of the students. The other factors that can be considered are the location of the companies, change in company policy, or the liaison who saw a value in the program is no more working for the company. Okuma and Corning cables are located in North Carolina and have sponsored a single project until now which can be interpreted as a far distance challenge in sponsoring the projects and maintaining the relation with the department. Also, Square D/Schneider sponsor responded to have benefited with a near vicinity to the department, the company policy and management was responsible for sponsoring the project, which changed afterwards.

5.7.2 Pattern 1 Program Outcome

Pattern 1 is about the perceptions of the faculty on four topics: the students’ learning outcomes (1a), benefits as a student in working on company sponsored projects (1b), a company’s motivation in sponsoring a capstone design project (1c) and benefits to the faculty/academia from the capstone design projects. This pattern can be directly related to
5.7.2.1 Pattern 1a – Student deliverables:

The following pattern is based on the perception of the faculty members about the deliverables by the students for the capstone design program. This pattern includes the expectations from the faculty members regarding the program outcomes and students learning. After the pattern analysis there are seven unique responses found from all the faculty members’ interview transcripts. Table 13 shows three responses that were found to have validation from at least three faculty members, which means there are at least two faculty members who agree on a response for pattern 1a. It can be seen that Fa1 and Fa2 have a similar response on the practical application of the student learning on the projects and they expect the students to apply their learning to a real customer at the end of their curriculum.

<table>
<thead>
<tr>
<th>Pattern 1a Aspects</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical applications of learning</td>
<td>Fa1, Fa2, Fa4, Fa6</td>
</tr>
<tr>
<td>Ownership of project from definitions to final deliverables.</td>
<td>Fa2, Fa3, Fa4, Fa5, Fa6</td>
</tr>
<tr>
<td>Ability to carry out project analysis.</td>
<td>Fa2, Fa3, Fa6</td>
</tr>
</tbody>
</table>

Fa1 said “If you can do well in course work but you cannot fix a problem for a company, it means you haven’t really learned anything of value.” Also, Fa4 said, “Students
should be able to tie in all the course work into a particular project.” The discussion is about the learning that the students get from the program and it can be understood that the faculty members perceive the students outcome as application of their prior knowledge practically. This can be interpreted as, all the faculty members except one think that the value of the design courses can be tested only when the students are exposed to the actual environment. And in the capstone design course, the students must be able to carry out the project themselves, that is, be able to make choices and take responsibility of the decisions made.

The faculty member that seems not in alignment is Fa3, because the Bioengineering department at Clemson University, the faculty believes that the students prefer to undergo projects that are defined by the students which are then validated by the clinicians and not the companies. This shows a difference with the rest of the departments in a sense the other departments are in agreement of selecting real world projects for application of the students skills and curriculum knowledge from the companies and the facilitator or the head of the program defines the projects for the students and not the students itself.

Furthermore, Fa2 said that, “students have to work to move from problem definition to functional prototype at the end”. This means that the students should be able to take full ownership of the projects and they should be working their way on their own until the final deliverables. Fa3 said “Essentially if they are proposing to do something then they need to be experts in that particular field”. The following response can be considered as the knowledge that students have gained, which makes them expert in their field, the students should apply it and should make their own decisions in the project. The two responses
relate to the fact that in order to move from the problem definition to a final solution the students have to be experts, which is the prior knowledge they have gained, in their concept definition and the process they follow to yield the deliverables. This also means that the capstone program should be a last thing to offer in the undergraduate curriculum, as it tests their application ability to solve a real problem.

Fa6 said “There is an educational objective to teach them how to do projects themselves.” It can be interpreted from this response that, there is a slight guidance from the faculty member side to the students doing the projects in terms of teaching how to tackle the projects, but not working with them in terms of delivering the solutions. However, on guidance, the other faculties have not stated explicitly on guiding the students in their projects. This can be considered as a minor aside.

Fa6 said that “In terms of grading there is an element that, did the students satisfy what the client asked for and if they failed to satisfy the client it is not impossible to get an A but the students will have to explain why were they not able satisfy the client sufficiently.” This response highlights the fact that the students should learn to be goal oriented and the goal is to satisfy the clients. To satisfy the clients the students have to apply their prior knowledge to meet the requirements. If they are not able to satisfy the requirements then they should know how to justify on not meeting the requirements. This also points to the same direction that the students should have to ability to think critically and drive the project with the help of their prior knowledge.

The Fa1 and Fa2 faculty members belong to the Department of Mechanical Engineering at Clemson University, Fa3 belongs to be Department of Bio Engineering at
Clemson University, Fa4 belongs to the Department of Mechanical at Mississippi State University, Fa5 belongs to the Department of Industrial Engineering at Clemson University and Fa6 belongs to the Department of Mechanical Engineering at Colorado School of Mines. It is seen from the Table 13 that there is a similarity in responses for student deliverables regarding applying their knowledge from the problem definition to final deliverables. There is a slight aside with the Bio Engineering Department, as the faculty member responded to have students finding their own needs and working their own way to find those needs and getting their own problem definition.

The significant difference that can be seen is the practical application of the students learning. All the departments except the Bioengineering Department perceive that the students in order to apply their learning practically, should do company sponsored projects. While the Bioengineering Department perceive that the students should learn to exhaust their project completely on their own by coming up from the need to the final deliverable with a guidance and validation from the faculty and the clinicians, which are not company sponsor.

It is interpreted from this pattern that, the students should apply their prior knowledge and think critically by applying their analysis skills in the capstone program.

5.7.2.2 Pattern 1b - Students benefit in undergoing the capstone projects:

This pattern covers the views of the faculty members about the benefits to the students when they carry out senior year design projects. Table 14 shows five responses having an external validation with more than two faculty members confirming to these responses. The two ME 4020 faculty have the same opinion on the students benefits in the
industry exposure of solving real world problems. Fa2 responded that there should be a champion for the students’ capstone design projects and Fa1 responded that there should be a real sponsor for the student’s capstone projects. This can be a difference between a project champion and a real project sponsor because the project champion need not to be an industrial sponsor.

Table 14 Pattern 1b

<table>
<thead>
<tr>
<th>Pattern 1b Aspects</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry exposure—solve open ended problems</td>
<td>Fa1, Fa2, Fa4, Fa5, Fa6</td>
</tr>
<tr>
<td>Opportunity for future employment from project sponsor</td>
<td>Fa1,Fa5,Fa6</td>
</tr>
<tr>
<td>Chance to apply learning in a controlled environment.</td>
<td>Fa1,Fa2,Fa4,Fa6</td>
</tr>
<tr>
<td>Opportunity to work on professional development.</td>
<td>Fa1,Fa3,Fa4,Fa5</td>
</tr>
</tbody>
</table>

Fa2 stated that, “The capstone program provides the students an opportunity to address open problems and interact with practicing engineers.” Also, Fa5 said “benefits for students is that they are placed in a non-typical academic environment having a real world problem to work on with no text book to teach how to answer it.” This means that the students benefit in experiencing a real world scenario, as the problems are open ended with no clear solution and no specific methodology to solve them. This also means that the open ended problems help the students to think critically, as there is no written text book to solve a problem that they get in assignments. This can also be interpreted as, the students should do company sponsored project in their capstone design program in order to gain a real world experience. Apart from these two faculty members, even the faculty members Fa1,
Fa4 and Fa6 are in alignment with the fact that the students benefit from the exposure to the actual industry and from a chance to solve unknown problems.

Regarding students’ potential for a solution deficit, Fa6 sees this as a positive chance of working in a controlled environment, “Students have enough latitude in the capstone design program where they can make some of their own mistakes and learn from it.” Similarly, Fa1 said, “The capstone design program allows a chance for the students to fail in a controlled environment and if their prototypes don’t work they are not going to be fired.” This means that even if the students fail in delivering their proposed outcomes, they still can learn and justify what went wrong without costing them their job. It highlights the fact that, capstone design program is the best way that the students can test their ability and apply their learning to solve open ended problems without any contingency that if they do not deliver what is expected they might lose their jobs.

Faculty member, Fa3 was having different thoughts apart from the others on the idea of students working on a company sponsored projects. Fa3 said “students do not like the guidance from the company sponsors and want to pick their own choice of projects. Also, students find the idea of designing a solution for a company sponsor to be limiting in terms of their entrepreneurship potential”. This means that the faculty member of Bio Engineering Department believes that the students rarely prefer doing company sponsored projects because they prefer to choose their own problem and find needs on their own. However, this response is relative to the Bioengineering Department at Clemson University, which definitely show a difference in the perceptions between two departments regarding the students doing company sponsored projects, but as the focus of this thesis is
the ME 4020 it is considered as a difference of opinion within the Department of Bioengineering and the rest of the departments.

Apart from Bioengineering, the other department and schools agree to the fact that the students benefit from doing company sponsored projects.

It can be suggested from the strong validated responses in the table and the above discussion that students benefit from the experience of a real world scenario in a controlled environment and benefit from solving open ended problems through company sponsored projects. The students also get the opportunity for a future employment from the sponsor.

5.7.2.3 Pattern 1c - Motivation as a company in sponsoring the capstone projects:

This sub pattern takes into consideration the opinion of faculty members regarding the motivation as a company to sponsor the capstone design projects. The unique responses with external corroborations are summarized as shown in Table 15.

According to the below table, capstone design projects are attractive to companies for sponsorship for the following reasons: they feel it to be a professional responsibility, it provides access to qualified students for a potential future employment, capstone generates new ideas, and it provides an economical means for low priority engineering problems.

Fa1 and Fa2 are aligning with the motivation as company in seeing the capstone as a business model to solve their problems economically. This means that the companies sponsor the projects because it can save their time and money in solving their problems. They also respond that the companies sponsor the projects to build relationship with academia. However, Fa2 has not responded on the companies using this as a tool for direct employment of the students doing the projects.
Table 15 Pattern 1c

<table>
<thead>
<tr>
<th>Pattern 1c Aspects</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business model</td>
<td>Fa1, Fa2, Fa5, Fa6</td>
</tr>
<tr>
<td>Future employment</td>
<td>Fa1, Fa4, Fa5, Fa6</td>
</tr>
<tr>
<td>Looking for new ideas</td>
<td>Fa1, Fa4</td>
</tr>
<tr>
<td>To build relationship with academia</td>
<td>Fa1, Fa2, Fa3, Fa4, Fa5</td>
</tr>
</tbody>
</table>

Fa5 said that “The companies are getting tremendous value on getting important problem solved for very little amount of money.” The response means that there is a value in doing capstone design projects because, what comes out from the program is far more than what the companies invest. This can also be seen in the other faculty member’s view point where it is said that capstone program is a way to invest in improving the process of a company. This can be seen in the response of Fa6 who said “We help the company reinvent itself so capstone design becomes investment of the company’s profession, investment of company in its performance and process that is why the companies sponsor the projects.” This discussion highlights the fact that the companies who do not want to invest a lot in solving their problems on their own, rather prefer investing in the capstone design program. Investing a lot can mean the investment in hiring full time engineers or outsourcing the projects.

Fa1 said, “The main motivation is the ability to have access to the undergraduate students because there are companies locally that are going to be hiring engineers”. Also Fa6 said, “the first reason the companies should sponsor the project is to develop the employment pipeline”. It can be understood from the responses that the faculty thinks that another motivation for the companies in sponsoring the projects, is to indirectly interview
capstone project students for a potential employment in their firm. The other way to interpret this is that apart from career fair the companies use capstone design program as a chance to hire future employees. Also, Fa2 said, “Realistically speaking, often a times the companies have got strategic partnership with local institutions and so they are trying to increase these partnership”. This response highlights the fact that the faculty member perceive that the industries have an incentive to build relationship with the academia. This incentive can be indirectly linked to the fact that the relationship building is an overall motivation to check the potential of the department and the students.

Also it was seen that small companies have a challenge in sponsoring projects to the capstone program as said by Fa3 “Smaller companies do not have a year to sit on a project and in one year the entire reason of doing it could change or another company could have come out with an innovative design” This can be interpreted as the capstone design project is funded by large scale companies and not the small scale companies. However there are no other answers to this pattern hence it is not considered as a counter response for this whole pattern rather a slight aside. Nonetheless this cannot be considered as a significant factor for this pattern.

From this pattern, it is considered that there is a general agreement on the faculty members except the faculty from the Bioengineering Department at Clemson University regarding the motivation for a company to sponsor the capstone program, as a low investment solution for their back burner problems and for companies that are consequently looking to build academic relationship. The back burner problems are the problems which
are not time sensitive and are the optimum sized project in terms of duration and complexity which help the companies in continuous improvement.

It is suggested that the best motivation for a company to solve backburner problems is by sponsoring the capstone design program. And even if they do not get all the requirements met, they still can get new ideas and a chance to check the ability of the future generation in terms of their potential hires.

5.7.2.4 Pattern 1d – Benefits to the academia/faculty from capstone projects:

The following pattern discusses the value that faculty/academia get from the capstone design projects. Table 16 summarizes the strong responses from the Pattern 1d.

Fa6 said that, “Every department rely on senior design to support the assessment of their degree. This means that as a department the capstone design program is a way to evaluate the effectiveness of their degree curriculum. Also Fa5 said, “Faculties benefit, it is both feedback and information on what we are teaching but also potential relationship to industry. This can be interpreted as, the faculty members take feedback from the capstone design program in order to implement necessary changes in their curriculum. This can also be interpreted as the capstone design program is a way of maintaining and increasing the relationship with the companies that sponsor the projects. Again, Fa4 said, “There was a less participation from the faculty stand point in terms of offering projects and then take the feedback and evaluate the undergraduate curriculum”. This shows that getting the feedback is not only a value in terms of making necessary changes to the curriculum but also an important deliverable expected from a faculty member. It also highlights the fact that, maintaining a full circle evaluation of the program without any disconnect in the
iterative loop is important. Also, Fa2 said, “Often a time companies have got strategic partnership with local institutions and so they are trying to increase these partnership also in general faculties get to interact with the folks and it could possibly lead to research projects.” Also, Fa4 added saying, “We had couple of projects with faculty members that went right into their research areas” This means that the capstone projects help faculties in their research project by giving them ideas for potential research projects or helping them in their current research projects. This can be understood as, the academia and faculty benefit from the capstone project in terms of building relationship with industries leading to get more projects within the department.

It is understood from the above responses that getting feedback from the capstone projects is not only a value added in terms of assessing the curriculum but also an important deliverable from the faculties.

It is understood from this pattern that there is a significant value from the capstone projects as a faculty member. It is not only a potential visibility of what the whole degree program is capable of, which helps in building stronger relationship with the industry, but also a way to evaluate the curriculum.

From the below table, it can be seen that the schools and the departments are in an agreement of the benefits as a department/faculty in undergoing the capstone design projects.
Table 16 Pattern 1d

<table>
<thead>
<tr>
<th>Pattern 1d Aspects</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take feedback from the projects and implement necessary changes in curriculum</td>
<td>Fa1, Fa2, Fa3, Fa5, Fa6</td>
</tr>
<tr>
<td>The projects help in developing research projects</td>
<td>Fa1, Fa2, Fa3, Fa4, Fa5</td>
</tr>
<tr>
<td>Better relationship with the industry</td>
<td>Fa1, Fa2, Fa3, Fa4, Fa5, Fa6</td>
</tr>
</tbody>
</table>

5.7.3 Pattern 2 Project Impact

The following patterns are based on the company sponsors perception on the student’s deliverables and impact of the student’s project. It also covers the responses of the interviewed sponsors regarding the students benefit in participating in company sponsored capstone projects. It should be noted that the responses of the company sponsored are based on the experience with the ME 4020 projects.

5.7.3.1 Pattern 2a – Benefits of students:

The following pattern includes the company sponsors perceptions on the value as a student in doing company sponsored projects. The information is summarized in Table 17.

Table 17 Pattern 2a

<table>
<thead>
<tr>
<th>Pattern 2a Aspects</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience to real world problems</td>
<td>Co1,Co2,Co3,Co5,Co7</td>
</tr>
<tr>
<td>Application of the students learning</td>
<td>Co2,Co3,Co5,Co7,Co10</td>
</tr>
<tr>
<td>Students learn time management</td>
<td>Co6,Co8</td>
</tr>
</tbody>
</table>

Co5 said, “Our focus is that the students who are graduating understand the real industry problems and implement some solutions to help solve the issues”. The response
means that the students, after undergoing company sponsored projects benefit from understanding the real world issues. This can also interpret that the companies do not expect from the students to solve the complete problem. Moreover on getting hands on practice with tools Co3 said that “It is a good chance to exercise analysis and practice tools using the FEA techniques which helps bringing a real world problem.” Also Co7 said, “The students get a chance to work on open ended problems that we give rather than a problem out from a book or a school project which is pretty well defined.” This response highlights the fact that the problems found in the books are properly defined while the real world problems have a lot of unknowns to deal with and doing a sponsored capstone project is a best way to practice this open problems for the graduating students.

It is interpreted from this pattern that the company sponsors offer open ended problems to the capstone program and student’s benefit from applying their knowledge by delving into real world issues, as the open ended problems are different from the problems they find in their course work.

5.7.3.2 Pattern 2b – ME 4020 Project deliverables:

The following pattern is based on the company sponsors perception on the student’s deliverables and impact of the student’s project on the companies. Table 18 is the summary of responses that were collected from all the company liaison interviewees.
Table 18 Pattern 2b

<table>
<thead>
<tr>
<th>Pattern 2b</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reports and documentations provided</td>
<td>Co1, Co2, Co3, Co4, Co5, Co9</td>
</tr>
<tr>
<td>Solutions were satisfying the requirements</td>
<td>Co1, Co2, Co3, Co5, Co7, Co8, Co9, Co10</td>
</tr>
<tr>
<td>Obtained creative solutions</td>
<td>Co3, Co6, Co10</td>
</tr>
<tr>
<td>Final prototype provided</td>
<td>Co1, Co2, Co4, Co5, Co6, Co7, Co8, Co9</td>
</tr>
<tr>
<td>Implemented the solutions</td>
<td>Co1, Co2, Co6, Co8, Co10</td>
</tr>
<tr>
<td>Did not implement the solutions.</td>
<td>Co3, Co4, Co11</td>
</tr>
<tr>
<td>Patents</td>
<td>Co6, Co8, Co10</td>
</tr>
<tr>
<td>Got a return on investment</td>
<td>Co7</td>
</tr>
<tr>
<td>Future employment.</td>
<td>Co6, Co8</td>
</tr>
</tbody>
</table>

Co10 said a “spectacular example was with the concepts of lunar wheel where there were three patents and three teams were invited by NASA to Houston and one of the teams got to go to Korea and also Michelin took that work with NASA and really developed that several years later.” This means that there is an impact of the ME 4020 project in the company in terms of gaining patents and implementation of a new concept. Also it highlights the fact that the students have satisfied all the requirements of the company sponsor which means that the students are performing well in the ME 4020 projects. On the impact of the ME 4020, Co3 added and said, “For the first project we were pursing because it is a key part of what we are doing in this cell, our intention is to take the prototype that was developed and build that into a production machine”. This is interpreted as, the students have satisfied all the requirements and the company sponsor is making efforts to implement the solutions.
It is implied from the responses in the above discussion and validation from eight sponsors seen in the Table 18 that the ME 4020 project students have satisfying deliverables for the projects and are meeting the requirements of the projects that were sponsored.

As shown in the Table 19 the impact of the ME 4020 project is given in the sponsoring companies. It shows that three companies have implemented the solutions of the student projects. The implementation of the solutions can be in terms of bits and pieces of different student team solutions, ideas of the approach taken by the students which is then carried forward by the company in actually implementing in their firm.

On not implementing the solutions by the company, there are two possibilities, either the projects were back burner projects and were not given enough consideration by the company or the solutions were not meeting the requirements. Co3 said, “Three of the four concepts were quite practical, we could have found our way towards getting the designs or ideas, due to time conflicts we did not”. This completely agrees with the fact that the company sponsor did not give enough consideration to the project and that is why they were unable to implement the solutions. However, the solutions were still meeting the requirements.

There was only one company sponsor, Co4, who was disappointed with the solutions and said, “It was a disappointment because what the students gave me was a solution and a conceptual design which was in no way implementable, and we did not get any return on investment.” This means that the solutions were not meeting the requirements of the company sponsor or the requirements that were laid were totally different from what
the company sponsor was expecting. There can also be a possibility that the project scope was complex in terms of the work and expertise the students had to put. However, this questions as to why the company sponsor was disappointed with the solutions needs a specific description.

**Table 19 Impact of ME 4020 projects**

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Company</th>
<th>Implemented the solutions</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Techtronic</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Parker</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Michelin</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>BMW</td>
<td>No</td>
<td>Still working on the project</td>
</tr>
<tr>
<td>5</td>
<td>Corning</td>
<td>No</td>
<td>Sponsor unaware</td>
</tr>
<tr>
<td>6</td>
<td>General Electric</td>
<td>No</td>
<td>Put on hold</td>
</tr>
<tr>
<td>7</td>
<td>Okuma</td>
<td>No</td>
<td>Not manufacturable</td>
</tr>
<tr>
<td>8</td>
<td>Square D/Schneider</td>
<td>No</td>
<td>Put on hold</td>
</tr>
</tbody>
</table>

However, only one company sponsor was disappointed with the students’ deliverables. The rest of the company sponsors agreed that they considered the students’ solutions and were satisfied with the student’s requirements.

Additionally, three companies have implemented the ME 4020 project solutions and there are four patents in total, filed from ME 4020 projects, in Michelin and Techtronic Industries. The Techtronic Industries had also offered an employment opportunity to one of the students from ME 4020. This means that three companies have got quality and financial output from the projects. However, out of five companies that did not specify
regarding using the student team solutions, three companies mentioned of getting a quality output from the student projects. The companies not implementing the solutions even though getting a quality output, have more than one possible reason, either the projects were not in the companies’ critical path and were put on hold or the companies are still looking for new ideas.

Co6 said that, “The ME 4020 projects have been pretty good and the fact that we keep doing it every semester say something”. Again Co6 said, “We got a huge value out of it and that is why we did ten projects almost every semester”. This means that the companies namely BMW, Michelin, Parker Hannifin and Techtronic Industries get positive output from the projects and that is why they sponsor the projects multiple times. It also depend on the past projects impact on the company and the overall impression of the program on the company liaisons built by the faculty members of the department.

This patterns is interpreted as, there is a real value coming out from the ME 4020 projects in terms of quality output of obtaining creative solutions and new ideas from the ME 4020 projects. Also, the value from the past projects is a crucial factor for companies to return and sponsor the projects again to the capstone program, which is validated by the company liaisons for the companies such as Michelin, Parker, BMW and Techtronic Industry as they have sponsored multiple times to the same program. This discussion explains that the ME 4020 program has yielded quality output to six of the companies out of eight.
5.7.4 Pattern 3 Motivation as a Sponsor

This pattern is based on the responses of the company sponsors on the motivation as a company to sponsor the capstone design projects. Table 20 summarizes the predominant unique responses that were discovered from the Pattern 3.

<table>
<thead>
<tr>
<th>Pattern 3 Aspects</th>
<th>External corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company sees a great value in the format</td>
<td>Co4, Co9, Co10</td>
</tr>
<tr>
<td>Problems too small for plant engineers to handle</td>
<td>Co10</td>
</tr>
<tr>
<td>Hiring</td>
<td>Co5, Co6, Co8, Co7, Co10</td>
</tr>
<tr>
<td>Economical Engineering - saves company time and cost</td>
<td>Co1, Co2, Co6, Co8, Co10</td>
</tr>
<tr>
<td>Back Burner projects are feasible for the program</td>
<td>Co1, Co2, Co10</td>
</tr>
<tr>
<td>To obtain Creative thinking and new ideas</td>
<td>Co3, Co4, Co6, Co8, Co9, Co10</td>
</tr>
<tr>
<td>Company policy and management – partnership with academia</td>
<td>Co5, Co7, Co8, Co10</td>
</tr>
</tbody>
</table>

Co1 said, “The biggest reason why we take projects is what financially makes most sense for parker”. This can be interpreted as the company sponsor projects to solve their problems and capstone is the economical means for achieving that. It can also be thought as, the company sponsor the project to get more return on investment. Also, Co4 said, “Our incentive was to throw some issues regarding our machine to the engineers and see if they can come up with better design”. This also adds up to the fact that the companies want their issues to be solved by the undergraduate students to get new ideas. It can be interpreted that the students come up with fresh ideas and creative solutions and that is why the companies want their problems to be solved by the ME 4020 teams. This interpretation is
agreed by Co3 and other five company sponsors, Co3 said, “I had a specific problem which we were trying to solve and we ran out of ideas and we were looking for some new ideas and some new approach to our problem”. This makes clear that the ME 4020 is seen highly in terms of getting to new ideas and creative solution to a problem by the companies.

Regarding the motivation to potentially hire undergraduates, Co6 said, “Yes sure, searching for potential hires is another motivation for us.” This means that even if the companies have a main motive to solve the problems, a side motive is for looking for potential hires from the projects. Again, Co10 said, “Participating in capstone projects the undergraduates would tell other undergraduates about what great experience it was and it can help in hiring indirectly but not a direct link with hiring and capstone projects”. This means that even if the companies do not look for a hire directly from the capstone projects, still they expect to have an indirect word of mouth from students regarding company reputation and helps them in building a reputation in the University.

Co9 said, “The format is conducive to do sponsored projects while contracting out we end up with the same companies building the other ones in same place”. This can be interpreted as, the companies want new ideas and contractors are expected to do the same work they have been doing for the company and they would not deliver something new. On company policy and management, Co5 said that “The sponsoring of the project depends on company policy and at that time the company management wanted to have more interaction with the next generation so they can absorb it to the companies””. This means that the management also sees a value in interacting with the next generation engineers in order to absorb fresh ideas to the companies.
It is understood from this discussion and the corroboration table that the companies sponsor the project in order to get creative solutions to their problems and get new ideas economically from the ME 4020 students. They consecutively look for potential hires for their company as well directly through the program and/or an indirect publicity.

5.7.5 Pattern 4 Professionalism

This pattern talks about the view points of the company sponsors and the faculty members on the professional ability of the teams and presentation skills of the undergraduate students. Table 21 summarizes the information from the Pattern 4 including two responses namely, professionalism and presentation, having external validation for interviewed company sponsor and interviewed faculty members. Moreover, the two responses are agreed upon by at least one pair consisting of a company sponsor and faculty member.

It can be seen in the below table that Fa2 has not responded regarding the students professionalism. Fa1 has responded for the professionalism of the students as an important factor while undergoing the projects and perceives that the ME 4020 students are good in their professionalism. Even seven company sponsors agree on good presentation skills and five company sponsors agree on the good professionalism of the student teams that did projects.
Preparing the students for professionalism while presenting their work and communicating, Fa5 said that, “We give lectures on professional development and they have to present in a formal business attire, we grade them on content but also delivery and mannerisms”. This can be interpreted as, the faculties make the students learn how to be professional and the students have to apply it during their capstone design project in order to get good grades. This implies that the faculties feel, the professional and presentation skill are a very important part of the capstone project deliverables and anticipate students being good in those skills.

It is discovered that six company sponsors are satisfied with the level of effort the ME 4020 students put in terms of presenting their information in a professional manner. As said by Co9, “Georgia Tech program was not professional, while Clemson students are very professional and they are good in presenting the information”. Moreover, Co6 said, “All of the three occasions we met they made a very professional impression, and we liked their presentations where all the team members were involved”. It is interpreted that the ME 4020 students are good in presentations and professionalism and they have applied their learnt presentation skills. However two of the sponsors were less satisfied with the presentation skills of the students and their professionalism, as Co6 said, “For the most part
the students are less adapt at standing up and giving presentations, and they read off slides”. This can be interpreted as the students are not presenting their information as per the company sponsors requirements. However the company liaison gave a generalized answer regarding the presentation skills which can mean that some teams were good and majority of teams were having challenges with the presentation skills or some students within the teams were having difficulty presenting, which lead to the sponsors generalized perception. The most important expectation from the project that Co6 said is “We expect and we have always been clear of working prototypes at the end as the actual deliverables” if this response is taken into consideration than the presentation skills can be a minor disappointment for Co6. It is understood after this response that the important deliverable that is required is the final prototype and not the presentation by the students. The other company sponsor also gives more importance to the content and not the skills to present those content from the students, this company sponsor, Co10 said, “Our Company was heavily biased towards technical results so I was less impressed by fancy slides and fancy movies and I am more tolerant with a less quality presentation and good technical results.” The fact that is understood from the above discussion is that the company sponsors weigh the content of the student deliverables over their skills in presenting.

From this pattern, it is understood that the presentation skills of the students and professionalism are considered as an important aspect from the faculty member’s perception and they even give them lessons for the same. The faculty members also perceive that the students should be good in their presentation and professional skills.
There can be seen a general agreement between the departments and the schools in terms of the importance of the presentation skills from the Table 21.

Also, it is known from the responses of the seven sponsors regarding appreciating the student’s presentation skills that the students are good at presenting and communicating professionally. This is an alignment in the perceptions of the faculties and company sponsors in terms of the student’s ability in presenting and communicating. It also shows that the companies are getting professional engineers from the capstone program.

However, there is a dissimilarity between the faulty members and company liaison in terms of the importance rating of the presentation skills and professionalism in a student’s project. It is inferred that the company sponsors only see these skills as a side factor to the project and not an important deliverable in terms of the students’ outcome.

5.7.6 Pattern 5 Project Features

The following pattern consists of responses from all the interviewees on the project features which will be discussed below. It is the combination of responses from the faculty members and the company sponsors interviewed.

5.7.6.1 Pattern 5a - Project selection:

This discussion is about deciding an optimum project scope based on the responses of the company sponsors and faculty members. Table 22 shows three common responses taken from all the unique responses that were collected for this pattern.
The projects should be defined with an appropriate size as Fa5 says, “We work very carefully with the companies to make sure the projects are large enough, it is always easier to scale down the projects then to realize that this project is very small”. The faculty member Fa6 added to the previous faculty saying that “We try to look for projects where complexity is same level as you get in your senior level course. So, if the complexity is way beyond that then we try to narrow the scope down”. This responses highlight the fact that the faculties are cautious while defining a project and they prefer narrowing the scope down rather than defining a small project. It is understood that for the students to properly apply their learning in a capstone program, the scope should be optimum in terms of the project size and complexity. The project size is the level of efforts the students need to put in order to come up to a final deliverables and the complexity is the application of their fundamental learning of their curriculum.

Co10 said that “students cannot design the final product and install in manufacturing run-that’s too big” and Co7 said “I think it is going to be hard to get a group and ask them to deliver which is a huge breakthrough for the company that’s not what we are really after”. The above responses can be understood as, the selection of the project

<table>
<thead>
<tr>
<th>Pattern Aspects</th>
<th>External corroboration(faculty)</th>
<th>External corroboration(company)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum size of projects.</td>
<td>Fa1,Fa3,Fa4,Fa5</td>
<td>Co1,Co2,Co3,Co6,Co7,Co10</td>
</tr>
<tr>
<td>Picking diversity of projects.</td>
<td>Fa1,Fa3,Fa6</td>
<td>-</td>
</tr>
<tr>
<td>Picking up challenging projects</td>
<td>Fa1,Fa4,Fa5</td>
<td>Co1,Co2</td>
</tr>
</tbody>
</table>
should be related to the student’s ability to cope up with the deliverables and should be of optimum size with deliverables that can be achieved considering the level of understanding of the undergraduate students. Co1 said “We do not want to define a project that demands a lot of students for programming control systems or a lot of ergonomics because we know that is not in the scope of curriculum” The above responses mean that the company sponsors do not expect from the students to deliver complex solutions and to make a huge breakthrough out of their projects and the projects should be aligned with the students fundamental curriculum. It can also be interpreted as the company sponsors want small achievements from the students and the sponsors prefer new ideas and creative solutions rather than expecting students to deliver an installed final manufactured product.

Fa1 said, “If I can see a solution to a project when I first meet the company then it’s not a good project”. Fa4 said “the project has to challenge the students to think critically about what they are doing.” The two responses show that the projects should have enough challenge in terms of getting to the solutions. This can be interpreted as the projects should challenge students to think critically to reach to the final deliverables.

However, there is a difference in the process of coming up with the project need and problem, that is, the Bioengineering department professor believes that the students should find the needs and they validate those needs in terms of the scope, also the students can select from different options of their preference on what they want to work on in the projects, while in the rest of the departments the project head or facilitator select the project definition for the students.
It is understood from the above discussion on the faculty members and the company sponsors responses, alongside the corroboration in the table that, selecting an ideal project with an appropriate scope is an important factor that is of keen interest from both the stakeholders. The project should allow the students to think critically in achieving the final solution but should be optimum in terms of size and level of complexity of the curriculum learning. And if the project has to align with the curriculum then it should be optimum in terms of student’s efforts and their learnt fundamentals, to get to the solution.

5.7.6.2 Pattern 5b - Multiple team student projects:

This discussion is based on the responses of the interviewees regarding the aspect of multiple teams doing a same project. Table 23 summarizes the predominant responses for Pattern 5b. An alignment of response can be seen between the ME 4020 faculty and sponsors regarding the fact that there are multiple solutions possible from the teams doing the projects. This multiple solutions yield a wide variety of creative ideas.
Fa5 said “As a company they do not share information amongst teams and it is interesting to see how two different teams come up with same or completely different approach”. This is understood as a tool to figure out difference between the teams on how different teams work their way through getting the information from the company to get results, even though they have the same problem definition. It is interpreted that the multiple team projects are a way for faculty members to compare the teams in terms of their effort in getting information from the company, because the companies do not share all the information apart from the problem definition with all the student teams.

Co4 also said “It is beneficial from our standpoint to have three different solutions from three teams”. This can be interpreted that the multiple teams come up with multiple solutions and the companies benefit from the multiple solutions. Also Fa2 said “It mitigates risks, in a sense it increases the chance of successfully coming up with the final solutions”. The faculty means that as a company if they definitely want a final solution then multiple
teams can reduce risks in achieving that. It is understood from this responses that for a company to get to a final solution they should sponsor multiple teams so that they can either achieve the final solutions even when a single team fails in meeting the requirements or they can combine ideas from the different solutions and reach a final solution. The response given by Co1 explains that they combine solutions from different teams, as said by Co4, “It is almost a combination of different groups’ ideas coming together for our final piece of equipment”.

On multiple teams working in parallel for different aspects of a project Co9 said “Multiples teams working on different aspects of a project in parallel saves time and the competition element is nice and interesting, but on the other hand it is a bit of waste of resources too”. As there is not enough clarity from the response and as there is subjectivity involved in the response, it can be either considered as the fact that when parallel teams work on a final solution it saves time but funding all the teams is a waste of money and time as a company sponsor. Also Co7 explained saying, “I think from my side coping up with four teams was a little bit time consuming”. However, only these two responses describes multiple teams as a waste of resources and a time sink, while the other company sponsors which can be seen in the table have a positive response in terms of incentives from the multiple teams involved in capstone projects.

It can also be seen that there is a difference of opinion between different school and different departments. The Bioengineering Department do not see a value as multiple team competing for a same project rather they give students projects that the students feel comfortable with. Also, the faculty member from Mississippi State University suggests it
saying that it depends on the projects that the students do and there can be either different solutions or can be a repetitiveness in the solutions. Conversely, the faculty members from the Colorado School of Mines, the Industrial Department and Mechanical Department at Clemson University are in agreement with the fact that multiple teams come up with multiple solutions and better results are possible.

It is understood from the above discussion that multiple teams are a beneficial resource as a company sponsor to come up with multiple ideas to a project. Also, if a company wants to achieve a final solution without taking chances, then the company should sponsor multiple team projects.

5.7.6.3 Pattern 5c – Far distance projects for capstone design program:

This discussion is based on the responses of the faculty members on the aspect far distance projects in capstone program. Two company sponsors also mentioned it exclusively regarding the far distance projects. The far distance projects are seen challenging by all of the faculty members except the professor from Colorado School of Mines, in terms of yielding effective solutions by the students.

Fa1 said that “It becomes logistically difficult for students in doing projects outside a two hours’ drive”. This means that it is a taxing on the students to travel and visit the site when the company sponsors are located more than two hours’ drive. And other faculty member seems to see a value for students to visit the companies, Fa5 said that “I like the companies to be closer to the campus so that promotes the students to get more site visits”. The above responses highlight the fact that there is a value as a student in visiting the companies that they do projects for and far distance projects are logistically challenging,
which means that far distance project are not value adding. This can also be explained from
the response by Co1, who said that “It is a lot easier if the students can come to our facility
and actually see what they are either modifying or creating from scratch, it just so much
little you can do with email and phone call”. This means that it becomes easier for the
students to interact with the company liaisons and work with the problems when the
companies are close (within one hour) distance from the Department.

Geographic vicinity is another factor for the motivation for a company to sponsor
a project that is discovered from the transcripts. As said by Fa3 “We do not have Michelin,
BMW style companies and out geographic area is much more manufacturing and not a lot
of biotech which makes it challenging to have companies sponsor capstone design
projects”. Similarly Fa4 said, “The University is geographically challenged and companies
are far from the university which becomes a challenge”. It can be interpreted as the
companies prefer to sponsor projects that are in their vicinity and see far distance projects
as a challenge in terms of sponsoring the projects. It is interpreted from the responses that
if the companies are in the vicinity of the university than the chances of getting company
sponsors are more. However, there is no evidence regarding the companies’ perception
regarding the above responses proving that the companies prefer to sponsor projects to
Universities which are closer. Hence it is not considered as a strong response in terms of
concluding that geographic vicinity is a factor for the motivation for a company to sponsor
the project.

However, Fa6 said that, “We did a project in Antarctica and students had an access
to virtual environment nearby also virtual meetings went well and if you are creative and
you have a client to work with you will have good experience even if the client is not there.”

This response can be considered as a positive outcome from a far distance project but it also shows the fact the sponsor had the time and considerations for the sponsored project. This faculty member from Colorado School of Mines perceives that far distance projects are not a significant factor in determining the project success. The faculty member has difference in opinion from the faculty members at Clemson University and Mississippi State University in terms of the outcomes of the far distance projects, these schools are in an agreement that the far distance projects are logistically challenging for the students and the distance is significant in terms of determining the success of a project.

It is understood that distance of the sponsor and the University is a significant factor in selecting a project, as the students benefit from actually interacting with the liaison and looking at the project site, which far distance projects add a challenge for students to do site visits.

5.7.6.4 Pattern 5d – Interdisciplinary team project:

The following discussion is having a low external and cross corroboration and can be considered as a supplementary insight to this thesis. Fa6 said that “Even if the students don’t understand what the other discipline does, they start to understand how to communicate with them and value they bring to the project.” This means that the interdisciplinary projects are important in terms of students to get a real world experience in working with other disciplines. Also Co9 said that “We can sponsor more projects with inter disciplines and that can yield better results and also in a lot of ways reflective of the actual situation.” The company sponsor means that the interdisciplinary teams add a value
for students in terms of interacting with different disciplines and working alongside them. Also they can sponsor more projects with interdisciplinary teams. This can be interpreted as if for the capstone program ME 4020 has to have more projects from the sponsors than it should open up the option of interdisciplinary teams. However, there are not enough responses to come to this conclusion.

It is seen from this pattern that the Colorado School of Mines is the only University offering interdisciplinary projects and the faculty member has positive thoughts about the same, while none of the other schools have interdisciplinary project as an option. And two company sponsors responded that they could have sponsored more projects with interdisciplinary teams as an option.

5.8 Answers to the research questions

This sections answers the three research questions discussed in Chapter Two with the help of the responses gathered from all the interviewees and also the constructed pattern.

5.8.1 Research question 1

This section answers the first research question using the responses from eleven company sponsors. The first research question was the impact of the projects in the interviewed companies and the viewpoints of the company sponsors on the ME 4020 program regarding their motivation in sponsoring the projects, benefits as a students in undergoing the sponsored projects.
There is a commendable impact of the ME 4020 in the local interviewed companies. As seen in Table 19, three companies namely; Michelin, Techtronic Industries and Parker Hannifin, out of eight companies have implemented the project solutions directly. In total four patents came out of the ME 4020 projects in which three were for a lunar wheel project in Michelin and one patent from Techtronic Industries. Out of eleven company sponsors eight have agreed that, the solutions of the students were satisfying the requirements. This means that the students have done a satisfying job for the ME 4020 projects and eight companies have obtained quality output in terms of creative solutions and new ideas for their problem. The perceptions of the company sponsors regarding the motivation as a company to sponsor the capstone design projects is shown in Table 20, the most important motivation is to obtain creative solutions and new ideas to resolve the problems in the company. The companies also benefit from getting multiple solutions, when multiple teams are working on a same project.

The perceptions of the company sponsors regarding the value students get pursuing the ME 4020 projects can be seen in Table 17, it is understood from the validation of the company sponsors that the students get benefit from the company sponsored projects in terms of working with open ended problems and gain experience for the real world.

5.8.2 Research question 2

This section answers the second research question as discussed in Research Questions section, using the responses from six faculty members. It answers the faculty members’ perception on the capstone design projects regarding the benefits of the projects
to the company sponsors, students and academia/faculty. It also includes the difference between the responses found between different department and schools.

Table 13 shows two responses that are predominant from all the faculty members’ responses regarding the expectation of students’ outcomes from the projects. The faculties expect the students to apply their course work in the projects and should systematically undergo the projects. They should also think critically while undergoing the projects in order to get to creative solutions.

Table 14 shows the responses regarding the value as a student in pursuing the capstone design projects. The responses with a strong external corroborations suggest that the students benefit from the experience of a real world scenario in a controlled environment and benefit from solving open ended problems through company sponsored projects. The companies sponsor the projects to get incentives in terms getting their problems solved economically and consecutively search for potential hires, build relationship with academia. It was also understood from the responses of the faculty members that there is a significant value from the capstone projects as a faculty member. It is not only a potential visibility of what the whole degree program is capable of, which helps in building stronger relationship with the industry, but also a way to evaluate the curriculum.

5.8.3 Research questions 3

This section answers the third research question, and compares responses of the company sponsors and the faculty members using all the patterns. The Pattern 4, 5a, 5b, 5c and 5d are the answers on the professionalism of the students and the program features and
the found comparison is discussed below. Also there is a comparison of responses of both for the benefits as a students in doing the capstone projects and the motivation as a company in sponsoring the projects.

From the responses of the seven sponsors regarding appreciating the student’s presentation skills, it is understood that the students are good at presenting and communicating professionally and the companies are getting professional engineers from the ME 4020 capstone program.

The selection of the projects is seen as a crucial factor in the capstone program by both. It is understood from the Pattern 5a that, an ideal project should allow the students to think critically in achieving the final solution but should be optimum in terms of size, which is the level of efforts and time the students have to put in getting to a final solution and the level of complexity in terms of curriculum learning. There is also a cross corroboration seen in Table 23, which is used to understand that the multiple team format of the ME 4020, which is considered highly by the faculty and company sponsors as it yield more than one creative solutions and increase the chance of getting better results rather than one team working on a project.

In terms of interdisciplinary projects, there is insufficient data to show any alignment between the responses of the faculty and company sponsors, also owing to the responses it needs more validation from company sponsors, to suggest that the ME 4020 program can be benefitted from opening up the option of the interdisciplinary teams doing capstone projects. The cross corroboration for the responses of the company sponsors and
the faculty members regarding the students value in doing the capstone projects is shown in projects in capstone program. This suggests that the students benefit from the exposure to real world and they can apply their learning through the sponsored projects in capstone program.

**Table 24 Cross corroboration for students value**

<table>
<thead>
<tr>
<th>Students value in doing capstone program</th>
<th>Cross corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure to real world problems</td>
<td>Co1,Co2,Co3,Co5,Co7</td>
</tr>
<tr>
<td></td>
<td>Fa1,Fa2,Fa6,Fa4,Fa5</td>
</tr>
<tr>
<td>Application of the students learning</td>
<td>Co3,Co10,Co5,Co2,Co7</td>
</tr>
<tr>
<td></td>
<td>Fa1,Fa2,Fa6,Fa4</td>
</tr>
</tbody>
</table>

Additionally, Table 25 shows the alignment of thoughts on the companies’ motivation in sponsoring the capstone design projects. The strongest agreement from faculty side regarding motivation as a company is seen to be building relationship with academia and solve problems economically. However, the strong validation from the company sponsor regarding their motivation to sponsor the projects, was found to obtain creative solutions and new ideas for their problems. Owing to this it is understood that there is a difference between getting a problem solved and getting creative ideas. As, creative ideas can either be in terms bits and pieces of the student teams approach followed to get to the solutions, or bits and pieces from the overall deliverables by the teams.
Table 25 Cross corroboration for companies motivation

<table>
<thead>
<tr>
<th>Motivation to sponsor students projects</th>
<th>Cross corroboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company sees a great value in the format</td>
<td>Co9,Co4,Co10</td>
</tr>
<tr>
<td></td>
<td>Fa1,Fa5</td>
</tr>
<tr>
<td>Opportunity for future employment from the project sponsor</td>
<td>Co5,Co6,Co7,Co8, Co10</td>
</tr>
<tr>
<td></td>
<td>Fa1,Fa6,Fa4,Fa5</td>
</tr>
<tr>
<td>Economical Engineering</td>
<td>Co1,Co2,Co6,Co8,Co10</td>
</tr>
<tr>
<td></td>
<td>Fa1,Fa2,Fa5,Fa6</td>
</tr>
<tr>
<td>To obtain Creative thinking and new ideas</td>
<td>Co9,Co3,Co4,Co10,Co6,Co8</td>
</tr>
<tr>
<td></td>
<td>Fa1,Fa4</td>
</tr>
</tbody>
</table>

After going through the above pattern discussions and relating them to the ME 4020 it is seen that, there are three benefits possible from the capstone projects to the company sponsors; quality output, company publicity and saving of money and time from sponsoring the projects. The financial output that the companies get and how they get the financial output is not mentioned and discussed in this thesis.

The students should apply their prior knowledge and think critically by applying their analysis skills in the capstone program. And the company sponsored projects are the effective way of applying their skills, eventually giving the students real world experience.

It is also suggested that, the capstone design program is a best way for a company to solve back burner problems with a low investment. And even if they do not get all the requirements met, they still can get new ideas and a chance to check the ability of the future generation in terms of their potential hires. According to the company sponsors, there is a real value coming out in terms of quality output from the ME 4020 projects. Also, it is the
value that is coming out from the ME 4020 project, a reason for the companies such as Michelin, Parker and BMW to sponsor projects multiple times to the same program.

The presentation skills of the students and professionalism are considered as an important aspect from the faculty member’s perception and they even give them lessons for the same. The faculty members also perceive that the students should be good in their presentation and professional skills. The interviewed project sponsored are satisfied with the communication and presentation of the students except two sponsors.

However, there is a dissimilarity between the faulty members and company liaison in terms of the importance rating of the presentation skills and professionalism in a student’s project. It is inferred that the company sponsors only see these skills as a side factor to the project and not an important deliverable in terms of the students’ outcome. In other words they are more interested with the content of the presentations rather than the presentation itself.

The faculty members and the company sponsors perceive a high value in terms of selecting a project scope. They need a project that allows the students to think critically in order to achieve the solution but should have an optimum size in terms of their level of their curriculum learning. And if the project has to align with the curriculum then it should be optimum in terms of student’s efforts and learning to get to the solution. Moreover they should also be able to think critically while pursuing a project.

There is an alignment of thoughts between the faculty and company sponsors for ME 4020 in terms of multiple teams as a beneficial resource to come up with multiple ideas.
to a project. Also if a company needs to achieve final solution then the company should sponsor multiple team projects.

There is an alignment of thoughts between the faculty members from different school/department except Colorado School of Mines in terms of far distance projects as a challenge for the capstone design program. There is a value as a student to do site visits, as they benefit from actually looking at what they are trying to solve and far distance projects add a logistical challenge on those visits.

If ME 4020 has to have more projects from the sponsors than it should open up the option of interdisciplinary teams. However, there are not enough responses to come to this conclusion.

There is a significant value from the capstone projects as a faculty member. It is not only a potential visibility of what the whole degree program is capable of which help in building stronger relationship with the industry, but also a way to evaluate the curriculum.

5.9 Supplementary Insight

Apart from patterns, there are certain responses which were found related to a key point which is discussed below.

5.9.1 Company sponsor time

The time spent by company sponsor is a significant factor to be found in the capstone design projects in order to yield better results. As the students have to get information and data from the company liaison helping them to complete the final solution
in a timely fashion. The students feel motivated to work harder if they get all the required support from the company liaison.

Fa6 said that, “If you are creative and you have a good client to work with you will have a great experience even if the client is not there because being good client is not actually just writing a check and forget about the projects they have to spend time identifying it and interfacing with students”. Interestingly, Co3 said that “I do not feel I gave as much attention and time and I would have considered looking at the solutions more carefully.” Fa1 described their experience with company liaisons as, “It was not a great experience with one of the projects as the company never identified a sponsor and they did not really care about it and it became clear to students that the company did not care.” This responses suggests that the company sponsor time is directly related to the success of the project. It also highlights the fact that for the students to be motivated and to deliver solutions as per the company requirements, the company sponsor should be active in terms of interacting and getting information for the students.

Additionally, Co10 said, “Because there is a short time period of three months, a company investigator needs to be present during the project and cannot take vacation or traveling and needs to make sure he/she is responsible.” The presence of a company liaison is important in terms of delivering information to the students. Co6 also said that, “What we have found with previous ten projects is that, the more involved we are, the better the output.” This response clearly mean that the awareness of the company sponsor regarding the project determines its success.
It is understood from the response that even the company see a huge importance of the time spent as a company sponsor in determining the success of a capstone project.
Chapter Six
CONCLUSIONS

The ME 4020 faculty members and the company sponsors have an alignment of thoughts for the benefits as a company sponsor related to the quality output and the publicity the companies get in sponsoring the capstone project. Ninety two percentage of projects for ME 4020 are company sponsored from 2004 until 2014, this shows that the Department of Mechanical Engineering at Clemson University has been successful in getting sponsors for their student projects. It is understood from the pattern discussions that, company sponsors satisfaction with the quality output they get from the ME 4020 projects is one of the factors in getting sponsors every year, which includes the new and existing sponsors. Also, the interviewed ME 4020 faculty members headed the program spanning from 2004 until 2014 in turns and it was found that they understand the benefits that the companies get from sponsoring the projects in general. This explains that the faculties have done a good marketing of the ME 4020 program to get company sponsors, which can be another factor in the success of getting projects from outside sponsors.

There are still new benefits that are mentioned by the company sponsors and not by Fa1 and Fa2. The faculties did not mention the benefits as a company in saving the time and money in hiring full time engineers or outsourcing the projects that need a creative solution. The sponsors from Parker Hannifin, BMW, Michelin and Okuma mentioned the benefits they can get in term of saving their time and money from sponsoring the capstone projects. Also, the companies see benefits in using the capstone program as a tool to solve the back burner projects and linking it to their continuous improvement procedures. Also,
from the discussions, the all except two sponsors mentioned the benefits in sponsoring multiple teams for a project, giving them a quality output in terms of multiple ideas for their problem.

It can be understood that the companies that are distant from the department are challenging for the students to do projects. All except one faculty member found the far distance project as logistically challenging for students to work on the projects. The faculty member in Colorado School of Mines believes that the project scope and the commitment of the project sponsor is more important than the distance of the project. The rest of the faculty members believe it as a taxing on students’ visits and eventually adding a challenge to an effective communication between the students and the sponsors. Parker, Michelin and Techtronic company sponsors mentioned the importance of interacting with the company sponsors and doing the site visits for students to work on the problems more closely. This can be understood that the student’s visits are important in terms of working more closely with the projects and the far distance projects are logistically challenging to make in-person visits.

The company sponsors did not respond on picking diverse and challenging projects for the students to work on, while the faculty member Fa1 responded the projects should also be diverse and challenging. This can be interpreted as the company sponsors see benefit from the projects that are less time sensitive and the projects that they get creative solutions faster and are not challenging in terms of getting to a solution. As, the students only have a semester to work on, an extra challenge can work against giving the final deliverables on time.
There is a difference of opinion between the Mechanical Department and the Bioengineering department in terms of the students doing the capstone projects. The Bioengineering department see value as a student in doing their own projects which can develop their entrepreneur potential. Also, there are not many Bioengineering companies in the vicinity of the department which adds another challenge in getting sponsors for the program. The other departments prefer sponsored projects as it is more realistic to the real world situation having a need based customer to work for. More than sixty percentage of projects are interdisciplinary in Colorado School of Mines, which is different from the departments in Clemson and Mississippi State University.

It can be concluded from the patterns that the capstone design program has an impact on the companies sponsoring the projects. Faculty members see a high value in the capstone design program, as they perceive that the program is beneficial to both the students and the company sponsors. Similarly, company sponsors have a similar opinion on the value that the students and companies get from capstone design program. Moreover, all but one of the interviewed company sponsors had positive feedback on the students’ deliverables for ME 4020. This explains that there is an overall impact of the ME 4020 on the company sponsors. Multiple teams on projects are beneficial for providing multiple solutions for the company sponsors.

In terms of student outcomes, the students should apply their prior knowledge and think critically by applying their analysis skills in the capstone program. And the company sponsored projects are the effective way of applying their skills, eventually giving the students real world experience. It is also suggested that, the capstone design program is a
best way for a company to solve back burner problems with a low investment. And even if they do not get all the requirements met, they still can get new ideas and a chance to check the ability of the future generation in terms of their potential hires directly from the projects or indirectly in terms of building company reputation in the department.

The financial output that the companies get from sponsoring the project is less talked in this thesis and is another area to investigate about. The financial return on investment for the sponsorship fee that is provided by the company is not determined in this thesis. Is there any linking between the quality output, company publicity and the financial output? The companies that responded to have used the solutions of the students can be investigated further for the profits made after implementing the solutions. And do the companies at all consider the benefit in the financial output along with the quality output that they get.

There are instances when faculty members are typically more interested with the learning outcomes of the students as they want the students to develop in their education and apply it practically. The company sponsors tend to care about the final deliverable from the student projects. This dissimilarity is still unanswered by this thesis and needs clarifications and additional data to prove this dissimilarity.

The following thesis investigated the faculty members and the company sponsors regarding their thoughts related to the capstone design program. However, in order to have a complete feedback of the capstone program, there is a need to investigate the students doing these projects about their perceptions towards the capstone design program. For instance, faculties and company sponsors came to a general conclusion that the students
get a huge value from working on the real world problems. However, the students’ perceptions regarding the value to undergo a capstone project can be same or completely different. Also, to get outcome in terms of students, their experience in doing the capstone design program and how it helped them after graduating can be investigated.

Also, survey as a new method to gather the data can be used along with the interviews to investigate the above topics, as there can be a challenge in getting respondents for an interview process. Whereas, surveys can be conducted offline which can have more respondents for the research. The questions that need less elaborated answers can be investigated with sufficient data using surveys for statistical proof.
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APPENDIX A

Transcript 1: Interviewer – Varun Rawal, Interviewee – Dr. Joshua D. Summers (Fa1)

How many years have you taught a design course?

Fa1 – How many years have I taught design!! I have taught design ever since I arrived here, so about 12 years.

Alright, 12 years is a long time. And how many years have you taken a part in undergraduate projects?

Fa1 – As a student? As a graduate student?

As an advisor, mentor or working in collaboration with them (the students)?

Fa1 – Class projects? Out of class projects? What exactly are you saying? Participated as class projects? What do you mean? Or just a student project, what do you mean?

Basically students projects, let’s say the Capstone program projects (specifically the capstone).

Fa1 – The very first semester I arrived here was the very first time I was an advisor for one of the Clemson senior design teams, so I have been on about 35 senior design projects.

I am talking about the role the Capstone Design projects. What role have you most performed? Is it advising the students mentoring them or working in collaboration?

Fa1 – Well, if we are talking about the Capstone program our role as faculty here at Clemson is really for hands off advising not really may be mentoring but not guiding the
projects, not telling what to do. We ask them questions and seek clarification. Almost like a high level management we conduct. We only do the design reviews once a week. If students need additional help they can come by. We are not actively engaged as part of the projects for the capstone. Now there are other examples, creative inquiry and stuff like that where I have very different role. However, you are asking about Capstone.

So basically you are trying to say is you just guide them indirectly.

Fa1 – I won’t even say that we guide them indirectly, I say that we prod them.

Alright, how central is the capstone course to your undergraduate program?

Fa1 – To these program?

Yeah

Fa1 – It’s essentially there an exit exam. So by the time they get to capstone they are almost engineers so it’s our chance to see if they are worthy of being engineers. So it’s like an exit test. So I would say its “very central is very core to Clemson to mechanical engineering”.

So I mean the entry level engineers we could say. Are they groomed to directly go to the industries?

Fa1 – Yeah, after this if, they successfully complete the capstone then the faculty basically feel that they are ready to be new engineers in industry.

It’s the faculties perception right?

Fa1 – Yeah, I didn’t say they are going to be good engineers. I just said they are capable past the minimum threshold.
And, I would like to understand the structure of your capstone project. Few things as the Types of projects.

Fa1 – All of our projects are industry sponsored projects well 99 %. Every one semester we will take a projects say from geology department so a faculty member in that department needs a mechanical testing device so we might pick one small team of students on that but, for the most part industry sponsored projects we put parallel teams on each projects, so that the company has multiple solutions. All of the projects are company sponsored projects so that they are putting some actual money and resources into it. First for supporting the undergraduate program and secondly for supporting that team specific prototyping and development cost. Teams are formed in different ways. I believe when Fa1 Fadel was the coordinator teams were self-selected. When I was the coordinator we had a submitted resumes with choice and I tried to form teams creating a balanced experiential mix. Fa1 Mocko I think he has done it very similar to how I did it. But I am 100% positive. We try to form the teams assign the teams to a project and then each project is assigned an advisory committee.

So I mean what you are trying to say is form teams based on their resumes, their competencies.

Fa1 – Their course also what course they have, what their interest are, whether or not they had work experience or co-op experience these types of things.

Size of the teams?

Fa1 – Size typically is 4, sometimes 5. There have been instances where we had a much larger teams 16 and that was broken up into sub groups, working on a satellite design
project for NASA and then there have been a couple of times we had teams of three> But those I can remember only one team of three to be honest. So we try to keep the size 4 to 5.

As to be more efficient?

Fa1 – To be large enough to actually have collaborative challenges but small enough that he students without formal training in leadership and management can still handle it.

Alright, what’s the duration of the project?

Fa1 – One semester project. So about 17 weeks. Students will get the project descriptions before the class starts so will submit their resumes and then the teams will be formed and given to them on the first day of class. And so the second week of class the companies come in and present the problem and then they have until the last week of the class to develop the solutions.

Yeah, and the structure of the course, Do you give them lectures and projects?

Fa1 – They are not given any content lectures in their capstone program. All of the design lectures, design tools, process and method that actually comes the semester before, what we call 4010 and so that’s a pre capstone class. And the actual capstone class we could lecture periods that are helped but those are used for organizational issues, bringing a guest speaker from the company talk about value engineering or something like that. So that’s not about content delivery that they are going to be tested on or anything like that.

Once again, I would like to go to the industry involvement of the projects. How much involved are the companies?
So the companies are the customers and they are the sponsors of the projects they will come down to the campus the second week of the class to present the problem. The students would work trying understand the problem and then they would go up (3rd week of the class) typically visit the company and have more questions answered. Then probably about three weeks later the company will come down again for preliminary design review. And normally when they come down there is only one person that’s assigned as the liaison from the company. But they will come down with another two or other from the company and the liaison and the company provide feedback at the preliminary design review. And they come down again or we go up there for final design review, the last week of the class. The liaison is tasked with responding answering questions students might have. So he is putting in maybe one hour a week and gathering the data and responding to it helping the students arrange site visits if necessary. So they are a liaison they are not providing technical management or guidance or anything like that.

So what are the benefits to the students in doing the projects, I mean in your program?

Fa1 – benefits as a student, I guarantee that all of our students have some exposure to actual industry where most of our students do co-ops and internships it’s not 100%. This is the way for us to capture that last little bit to make sure that they have some experience. It’s their opportunity to start to work on the professional development and communication and documentation. It allows them a chance to see what life is going to be like in the future. It allows them a chance to fail in a controlled environment. So a failure on senior design they develop a prototype that does not work they are not going to be fired they do not lose
their job. But they need to learn that failure is going to happen and how do you learn from it and grow from it. So, every once in a while students will use the context developed from the senior design to get internship or job offers or stuff like that and important thing is that they have at the end of the class is a completed project to a certain degree which can be discussed, I mean we have there is preparatory confidential information that cant share everything or talk about that but having a story to tell at an interview about a project is a very important thing. And while our students tend to have jobs before they graduate those don’t have now have a project to talk about.

Okay, how is the project viewed in your department I mean the mechanical department?

Fa1 – Are you talking about specific projects?

No, in general, are there clear learning objectives?

Fa1 - Yeah we have identified several main learning objectives and ways how we do assessment. The program itself has been roughly in this form for three decades. It’s not a something that is changing. Any faculty belief in the capstone program as a stance some are frustrated and look as a tome sink for them and they are not necessarily growing strain but overall I think the capstone program is viewed as a very important thing in the department.

As you say in the first few questions the exit exams so do you prioritize exit exams?

Fa1 – So there is not a real exam I am just saying that this kind of serves as the exit exam. It’s our last point last gate for us to look at the students and make sure that they are competent. It’s our last chance to see that they can actually do some engineering whereas
most of the courses are engineering science and engineering analysis, can they take that and use it appropriately that is what I mean by the exit exams of capstone. It’s not the real exam.

So what will you weigh between taking courses for clearing the exams and building something?

Fal – Well if you can do well in course work but you can’t do anything with it and you can’t design something or fix a problem for a company then I mean you haven’t really learned anything of value. And so that everything you are learning in all analysis classes and all the engineering science classes are tools to help you in your manufacturing and your design work. I mean that’s what engineering is design and manufacturing.

Does the faculties use these projects as a way to evaluate the effectiveness of the rest of the undergraduate program?

Fal – There is a little bit we do formally through exit advisor survey and stuff like that, but most it comes informally you know, students are not able to use software appropriately may be they don’t do simulations well so we go back and we look at where in our curriculum do we introduce them to computer tools. May be they are not writing or communicating well we go back and look at that, may be the assumptions they don’t take, have good assumptions for different analysis. So we go back and there are heat transfer topics and see are they really been clearly taught how to document those assumption but its informal and it’s based on the individual faculty on a project taking it back into their course.

About the types of projects a student can do, are those user defined?
Like I said almost all of our projects are industry sponsored projects. So you know the students don’t define the projects the company defines the projects. Most of the time the projects is about the manufacturing process improvement. Every once in a while it will be about a product improvement, fixtures and the test equipment these are common type of projects.

What about a good project? What according to you is a good project? Do the deliverables by the student interest you or the impact of them in the company?

Fa1 – So when we look at a project coming from a company we spend a lot of time talking to the company about expectations, scope and everything. We are looking for projects that would normally take about 3-4 months for a new hire engineer to complete. We are looking for projects that are going to have some sort of hardware requiring some diversity of discipline, skill and background that they can apply it’s not just a clear single answer, it’s not just incremental as clearly defined. What the next steps are looking for open challenge in projects. If I can see a solution to a project when I first meet the company then it’s not a good project. I should not be able to see an obvious solution.

But eventually it would be hard for the students.

Fa1 – Yeah, I want it hard for the students and I want it interesting for the students. So if it’s difficult the students always rise to the occasion if it’s interesting and so we don’t constraint ourselves to you know projects that they are not being exposed to the classes. We have done acoustic projects, materials related projects, ergonomics and human factors related projects. The students aren’t necessarily trained in all those but they are trained in
how to learn, what they need to do. We like projects that require some experimentation for validation.

Should there be a sponsor for a good project?

Fa1 – For us all of our projects are live real sponsors. We intentionally avoid the things like the competition ASME, HPV or SAE formula or BAHA, those are rule driven competition where there is no clear customer there is no interaction and so you are missing that aspect of the professional development and that’s why we don’t include those. We go after projects that have customers.

What are the learning objectives or the expectations between the undergraduate projects and the research projects (faculty driven research)?

Fa1 – Completely different, for us all of our projects are students designed projects all of them are with external customers. And we are wanting them how to work in a team, to learn how to be proactive and responsive to changing customers. We want them to learn how to pull the information from people, we want them to learn professional communication, professional conduct where as in undergraduate research projects you are teaching the students a more specific method a research method. And it’s a lot more interactive, lot more guided, lot more teaching going on in the research than on the design projects. So it’s completely different I would not equate the two and in fact our department does not equate the two, they are completely separate.

Why should a student do a company sponsored project?

Fa1 – They have to, to graduate. It’s very simple they don’t get a choice.

Why do you feel so, I know it is a constraint for them but what are your thoughts?
It is a very valuable thing to be able to learn how to interact with people from industry like I said most of our students do co-ops and internships and not all of them. And even those who do coops and internships sometimes they are doing paper works, paper pushing and stuff like that. It’s not real it’s a mixed bag at that point. So this gives us a chance to guarantee that they have some exposure and experience. They get a taste in sample of what companies do, it introduces students to companies and industries that they may not even have considered as a possible direction for them to work in. It shows them the diversity of what is out there for mechanical engineers. I think it’s very good and important to the point where it is institutionalized at Clemson.

How do you approach to a company I mean as you said its 99% company sponsored while taking projects how do you approach to several companies?

We approach companies we already have relations with, we call them up possibly about 6 months before the semester begins asking if they projects. We are contacted by companies or by former design students at companies saying “Hey I remember my senior design project is there any way that we could sponsor one now” that’s great. We also do cold calls, I mean I will contact local companies and say you know “Can I set up a meeting to explain what our program is and what we do”. So it’s all different ways on the table, one way works best.

Trying to get as many sponsors.

We try to have diversity of projects from diversity of companies there have been years and semester where Michelin asked to sponsor 4 projects and I only have availability of 4 then I said no, I will take one of the projects I can’t take all of them. And
that’s because a lot of companies see great value in it. But I want to distribute that to as many companies as possible for the students sake.

So sometimes event the company approaches from their side?

Fal – Yes

Do they see value in the program?

Fal – I think so, from a company point of view the main value I would think that they get out of this is the ability to have access to the undergraduates because these are companies locally that are going to be hiring engineers and they need to know what kind of quality students they are going to get from Clemson. They may be looking for an engineer that year so they are kind of interviewing 20 engineers at the same time. There is also value in the solutions that are generated, the multiple teams on one project means we give them multiple solutions. The solutions are probably not the final solutions but they might offer up new ideas that they had considered before that they can explore deeper. There is also some advantage to just being on campus and being able to learn about different resources and available research being done here on campus. Through the sponsorship of Michelin projects the coordinator of that was Ralph Hulsmen and he want and started his own company with couple other people because of the relationship developed through senior design he has come back to us multiple times in his new role and asked individual faculty to do small projects with them. So it’s not just a short term win on solutions it’s a long term win on relationships. Therefore, I think from a company point of view helps develop a longer term relationship with Clemson (both students and faculty).

Do the projects done by ME 402 do any impact?
Fa1 – Some projects that have worked their way into the company are still in use. There are some testing equipment developed by Michelin that is still being used. There is fixture solutions that have been integrated and used at BMW and other places. There is some product stuff that has been integrated into TTI, patents have been filed but I think the longer-term impacts that we have really centered in around the relationships.

So that’s working out.

Fa1 – Yes

What are the limitations of the projects?

Fa1 – What do you mean?

Is there a constraint to your giving away the project, I mean is there a certain amount of projects that you can give away?

Fa1 – We have limited capacity, so we try to run multiple teams on a project, we have to look at the student enrollment. We also try to put couple of faculty on each committee, which means that another resources that’s limited as the number of faculty increases that freezes up to do more projects. Right now, our biggest constraint is not students but faculty. And it’s not about the company sponsorship I have never had problems collecting up projects we almost always turn companies.

Even the companies should be satisfied in sponsoring the capstone design program.

Fa1 – I think they are, they keep coming back for more. I had no complains expressed to me, typically when they come back they are even more interested. In addition, a lot of that has to be with the fact that it takes a while for us to learn each other. I am learning the culture of company just as they are learning the culture of Clemson and so that
takes time. All relationship takes a serious amount of time investment. The more projects they do the better the quality the more value they get out of it.

Previously we talked about the local companies but what about the companies that are far away (other states)?

Fall – We have some projects with Boeing in Charleston, also NC the farthest away that we have done a project I believe was Raytheon project where we were redesigning the landing gear for a UAV and that was located in Tucson, Arizona and this was actually not a great experience because the company never identified a sponsor. The entire project was actually coming from an academic relations group not from an engineering group. They did not really care about it and became really clear to the students and to the advisory team that Raytheon did not care. If they don’t why should the students care so the faculty had to make them care, with other ways? Great solutions came out of it but none of them were taken care of.

So was the distance a constraint or the company itself?

Fall – This was an example of some of in the Deans office having relationships with Raytheon and saying you will do a project and here is the project. The scope of the problem was probably right but no clear liaison and it was just all the interaction that we do and the education the education we do with the company to train them or being a capstone sponsor did not occur and therefore it was not a good experience.

What about a good experience? Any example you can specify?

Fall – In North Carolina, caterpillar or up in corning we have done some good projects. It’s a couple of hour drive and that is a little bit taxing on the students that they
can’t just go there only to visit. Companies have to really make an intentional point of coming down. So lot more planning required so it’s easier if everyone is within an hour drive. Outside of a 2 hour drive it becomes logistically difficult, Charleston was very difficult students had to go spend a night down in Charleston.

Is there any added benefit to the faculty or the department?

Fa1 – For me it is a huge added value, I have had lots of project that came of m relationships with the companies. So it’s not senior design based my relationship and interaction. I have been able to provide access for my graduate students to this companies in terms of jobs we have been able to use the companies as case study examples and interactions. But overall there is value I get lots of stories, I have recruited well over a third of my graduated students from senior design. There is a great opportunity for us to look at using the senior design projects themselves as case studies. Huge value for me

Are the companies providing any resources to the students?

Fa1 – First of all every project has a 7500 $ sponsorship fee, beyond that the company also provides a 500 $ project fee for each team. So the team has 500 $ to use as they see fit to execute the project beyond that companies will provide test equipment or raw materials or lab space as needed. They will run the test for them sometimes and sometimes they will do machining for them. There’s a lot of different ways that companies have interacted and more they invest the more get out of it.

And if they just say here is the problem I will see you in 16 weeks, thank you. They are not going to get much out of it but if they are willing to be interactive with students and let the students pull resources as needed and it works out.
So how this value is defined (the sponsorship fee)?

Fa1 – The 7500?

Yes.

Fa1 – That value is big enough value that they have to put an investment in. If it were free they wouldn’t care so they pay to care. We also kept it under 15,000$ threshold that’s about where you have to move up to the president level to make decisions. If we keep it down under 15,000$ then engineering managers, plant managers can make call on sponsorships.

I cannot get you about the 15000$ threshold?

Fa1 – At 15,000 $ the person that has the authority to make decision is typically the president of the company. If it’s under 15,000 then the plant managers or engineering managers or manufacturing managers they tend to have more discretionary. So we keep it so that we are within the discretionary range typically.

Role of the company sponsor does he frequently mentor the students?

Fa1 – There might be a little bit of that but we try to have them treat this as an external consulting engineering firm they provide the problem, provide answers to the question and all. But don’t want them to provide the guideline in this, I want you to do X by next week, X and Y by the following week so no management that is explicitly not asked for and discouraged.

I have covered as much as possible. If you could like to add anything?

Fa1 – Not at this time, I think you have asked some pretty good questions. If there is anything, you can think of feel free to give me a holler.
Transcript 2: Interviewer – Varun Rawal, Interviewee – Dr. Gregory Mocko (Fa2)

How many years have you taught a design course.

Fa2 – Since 2006 when I joined.

Was it a lecture based course?

Fa2 – Yes, since 2006 and before that I was a co teacher at Georgia tech, so since 2005

How many years have you been doing the projects?

Fa4 – Since 2006.

How critical is the capstone course to your undergraduate program?

Fa2 – I think very critical. It enables the students to bring together all the previous course work that they have had it provides them with an opportunity to basically interact with practicing engineers

Can you please explain the structure of the capstone design program?

Fa2 – You may want to check with Dr. Summers, I think he has indicated that ME 4010 is the capstone sequence as well. So I do not know that, but second semester ME 4020 is the internship in engineering design is a one semester course, students work on industrial sponsored projects students work in teams of say three to five and multiple teams address the same project – students work to move from the problem definition as provided by the industry to functional prototype at the end. It usually involves a physical object that they are developing

What is the benefit of multiple team doing the same project?
It mitigates risks in a sense that it increases the chance of successfully coming up with a solution, is one of the benefits and the second is it gives multiple ideas for the same problem other benefits is the industry gets a chance to interact with more students.

Duration of the project.

Fa2- One semester, 14 weeks.

What is the structure of the course?

Fa2 – Lecture/week and the students work on the projects.

What about the industry involvement in those projects?

Fa2 – Yes, most are industry sponsored.

What the benefits as a students in doing those projects?

Fa2 – Pragmatically the benefit is you get a design experience, lots of time the students don’t have a full design experience I think the benefits are you get to meet folks from industry, you get to see what is important to them in industry, you get to involve in a real problem likely has real implications.

How is the program viewed in your department? Are there clear learning objectives, treated as an exit exam?

Fa2 – I do not think those two are independent. I hope that an exit exam has learning objectives in it. So it think it is the practical application of what they have learned.

What are your expectations regarding the prior knowledge of the students?

Fa2 – Yes, it’s at the senior year with a bunch of prerequisites from the course hopefully they have some point of mechanical system analysis knowledge on how you work on a design.
Do faculty use these as a way to evaluate the effectiveness of the rest of the undergraduate program?

Fa2 – Yes, there is an assessment that goes out at the end. There is an assessment committee that is ideally used to assess whether other courses are actually adequately preparing students for their capstone experience. There is a survey that goes out captured by the assessment committee.

What are the types of projects that students can do?

Fa2 – Industry sponsored and formulated both manufacturing and product development. Have some folks have sponsored both internal and external projects.

Do you have any idea about the percentage of company sponsored projects?

Fa2 – More than ninety percentage.

What according to you makes a good project? Must there be a sponsor to it?

Fa2 – I don’t see them different if the company has defined the problem and they have defined a set of expectations that they want the students to generate then those two things are aligned in my opinion. There is got to be a champion, sponsor to me means money but there should be a champion for a project to be good there is got to be some relevance.

What are the learning objectives and expectation difference between a companies sponsored undergraduate project and a research project?

Fa2 – If we look at the design projects, it is going to be a tangible project, it could be a piece of software or hardware. In research project there is not always a tangible product, you are often trying to answer a question but not necessarily developing a product
that’s the difference whether be a faculty sponsored project or an industrial sponsored product, what makes a good capstone design is the fact that you look into a solution to a problem that is a product.

   Why should a student do a company sponsored project?

   Fa2 – It can be, I believe that the important aspect of an industry sponsored project if the fact that it’s got a champion and got a problem that some ones trying to address regardless of whether student or a company sponsored.

   What about the motivation?

   Fa2 – Yes, motivation for doing company sponsored project is a big deal.

   How do you approach while taking the projects to the companies?

   Fa2 – We do can and email them talk to some folks, email visit companies.

   Do companies approach from their side?

   Fa2 – Yes, though it still requires we go ahead and contact them, they don’t necessarily have an idea of what program is like so yes, they do approach naively but still requires communication and discussion with them.

   Are there any companies that come again for projects?

   Fa2 – Yes.

   Why do you think they do that?

   Fa2 – Realistically speaking often a times the companies have got strategic partnership with local institutions and so they are trying to increase these partnerships. Other times they like students to look at idea that they have been kicking around. So I think we have success in the past and they approach us again.
Is there a limit to the projects that you can offer in a semester? What is the constraint?

Fa2 – The faculties and students both are a constraint often a times in spring it is number of faculties and fall it is number of students.

Has companies been a constraint?

Fa2 – No

How satisfied are the companies with their experience in sponsoring capstone design projects?

Fa2 – Not asked them how much satisfied they are in terms of number but the number of repeated projects we have is fairly high. So I would assume that there a high level of satisfaction.

Specifics of certain companies?

Fa2 – Can’t give specifics, certainly companies have expressed through repeated sponsored project and/or intellectual property patents that they have received.

Where in general the companies located?

Fa2 – Probably within two and half hours, mostly SC.

Are there other state projects that are far off?

Fa2 – Yes.

Is there any benefit to do other state projects?

Fa2 – Certainly, the closer the company the easier the students to visit the companies. So, as you increase the distance away from Clemson you get to little bit more
challenging and we have seen this even with companies that are in South Carolina down by the coast, students find a little bit more challenging to travel.

General benefits to the faculties?

Fa2 – If you got faculties involved in the program and they have got to travel that’s a challenge, so it’s important you travel and visit sponsors. So the faculties who are involved in advising a project to the students it’s a challenge to carve out a day and a half to visit the company. In general the faculties get to interact with the folks. It could possibly lead to research projects. This is from my perspective, I get engineering examples of practical applications of engineering that can supplement my courses.

Do companies provide any resources to the students for the projects?

Fa2 – Yes, it is between nine to ten thousand dollars.

How is the value defined?

Fa2 – There’s something I inherited and mostly came through a contract and often times we were collecting that amount of money. I did because of the people that have did the same before me. There have been instances where I have got lesser in money because it’s a good project.

If any sponsorship fee is involved do you think that the industries care more?

Fa2 – it depends, it is based on how the large company is. Ten thousand to a small company is a significant amount of money and to large company it still has to come from a budget item but I do not think there is a mapping amount of money and caring for the projects.

What is the role of a company liaison?
It’s not just management and usually more than one person so it’s not just a single
guy and could be multiple people.

How frequently does the team meet the company sponsor?

Fa2 – Completely depends on the projects along the team and the sponsors.

Apart from this if you have any additional information?

Fa2 – Projects have not been the challenge, contact with the companies are not a
challenge certainly there is probably some aspects of our infrastructure that a challenge, in
terms of size, spaces and access to spaces for prototyping in building is a challenge. Biggest
challenge that I am seeing now is with the most projects the mechatronic aspects of things,
electronic aspects are growing and so students don’t come in with a strong background in
the electronics aspects. So they are learning often times during their projects and I could
see it being better if they have some aspect of that earlier.

Do you try to implement the required changes in your curriculum from the feedback
or you feel changing after the projects?

Fa2 – I don’t do that, this is been recent, certainly ME students take electrical
engineering course there’s the extent to which they have a formal training. When I teach
machines course I talk about it but we don’t do any major aspects of it. No I have not used
it to implement any curriculum changes in the course.

Transcript 3: Interviewer – Varun Rawal, Interviewee – Dr. John Desjardins (Fa6)

How many years have you been teaching?

Fa3 - I have been teaching senior design basically the first and second semester Bio
E 401 design theory and Bio E 402 application since 2009.
Have you been working with the students in the projects as an advisor or in collaboration with them?

Fa3 - I teach and content of the course and also we have an advisory commute that meets all the students and team.

Don’t you work in collaboration with them or just advise them?

Fa3 - Teams meet once in a two week for the project gate meeting. The advisory group me and one or two other faculty and graduate students. The students explain us what they are doing and we then tell them what is right and what is wrong every two (six meetings per semester). They run through either proposal or prototype production plans. Verification, validation and testing plans. Then then prototype results and testing results and final presentations. They have to submit documentation in the presentation submission.

Two semester course?

Fa3 - The first semester is finding the problems, working with clinicians we work with doctors and health care facilities find a problem, define and determine if it is useful need. Then we come up with a proposal. The second semester is dedicated to building testing.

Do you feel that a yearlong project is enough?

Fa3 - yes one year works students have felt that the students can have weeks more for actual building and testing from this year we will move up first semester with the actual construction earlier. For first semester we were able to incorporate a larger need finding experience. So we have been able to collect large number of needs now. And it should accelerate our first semester work. My goal for this semester is to incorporate actual design
proposals move to first semester starting constructing the first data prototype at the end of the first semester.

How critical is the undergraduate program in your department:

Fa3 - Very critical, it is required it has received a lot of positive attention. We have hired a lot of faculty in the area of design. The department motto is that we train thinkers, leaders and entrepreneurs. Entrepreneurship goes hand in hand with design. So it has received a lot of positive feedback and part of our collaboration with the Greenville hospital health system at the student level. It is fairly well engrained and important and most of our faculty participates as advisors on the design teams.

Structure of the program?

Fa3 - Department has been growing we have gone from 27 seniors in 2010 to 100 seniors entering right now. So the structure of the program in the first is the design theory, decision matrices, needs finding and prototyping and manufacturing fundamentals, regulatory of actual property and things like that, end of first semester output is design proposal- defines the need, validate the need and have a initial proposal of the idea. Second is structured in a six gate process where the students re propose what they want to do. They have a prototype production plan. We have added a new gate last year incorporates a deep dive into prior art and research. Essentially if they are proposing to do something then they need to be experts in that particular field. So whether it is clinical terminology they need to master or manufacturing process or finding five research articles that are cutting edge in that area whether it be device or materials or whatever they are trying to incorporate something novel. They kind of completely exhaust.
Then there how we will do it phase where there is prototype production plan where they detail materials, parts, resources, timelines collaboration with outside entities. This is how we will test it (verification and validation gate). Then they are approved for the volume of the work that they are proposing to test their device. So these are my requirements, these are the tests that I will do to validate these requirements. This are the statistics that we are going to use, this are the machineries available to us. Basically three last weeks where they finish making and present that they make. Last gate is the results.

Final symposium where we have posters, devices and all the clinicians and industry people come as well.

What types of projects you take?

Fa3 - For the last four years they have been student selected we define the clinician or the clinical area that we have partnerships with. The students select those areas interested in and they go and find the problem to solve. Their proposal is to be validated by me.

So not industrial defined per se?

Fa3 - Yes, not industrial defined. We have done that in past with mechanical engineering department and we have discovered that students do not like the guidance. They want to pick their own stuff and learn. They find problems that are well defined to be just a class exercise. They find that the room for innovation comes in identifying a need. I suppose to identify a novel solution one extra level of interest. Additionally they find the idea of designing a solution for a company to be limiting in terms of their entrepreneurship potential, intellectual property. They like find that working for a company and get a lot of negative feedback about the idea of selling our students that is why we do not. We did that
for two semesters from a procedural perspective and it worked very well but from a student’s side of perspective and interest it did not work very well.

What are the benefits in doing projects that are students defined?

Fa3 - A third of our students just want to go to med school so the students find it very exciting to be able to go into the clinic or go into the operating room shadow surgeons me and talk to professionals. Basically get that professional development component to their education. Students who want to go to grad school and industry find that the product development portion of it is very exciting. For those students who are really interested in entrepreneurship or small business they find that potential of making their own novel device to be very exciting. So it is a win win for most of them. As it is a design class there are always students who have no interest in design what so ever. Some students have said it would be good if their work. One problem with open ended project is that the students have to invest a lot more into it They have to think more independently and come up to their own projects. So it is very likely they might pick one that's not the best we make them pick a bunch and then select and we make the clinicians validate that it's a good problem to solve so that we are going straight to the customer. Just like working with the industry but industry is paying for dissolving the problem for them where as we are paying the students to solve these problems we do not get money from the clinicians.

Do you have any clear learning objectives of the program?

Fa3 - At graduate level most of them are tied to ABET criteria working in teams and solving problems. Almost all of them we can choose which ones they target but from a design perspective you pretty want to cover them all.
Is it treated as an exit exam?

Fa3 - No, it is required class so they have to pass it to graduate. It is one of the core classes, so it is one of the last courses to take usually in the survey they are asked about classes and courses. They have to pass it to graduate.

Do the faculty use the projects to evaluate the effectiveness of the rest of the undergraduate program?

Fa3 - Yes they do, one of the reason they brought faculty to do the advisory role is that they can see how the students are making use of the tools, techniques and knowledge that they were supposed to learn in class they have taught. We have teachers that teach sophomores level, senior level and junior level classes and some very quick feedback from faculty about the students should have known that or we should really teach something else. We have iterated our class structure we have added things like solid works drafting, matlab coding. From Bio engineering perspective most of the faculties did not take Bio E as an undergrad because there was not anything like that so Bio E programs are most twenty years old. So we have faculty who are trained as chemist or mechanical engineers. SO they have different undergrad experience. SO when they see our students and see what they are lacking they add components.

Example one of our faculty does computer science as part of his research. After second year of seeing that students could not do numerical modeling he offered an elective course in that. It has kind of built up our undergraduate technical elective.

What are the challenges with the company sponsored projects?
Fa3 - If the company wants you to do it, it is clearly an idea that the company is interested in. That’s the easy part of that the hard part is to ensure that the project is technically challenging and it should be easy enough for them to finish. But it has enough scope within the creativity side of thing so there will be more than one solution that is evident, because if they just want you to do something important for them then it’s not really a design project. That is always the hard part but the hardest part I think is to spend the time with these companies to establish a relationship and get a project definition workout the finances of it negotiating the contract, financial incentives and then have the students being competent in reporting back to them. A lot of administrative work and if you have twenty design teams it will suck a lot of time from doing what you really should be doing which is assisting the students. About the point where I got up to eleven design team and finding to sponsor them that can waste my entire summer negotiating design projects that student didn’t like. Because let’s say a student’s comes in and they have been working in a vascular research lab for three years and they come into senior year design program and say I have a good idea for vascular device that I want to design and then I say no you have to work for company B. a little bit of creativity is good if the senior design has to be the capstone of their experience one can also say that’s not the way it’s going to happen in industry because industry you are told this is what you have to do so you better do it. My perspective on that is well than you only have one year left to be truly creative so you might do it now instead of pushing industry back into education. So that is two ways to go but fundamentally it is coming down to the projects because students spend an entire semester defining a problem and coming up with a set of requirements for doing design.
Then you are expecting a faculty member to do all of that for twenty two teams it will take a whole year that’s been the hardest part. And it is definitely a model which other program in universities where industries guide the projects works from mechanical perspective it is a straight forward one. One thing I notice that’s different in Bio E is it’s not a very established field so lots of companies are smaller and they do not have enough time and a year to sit on a project. In one year the entire reason for doing it could change or another company could have come out with an innovative device in that area so plus the back end of a design project in Bio E it can take years to actually get the product to market because of regulatory concerns. So it is not like you can come up with a solution and it could be implemented for a month or given over to a company and then they market it. So there’s a lot of risk in design in Bio E the time line really. So the summer before on defining a problem or by the time you have defined most Bio E companies will not want to do that with you because profit margins are tight idea are coveted and you come up with an innovation problem (that’s three quarters of it) they not going to let you do some work on that they got their own design R and D to do that. So finding a company that’s willing to take a back burner project and let students work on it intellectual risks, the timeline constraints they are usually different than I find out. So that’s been a big problem working with companies, working in Bio tech space so it is not fit very well. We have worked for a sponsorship at a curriculum level from companies but our geographic area is much more manufacturing and not a lot of Bio tech. we do not have larger companies like BMW or Michelin to go to or for a philanthropic sponsorship. There is not a large Bio tech company here at least in biomedical devices there are some pharmacy companies and some genetic
companies. So it is a little harder but what we do have is a big hospital so we get the raw needs, problem statements. We have found searched and backed national attention because company themselves are not necessity allowed to interact with the clinicians at that level. So regulatory laws have recently been revised and companies are not allowed to entertain doctors. It is considered to be conflictive interest, a doctor buys biomedical decide that are put into patients so id a company influences the doctors it can get him into a lot of trouble to the order of billions of dollars. They are actually not allowed to talk to doctors about their needs and interests. So it is an interesting situation you have doctors and problems and biomedical device companies and those two are not actually allowed to talk to each other very much. It is an idea that doctor makes money from patient. So a doctor choice should be made from the need of patients and not from the profit or relationships with the company. That’s kind of fundamental in conflictive interest in health care. And that’s completely different than most of other industries you are trying to sell a quality product for the lowest cost and your relationship with your supplier is very important. So we as a student or academia can serve as a bridge and so we go talk to doctors. We find their problems and documents and we can take back to the industry. So we have attracted a lot of national attention and in that we are solving or identifying the need of doctor that develop innovative devices and then we go license them to companies. If we went straight to the industry we bypass the person we kind of serve which is the doctor (customer) and so from our design perspective that’s just not the right way to go. But we get to design the perfect thing for the company but we get no clinical feedback, no validation that what we did is right.
It is great to design for the end customer?

Fa3 - yes, there are lot of things in Bio E a lot of rehabilitation devices sports devices everybody that has disability has slightly different disability. So designing a prosthetic per person as every person is different, so if you give a design team a challenge of designing a crutch solution for a patient it is a singular event and obviously they have to set back and take a long term look at it and may be making something that’s more universal for the general condition but for a small scale design projects you never make that for a company you make that for the personal patient. And that is how lot of doctors works one prescription per patient.

When you work with a company you lose that for sure and certainly lose the ability to interact with the customers. In the end we establish a relationship with a doctor and they contribute to the intellectual property, they usually co listed as inventors. So that’s another aspect we incorporate into design as our students are enlisted as investors in projects until they lean about intellectual property licensing and all that.

What according to you makes a good project? Deliverables or the real impact?

Fa3 - Clearly defined need worthwhile need just if you define won’t mean any good. So it has to be validated in the market by how many people it can serve or if it’s just for one or two people but it’s a really big problem then a doable solution. So adequate scope to the solution if needs to be something doable in a two semester otherwise its useless (deliverables). In the area of design lot of times you come up with initial solutions that are two years’ worth of research your masters is fine but design vise you have to identify all the resources necessary to get that done so that’s when we do the prototype productions.
We do the need first and then they have to say that they can actually make it, we get everything down up to a nut and bolt where we going buy this if there is something in there that is still magic (black box) they are not allowed to do it. We let them stretch a tiny bit not quite sure how this gear mechanism till work yet or not quite not sure whether I am going to choose from these materials but all of them would work. We enter in to a contract with the students that basically say this is the amount of work they are going to be putting in so they have to basically do the timeline of responsibility and demand. We demand that they put in a three credit hour worth of content in their design, but honestly their expected to function and work well as a team that’s fundamentally what this is all about (team dynamics). Work as a team to come up with cohesive solution even if that solution isn’t really rocket science and isn’t going to be patented. Clearly defined problem, clearly defined solution and everything in between working well from a team that’s what we want. (Deliverables and team dynamics).

Have they worked with other universities?

Fa3 – No.

Must there be a sponsor for a project to be good?

Fa3 - No, sometimes the students identify a problem that is more generic or more universal or they have seen in literature even they are required to get an external validation so that wouldn’t be a sponsor it will be a stake holder so we do not really have sponsors we have collaborators. So no they just need to define need and need to validate that need and in order to do that they need to have some type of external support.
Do you have any expectation difference from the undergraduate and the graduate student’s research projects?

Fa3 - The design stuff rarely gets published there are no expectation on publications and things I think there is a research is not necessarily a team sport it is you and your advisor. So the expectation are clear more team based that their equal contributions and there everybody are organized so that is different. They have to make something but that’s about it.

How satisfied are you or the faculties/collaborators with the students?

Fa3 - I think for the most part of our external collaborators are happy with what they have them so far. They like the energy and the excitement and the curiosity of the student’s teams. They themselves are clinicians they themselves might be 5 – 10 years out from actually being a student themselves so they see a young energetic group of students to be a very eye opening and exciting thing. They still on the improvement side of things do not necessarily understand what the student is supposed to produce; what the outcomes are going to be and how they can interact with them it’s been a process of building up that expectation level. The doctors somehow sometimes say think on student making something for me that’s not exactly the case, they are making something with them and then the doctors are expected to participate in the translation of that technology. So by the times when we get to the end of the design process and the students will go away they graduate and leave and doctors will be like where is my device and then I too need to communicate with them you need to work with tech transfer office you have to work with your tech
transfer office to forward that technology hence you have a final report but there is no guarantee that the device makes it to market.

Do you have some specifics?

Fa3 - We had a presentation the other day that you can expect that a in bio medical device space to eventually make it to help a patient may be six years you can design it, develop, test it and work through patenting and tech transfer. It gets to a company or incubator for further validation. It gets out through food and drug administration pathway and finally get produces and make it through patent. I had a group in 2012 make a device shoulder brace device patented it student group actually went out and got their MBA and then came back and licensed it back from Clemson and start their own company “opterian orthodox” and they are down in Charleston and sell this device to athletes, high performance sports athletes for shoulders dislocation. Another is a small silicon device that helps; you have a tube that has to go into your chest and has to be secured to your chest wall kind of a chest tube stabilization chord. The small elastomeric device very simple and to one piece thins disposal a dollar 1.15 but is a high volume product. S again patented and licensed to a tech incubator company that is doing further testing and validation on it they had it for the last year and to be able to finish off a manufacturing cycle and marketing in the year. There are about six to seven other devices that are going to the patenting process right now that are younger and have not yet been licensed to anyone and there are couple of designs or ideas that have sparked graduate level masters project that basically needed more research three or four of the and one students is investigating the program itself and more on developing entrepreneurship outlets.
How do you sponsor them?

Fa3 - Most of our projects at moment are colorations with doctors who have said yes I love to participate and then we basically just send them a student’s team the option of different clinical areas that they like to participate in so we say any student team who want to do orthopedic, sports medicine, vascular or imaging or about 22 different areas. We pair up the students by the area and we say here you contact they go down to doctors and talk about the problems.

Do you provide resources?

Fa3 - Yes senior design have couple of labs and offer them money for their prototype production plan they have to ask for certain amount of money, no predefined value. They should specify what they need and why it is not like I do not know how much it is going to cost because I have not planned yet and it never works out but they have to look far enough ahead that they can price out enough stuff most of the time they say I need $2000 and we say no you cannot. In some cases we give because everything you have makes sense and if it is logical plus we know you not going to spend that. If they make a proposal that is concrete well justified they have done what we want them to do which is plan and there are obviously unexpected contingencies they have always have to come back and justify those but we make our budgets at second third week of the classes and I get everything from 50 to 2000 bucks but it all works out on an average students pond about 500 dollars a team. And this is whatever they want to do this is them solving the problems. We have lot of design smaller fit in or around human body so definitely machine shop involves and things get expensive.
Do you have any other questions for me?

Fa3 - What is the basic goal of this interview?

It is to know your perception of the program.

Fa3 - About the company sponsoring the projects. It is just redefining the customers we do not have companies we have customers. We have defined our role as connecting students with customers not connecting them with companies with problems because companies do not have problems the patients have the problems. We have just short circuited that we find that they students when they go for actual interview with the companies they are able to focus on that message a little more clearly, companies are not solving problems that they have defined.

Do you survey patients?

Fa3 - In health care you are not necessarily supposed to do that. Students can talk to customers but not patients. So there is clear division between talking to a patient which is under the care of a clinician again it is conflictive interest so they have to go outside the clinicians environment find neighbors, friends, parents or somebody in the community who has this condition and they interview them that is validation as you cannot go directly interview patients or doctors. That’s just the way we do it but within the biomedical device or Bio E curriculum there are 130-140 programs approximately I would say that it is probably one third do this needs based clinical finding. One third do industrial projects and one third do the faculty level students idea. We also need mechanical students in our design teams (multi-disciplinary team)

Transcript 4: Interviewer – Varun Rawal, Interviewee – Dr. Oliver Myers (Fa4)
How many years have you taught the design course?

Fa4 – Minimum two-three years again this was at Mississippi State University.

How many undergraduate projects have you done so far?

Fa4 – At least twenty five projects, some projects were carry over from semesters so projects that were continuations but I want to say roughly twenty five projects.

What about your role in those projects?

Fa4 – The way I ran my capstone class was that I was the facilitator and so I literally got the projects made up teams somewhat scientifically bit I made sure I tried to do it as objectively as possible so that no one team had all the friends. So I worked as facilitator of giving the projects The students were responsible for interacting with the project manager which could be another faculty member or somebody from industry so I was just there as more of a facilitator and a times I served as advisor, just to may be direct them on some concepts and ideas but the students responsibility was to interact on a regular basis with the customer or program manager.

How critical was the capstone design program to your undergraduate department?

Fa4 – It was literally the last class. It was required course for graduation and it was the course where students were able to tie in all the course work into one particular project, it may not be all the courses but a majority of course work. So you were able to bring in statistics and dynamics along with the heat transfer and thermodynamics as well as mechanics and machine design all into one course.

Was it treated as an exit exam for the students?
Yes, kind of if you want to categorize it that way we gave them most of the projects were from the industry so they were working on real world projects and teams of four to sit and the students had to interact with the program manager so they were getting the real world experience just in a relatively safe environment vs getting this projects right there at the jobs.

Can you tell me about the types of the projects that you offer?

Not all of them are industrial sponsors we had couple of projects that were sponsored by faculty that needed some fixture designs that were a couple of projects that were sponsored by an aerospace industry that wanted some design for unmanned vehicle launch system, there were couple of projects from a large structured manufacturer that wanted some designs on a trunk mounting system. It was an unmanned aerial vehicle design from the department of defense, there was some even down to a bed redesign from a bed manufacturer so we had a pretty good variety of different things.

What are the benefits to the students in doing the company sponsored projects?

Essentially it gives them a precursor to what they are going to do when they get to the industry. The type of work, the type of collaborations that they have to have. They are not going to work in isolation they are going to work on teams, if they are going to work in teams that have a good people and bad people, you get to develop leadership capabilities, leadership skills, who is going to be spokesperson, who is going to do the technical work, you have to have team work as said team work is essential because as I said you are not going to work in isolation. You have to work to the customers’ requirements I made a class similar to my corporate experience as well where we had
system requirements reviews where students had to understand what was required from the customer then we had preliminary design reviews and we had critical design reviews, where the program manager was actually brought in and they were allowed to critique the students’ progress and for the majority of the classes the students grades came from the program manager now of course U had to grade the students in terms of class but some of their project grades were actually more dependent on the program manager than from me and so that just ties into what happens when you are getting evaluated at work, your calculations come from your program manager and your team leads.

So was it like an industrial setting?

Fa4 – Yes, as much as possible within classroom setting.

Are there any clear learning objectives while you solicit the projects?

Fa4 – The learning would be directly related to the requirements from the company sponsored projects, but the leaning objectives from a particular class are integration of all the course work into the project, everything that you have learned over your four years at Mississippi State that you apply to this. Again team development, team leadership those are less measurable until you see them but then there is not something you can put on paper but you have to develop those skills, you can be technically savvy, you can do all the sum of forces but can you communicate? Communication was a big key because students had to present a minimum of three times during a semester so it was clear they had to be able to do a power point presentation and speak to audience, peers as well as technical experts, communication was absolutely key.

Does the rest of the faculty use this as a way to evaluate the undergraduate program?
In my former institution the faculty were not as participatory as I would like to have them, there were some faculty that participate in gate projects, came in and evaluated the students but by and large the majority do not participate as much and so they really had no foundation to evaluate the students’ progress of what they have learned over the course of four five years.

Is that a challenge from faculty side to cope up with time?

Fa4 – Yes, it really is because most faculty are interested in research and to fully sponsor a project or take the time to sponsor a project and come in and sit and evaluate so of course there are scheduling issues some did have legitimate scheduling issues where they wither had class or conferences those you cannot do anything of course but there was participation from the faculty standpoint in terms of offering projects and then coming back and saying well the students have learned this or they have not learned this we need to evaluate the undergraduate curriculum a little more and so it needs to be a kind of full circle evaluation and saying okay we have been teaching this for four five years, have they actually learned in the capstone class, do we need to go back and evaluate. It needs to be more iterative loop and there was disconnect.

What according to you makes a good project?

Fa4 – It doesn’t have to be a company sponsored it just have to challenge the students to think critically about what they are doing be able to force the students to be as creative as possible within the guidelines of the requirements some projects that we had where relatively easy for instance the bed frame was nothing but a hollow bar. We wanted to use a modular system to a king frame to something that could break down and so I forced
the students to apply as much than possible within the guidelines, forced the students to use finite element analysis some thermal dynamics some fluid analysis, so it got them out of some other comfort zones but at the same time forced them to continue to learn, to do some research look up things not only in the archive literature articles but even things in popular sciences, mechanics, mechanical engineering magazines. So it forced them to go out of the text book frame of mind and go beyond what’s the traditional class room setting.

What do you think about multiple teams doing the same project?

Fa4 – That depends on the type of projects going on because in the past it were multiple teams working on the same project and if you get multiple perspective that’s fine if you get two or three different teams coming up with the same answers with the same result. It’s kind of repetitive it doesn’t necessarily indicate that the students were creative or that the project might have been too simple. So that’s more project dependent as a general statement.

Why do you think would a company need to sponsor the projects?

Fa4 – We got a couple of company sponsored projects because there was a need within a company but they did not necessarily want to hire or have a employed engineer work on his projects where there were many other priorities but it was still a need, so they were able to allow us as a university to work on these projects for semester, may be even two semesters and give students experience develop a relationship with the company, so now we have a nice conduit between the company and the university. So that the company can say oh yeah we have some students from Mississippi or Clemson work on these project may be we can hire as an engineer as they did a very good job and as a same time we can
grow their relationship and say we have worked with this company in past. So there should be a symbiotic relationship between university and a company not one directional.

Is there any limit to how many projects you can sponsor?

Fa4 – Well, the only thing that limited us was either the number of students, there were times I had more projects than I needed which was a great thing I can move that project to incoming semesters but there were also times where I needed more project that I had and I had to scramble. So having a multitude projects is not necessarily a problem, having students to work on those projects and having students of capable to work on those projects can be a challenge and the other side of it is making sure that the companies are willing to in com form of way sponsor the projects whether be financially would be ideal, we did not always get as much financial support from companies but at the same time we also got some type of material support or travel support sometimes would allow students to work in a non-secure area or area where visitors could work in not disturbing the regular employees, so we had that type of building and growing relationships.

How do you think about the experience of the companies in doing the projects?

Fa4 – They actually enjoyed doing it because the students did a very good job in the projects and the program managers that were able to come to the university were able to meet with all the professors and get an idea of some of our capabilities and we were able to interface that way and kind of developed and grow that relationship and see what all opportunities would be available.

Can you give me specifics about some projects that impacted the companies?
Fa4 – We had a project from a paper mill that was designing rollers and from the student results they were able to create a sensor that could detect how out of round the students could have and it was implemented by the company and if the students had not been hired by other companies I had a surety they would be hired on the paper mills to work on this rollers. We had another the UAV company wanted to create a launch mechanism and students that designed the launch mechanisms actually gave the presentation to the VP of the company and the VP wanted to implement and hire the students in that area since the students are coming in already at their senior year most of them already have a position and so it is kind of unfortunate that the students are getting these opportunities so late in their academic carrier because many of them do a fantastic job. The companies want to bring this students on nut they are already been hired by somebody else but we had couple of projects with faulty members that went right into their research projects. Which is great for testing mechanisms and fixtures, we have had those successes some weld designs for large trucking company implemented by the trucking company.

So, potential hires is the other motivation for the companies.

Fa4 – Yes.

Can you tell me the distance and locations of the companies? Any far distance projects?

Fa4 – No, it is ranged we had some companies that were four hours away and we have some companies that were twenty minutes away. Now again Mississippi State University is geographically challenged because couple of the companies were as I said
within close range – two companies were twenty minutes away, one company was thirty minutes away and we had one company about two and a half hours away and a company four hours away. So we had that range because of location but even still if we plan the presentation out as far enough the program managers work a schedule out and were ready to come out. I always have scheduled plan out early first week of the semester start date. The only strong request I had to the program manager is to attend the critical design review at the end of the semester and the students had to actually prepare themselves as if it was a corporate setting, they had to actually wear a business attire and that made a huge impression on a program managers just the professional and of course doing the actual presentation. So, students get a lot out of doing it from that stand point as I said I set up the class as a corporate setting.

So are they important?

Fa4 – Yes they are very important

Are long distance project challenging?

Fa4 – They are challenging because the students would have to either facetime or skype with the program managers, email and that could also be challenging because sometimes it is little bit to the interpretation of emails but there were times where the department and the company would sponsor one or two drives done for the students and students will get permission to drive down four hours depending on the company so we encourage that and my department head was actually supportive of the fact that we weren’t getting these industrial projects but even more so the students interface with the industrial sponsor on regular basis depending on proximity for those that were within twenty to thirty
minutes they go over every week or may be every other week but for those projects that were two to four hours away every month may be or every other month or six weeks they go.

What is the sponsorship fee?

Fa4 – We usually request a roughly $5 – 10,000 from a sponsor per semester 10K being the cap at that time, now there were some semesters we did not get any funding from particular project or particular company and the idea of establishing a relationship. One of the companies was a alumina and he donated several piece of equipment and money, so we did not ask any for sponsorship as he was a donor but from the other company we ask sponsorship fee and we has laid out say for instance, $5000, we will have money for student transportation, equipment material and some of the money went to the department for overhead fees-finite element, solid modelling code things and that nature so it ended up being useful not on to students but to department as well.

Apart from that do you have any other information regarding the program?

Fa4 – It was a quite bit of a work from faculty side or at least as an instructor because I would spend the summer working to get projects for the fall and I would spend fall to get projects for the spring and the cycle continued and in terms of lectures I try to keep it high level executive type of courses, I did not necessarily dig into the full mechanics of the course, at this point they should be functioning engineers they just need to demonstrate within the safety of the university course rather than in an industrial environment. So as a professor it is really gratifying to see students actually have that aha movement when they understand the process and to be able to tie everything or something
they have learned from the classroom to an industrial realistic project and to work to gather as a team to see that level of success if they have been able to make some good progress on the project. There have been times where I had to defend the students over the program manager regarding their hard work and the issues they faced as everything is not perfect and at the same time I had to come and say the managers about their critique of the program as it is too harsh and explain they have done a god job and number of time they have met me and I hard to work with them on this issues. And there’s time where the students have done an outstanding job.

Transcript 5: Interviewer – Varun Rawal, Interviewee – Dr. Scott Mason (Fa5)

How many years have you been teaching?

Fa5 – 2000 I have been teaching, so 15 years since teaching students. In general taken a part in student’s projects for 15 years. I was in Arkansas for 10 years 2000-2010, there I advised the undergraduate researchers. SO it is 12 years with undergrads.

What is your basic role in the undergraduate projects (Advising or working in collaboration with them).

Fa5 – Undergraduate can be very talented. I do a lot of work with them early. I teach them what I want from them. I show them how to do it and then over time they start delivering on my request and then give them a challenge. After that as they continue to grow, start to be a contributing member of the project then it becomes an advisory, guiding kind of role. As the relationship grows and matures the students really get equipped with all the classes they have taken and all the experiences they have had. I do a lot of advising and guiding but after getting my trust and demonstrated their abilities it is less hands on
and more helping and guiding like steering them. Though it is always a collaborative environment if it’s a project because it is different from honors thesis.

How critical is the capstone design course to your program?

Fa5 - Very critical as it is their last semester, it is a major experience for them working in a team with an industry sponsored project it is a major undertaking. Students will leave few other classes to take the capstone course. It is a large time commitment (10 hrs. a week), it is a visible demonstration to the industry what students can do. They get to teams working on the same project. After the final presentation they tell who’s the winner and why. It is does not impact on grades but they give feedback to students which team was better. “It is very much how we show to the industry what we can do (programs image and visibility)”.

Multiple teams working on the same project?

Fa5 – It is wonderful because as company they don’t share information amongst themselves it is interesting to see how two different teams can come up with same or completely different approach to the same problem. It is often similar usually some differentiating factors that make clear to the company that one team did a better job.

Structure of the capstone program.

Fa5 - Solicit projects every fall for spring capstone. The projects are very large in scope and important. Meaning the company has to make whether it is to relaying out a facility for improved efficiency designing a more ergonomic system, developing a scheduling system and “most projects have multiple objectives in them”. So we work very carefully with the companies in fall to make sure to scale down a project then to realize
that this project is very small. It is 2 lecture day and 1 lab day per week. Lectures are on deliverables, ethics, case study debate with interim presentations, moreover there are site visits and TA assistance during the lab day.

How is the Industrial involvement?

Fa5 - They are keen as they are paying for the project and students go out to the site visits, companies having a key point of contact with the students makes it successful. “Not successful when the sponsor is unavailable or do not take it seriously”. The students need the company professional to connect him to the right people, right data access for the site visit.

Benefits the students in doing projects?

Fa5 – Placed in a non-typical academic environment that have a real word problem to work on having no textbook to teach how to answer it. They have to () all the classes and everything they have leaned. Having to draw on other courses simulating the real world, have to work with people they may or may not like, figure out who is going to lead the team. It’s like same issue in industries you are put to a whole new team with a new problem. It is different than Homework problems. It ties all together and shows that you can really do this in practice.

Do students perform professional protocol?

Fa5 – Absolutely, we teach them, grade them on it. We get feedback from industries and also give lectures in it. They grow into professional type engineers. Presentations require formal business attire, grade them on content but also delivery and mannerism.
Hence we prepare them as if by the time they graduate they are ready to join the work force.

How is the program viewed in the department?

Fa5 – Seen favorably as we have done interviews. They are excited to be graduated but they value the experience of putting all together. Students getting ready for capstone they are not afraid of the program but they know it’s a great thing. When in Arkansas same thing capstone is the last thing that stands between you and graduation. It is a ton of work and effort but it is worth it.

Do you use the program to evaluate the effectiveness for the rest of the undergraduate program?

Fa5 - Yes, big part of the ABET assessment, all aspects criteria. Design class has many components that we evaluate through variety of matrix like survey, employer survey also recent graduate students have to fill out a post design questionnaire about how well they were prepared and where we could improve our education.

Types of projects?

Fa5 – Company defined projects. I want you to develop a software program that manages our warehouse(not a related project) though we want to figure out where the waste is in our system and how we can improve our efficiencies and of our worker safety and minimize our cost that an appropriate problem. We work with them and have done enough of this and know what a good project looks like and figure out what is an appropriate scope because the students when given projects are given a one paragraph description and they have to use that as a starting point. Project must be an industry sponsored. People who does
capstone at other schools with non-industry defined projects. I think it is benefit when it is a real project and you run into real issues. It is a huge disservice when students work on a fake project but clearly there are school that their engineers turn out just fine. If I was a student’s I would like a real world project that somebody is counting on.

So do the industries feel the same?

Fa5 – Yes, they keep coming back for more. We have companies waiting in line to pay for our projects because companies sponsor multiple projects also because value they get from the students for outweighs the cost of the project

Are the companies returning because of the value the get from the past projects?

Fa5 – Yes, if the students did a bad job why will the companies come back they come back because they like the value they get they like the results they get. They like the industrial engineers from the Clemson and this is true for the other departments. Companies don’t invest money without getting something in return.

Do you have some specifics?

Fa5 – Last semester we did two projects for Greenville hospital system, Milliken the projects were like how should we relay a distribution center for more efficient product flow, having right number of workers. People looking at an automated guided vehicle system at Greenville hospital designed one way they did not have enough vehicles to move material between different floors, the students had to look at the whole system and figure out cost effective way to change or modify the existing system and to get better performance. Other project was to when you checkout from the hospital they have people called transporters needed to push the wheelchairs if there are not enough transporters then
the patients have to wait. We did a study to figure out what’s the right number and how to staff the transporters based on the historical demand, such to improve process, patient experience, keep cost down and reduce patient waiting time.

How do you scope the project?

Fa5 - We won’t do projects that are easy where students won’t learn anything. Project had to have a significant scale, scope and complexity and we make sure through our projects every fall.

What are the limits to the projects?

Fa5 – Our class is only in the spring we meet with the companies in the fall to get ready for the spring. Last semester I had another team get formed more student’s joined the class. Beginning of the journey I had to find another projects and it was easy to find another project because there are companies waiting for this projects but typically these companies know what they are getting and keep coming back for more. The limitation is I have a company right now looking to start a relationship with Clemson. He wanted to do something this fall I said I could do a research project with you this Fall or can do consulting this fall but not capstone. Because it is in the spring but we can specify the project this fall and we can work out on it this spring. He was very excited about that. So we are going to do with another new company that has never done work before with Clemson. “They are using capstone as a way to see what Clemson is all about”

What does an industry see in students when they do projects? Their intentions.

Fa5 – A lot of them. First is that they want to get their project done, they are also getting to look at what the current students are capable of and often very impressed how
smart every year the student’s get. What they can do and what they are learning. They also see things like: how do you guys teach your students leadership, which class is that. Because we do not see any leadership (we can think about that) get feedback from the industry and can improve what’s good. But what the companies get out of it is almost (if they have two teams of four) getting four months to look at eight students graduating in industrial engineering. They might learn something about what IE is, might learn something about interviewing the students as they seem to be really good and we can hire them.

Do you try implementing changes in curriculum after the projects?

Fa5 – Yes, that’s part of our ABET assessment process. If we had every company or a lot of companies say your students are really bad with spreadsheets which they are not then we would probably say this is a consistent feedback where are we teaching this in our curriculum who is teaching that class. We would use feedback from capstone to make sure we could improve where necessary. If the industry is telling us we are not meeting the needs based on how we are educating the students then we need to make sure we are covering those gaps. We are training the next generation workforce.

What are the general locations of the companies?

Fa5 – That’s interesting part of the companies who signed up for these projects, the money they pay is also support for travel cost of the students project with Boeing in Charleston past we have Meritor three and half hours away, Elan Raven is fifteen minutes away. I like them to be closer so that promotes the students to get more site visits. It wouldn’t be good if students have to drive for seven hours for a design project. My
experience is that they are always in the state and within three hours of drives, we like closer than farther away.

Why is it so that you don’t like far distance projects?

Fa5 – If I want to have to do a good project. I need to go to the site to have data and if it takes me six hours to drive there with students regular class schedule it teams out to be very hard for people to have that much availability, where as local team could go to the plant any day of the week when it is fifteen minutes away so I do not prefer as I like students ideally to be less than two hours to the plant so there is no reason that they cannot go there for additional face time.

Do you have any past example with the other state projects?

Fa5 - In Arkansas I did a couple of projects, because of distance and time the project was fine but would have been better, do not find beneficial when students spend more time driving than meeting on site and collecting data.

Benefits to the faculties in doing capstone design projects?

Fa5 - Benefits for capstone is the companies who get to know our department might come back to us with another need later and we have a good visibility of what we do as a department. So let’s say we do a capstone project with Greenville hospital, the students do a great job may be later the hospital said we have a need of forecasting research Clemson people seem to be pretty good and let me ask them if they have any ability to help us. So it is faculties benefit is both feedback and re information on what we teaching but also potential relationship to the industry.

Do the companies sponsor research project as well?
Experience is whom I do research with want a capstone design project. I have not had any experience where a company who does capstone project and want a research project.

Do you find any difference between those?

Research projects I am heavily involved in and much more technical. Team of four very talented undergraduates with a little bit of faculty guidance is a design project but un research project I make sure the project gets right because my name is on it. I am associated with capstone but in students product I help them and do not let them to fail but I do not give them a way to do it. They do it themselves, in research I tell students what needs to be done.

What us the sponsorship fee?

It is 6000-7000 dollars for two teams to work for entire semester on the same project. It is a fee which is used to support the students travel, awards, banquets and it is an expense coverer kind of a thing.

What is the role of the company sponsor?

No guiding his job is only as a liaison to get data, getting students answer to their questions and attend presentations. I do not say that they never give students the suggestions if they have a problem they do not have time to solve it that is why they bring in the capstone team sometimes they do not have the ability to solve it. They are getting tremendous value and getting important problems solved for little money. Getting two different sets of eye working on the same problem. If they get some return on investment that’s the same questions why do they sponsor research projects, because if they give
hundred thousand and they can save two million it’s the value that’s coming out. Some companies are loyal to Clemson they want to give it back.

Do you have any additional information?

Fa5 – Capstone project is wonderful and successful program. The project has to be bigger and better and cost more money because they will be spending more time on it.

**Transcript 6:** Interviewer – Varun Rawal, Interviewee – Dr. Cameron Turner (Fa6)

How many years have you taken part in students projects.

Fa6 - I have been involved in capstone design program on and off since 1997 graduate student mentoring for the capstone design program in UT Austin later as an instructor in UT Austin. Did a project in los Almos national lab then running the capstone design program at Colorado school of mines through last December.

Were you the head of the program?

Fa6 - I am the head of the program from august 2009 to Dec 2013. And I am currently faculty teaching in the program as well as a client for a project in the program.

So what role do you feel is great mentoring, guiding or working in collaboration with the students?

Fa6 - There are very different roles when you are working and mentoring with the team you are developing that engineering talent on the team. Trying to guide them from your experience but also trying to give them enough latitude where they can make some of their own mistakes and learn from it. You are trying to balance that learning objective for the students with the program desire to deliver a successful project to the client. Trying to allow both the activities to happen when you are running a program your role is little
different. You do not get as much time with the students at least the way we operate because we have faculty that are weekend in daily basis with the teams. And then I see them sort of a big mile stone moments in the program or when there are problems but what I do running the program is I have a lot more interactions with the clients, finding out how clients are doing I interact with the faculty that are working with the teams trying to help teach them how to manage the teams. So I am seeing different aspects of the program depending on what our role. I think in many ways as more rewarding to work with the team. I think in many ways as more rewarding to work with the team. I would say that’s true even as a client (team dynamics). But at the same time there is a big picture operation and somebody has to do it. I describe it as you are teaching three classes. You are involved teaching the students at one level you are teaching the faculty that are working with the students at another level, also teaching the clients that here how we are doing how we instructing the student. And that’s something you always see when you are running the program.

So do you see some advantages in working with the team?

Fa6 - There is a fine line to tread. If it was all about I want to get this product out successfully I could be very perceptive and tell students to do it this way because I know this is going to work and produce good results and we will get the project done. If it was the industry setting probably how it operates managing students but because there is an educational objective to teach them how to do the project themselves you have to build in some latitude for them to go down the wrong path. I had a team once they were building basically dynamometer and I had this conceived notion as soon as I saw the problem that
okay we going to take the motor and test. We going to hook it up with another motor we once get the solution commonly employed. The team came back to me after their conceptual design they had all this ideas (motor generator combination) but they had these all fancy mechanical leakages and all that I asked them how are we going to get an arbitrary load profile how are we going to use weights and springs. Are you are going to mechanically program it? They said yes. As being a mechanical engineer they were afraid of lab view. And they kept telling me that this was the best solution and I knew that they were going down the wrong path instead of telling them they are going wrong I asked them to prove it to me that this path is better than that path. I made them sit down and do the analysis and they came back to me about two weeks later after the analysis and said you know what it is better to use lab view than it is to do this manual masses and all. So they learned if I was in industry I just need two weeks to schedule two weeks of engineering time and in academic setting like capstone it is valuable experience it is worth the two weeks it is worth to put the schedule at risk. Let them go off from that tangent far enough to realize that was a bad idea they had why it was bad.

Is it that they finally learn something? And what about the project scope?

Fa6 - Yes. When we select the projects we look for something we believe there is a solution to possible solutions. We may not know which one is the best but there are several feasible ways that this could be done. We try to look projects where complexity is same level as you get in your senior level course. So, if complexity is way beyond that then we talk about whether it should be graduate project or we try to narrow the scope down on the project. The team can really focus in depth as supposed to the whole fact. It is about
achieving we are not perfect at it, I do not think anyone has projects that you get into and they are sure it is going to work. This is not going to be a good result we try to be very upfront with the clients about that. Senior design as a failure I tell the clients coming in best projects that they can give us are the projects they look it as a business model. They say we are kind of stopping right here we are doing the same solution to this problem every time and you just want to see find something new we know what do works but can we do it better or there are the things they keep running into projects where they know that their solution is not a good way of doing it is workable but they do not have the time and money to spend to find a better way of doing it. Example: A project we had with Los Almos national lab they had a localized chilling system design had been around for 30 years as it works it costs them 120,000/unit it was not a flexible as some of their needs required to be kind of had to size it, change what they had maintenance was not good on it, it was doable but it was a pain and they knew they can spend six months of their time in redesigning and coming up with a lot better but they never had a project that could justify spending six months to do it. So they finally came to us what amount of nine month of their time in terms of cost that cost us to look at the project. Our students went and looked at it and ten months later they had in production they ordered a production run of ten of our units. They were so thrilled with the design and drawing they ordered a prototype. They came up with the cost and it was half of the old limit (s). Much better performance maintenance and flexibility able to justify small expenditure for something they were not doing very well and do it better. Key element is it was not in their critical path either if we fail at it they had a design it was workable but now they have a better design so they get benefit without
putting their business model at risk. So if you show up and expecting to create a product that saves your company we do not do that you cannot ask us that. We are in the business of training the students to be designers in the future which means some learn a lot as their design is very good and they have to have that opportunity so client should give us latitude to fail if they cannot do that then it is a long project they could hire professional consultant if they need a project that saves company

Structure of the program? Can you tell me the types of projects and how long the senior design projects are?

Fa6 - It is a two semester sequence one is the fall-spring normal semester and one for spring-fall for those students who miss a semester. We have at any given time in the program roughly 300-350 students half of those are mechanical. 25 percentage are civil, 25 percentage electrical and 5% are environmental and then remaining are others.

So no separate capstone program for the departments?

Fa6 - No, all together these are actually multiple field projects usually 60% of projects are two field projects we commonly see mechanical projects with electrical aspects and vice a versa, civil-environmental combination and vice a versa, but electrical-environmental or environmental – mechanical is occasional, sometimes there are three field projects Ex – design of solar array systems passive tracing involved mechanical, civil and environmental. We are having thirty percentages of projects that are one discipline, some of them will benefit of having some cross over but it is not essential. So we are dealing with mechanical systems that need a control and so could you have electrical engineers design control system, though a mechanical engineer can do it, maybe we cannot get as
high and sophisticated control. Out of the remaining ten percentage virtually all of those are of that three discipline split and we legitimately need four disciplines involved and we do some projects having group from our senior design program working with a group from chemical, with mining and usually those are client demands. We had one working ar natural gas production and power generation at landfills and so we have chemical engineers design basically a system to harvest, purify the natural gas landfill and then feeding it to the power plant involving work from civil, mechanical and electrical so they were figuring out to do that together, but team size on the projects varies depending on the scope average team size is six I would say it should be five but we are limited to how many projects we have and how many faculty advisors do we have to work with the individual teams. We have some projects with teams as big as nine; often some of the competition projects have bigger teams. Because senior design competition requirements both are there and there are several overlap not a perfect one they have extra work to do. “We have three per team as well for much more focused projects and some of those because we have limited students interested”(P2). And we usually when we drop below four we talk to teams and ask them if they are sure about the project or find another project with bigger team. And usually when we drop below four we will also talk to define by how we scope the project to recognize three students “first senior design projects ideal size is five”.

Why is ideal team size five?

Fa6 - too much opportunity at six for someone to hide on the team and not really pull their level and if it is five then everyone has got enough to do.

So how central is the capstone program in the department?
Fa6- It is we probably put more resources as a department to that program than we do for any other program. We do not charge fee at this moment to be in program, we are changing that model we got approval from the university to charge fee which is nice we have been funded asked client to pay for materials and stuff. But there has not to be a mandatory fee for the projects, we have some grants and foundation funds that help support some of the projects up to this point so we have been self-sufficient, we have not be covering the instruction cost that comes from the coverage. Roughly $ 300,000-350,000 to pay for the faculty and staff running the program. However, that is probably the biggest single line in terms of the whole college sort of investment on one particular class. We are also the only class that has the ability now that we can charge fee we could actually take that out in couple of years we have enough client that are entrepreneur participants. In the program we expect that we would probably pat for our own budget we would probably be.

It is a big deal we have just been through our ABET accreditation. “Every department relied on senior design to support the assessment of their degrees”. We have probably responsible for seventy percentage of the ABET objective assessments so it is a lot I think. The administration looks at the program and says that capstone should be the signature program that the students take as they go through the graduate school while students I do not think see it that way we have been a lot of the senior problems like I am ready to graduate and nothing left for you to teach me about being an engineer I have this coops, I know what I am doing, why are you now telling me how to design I have already been doing it for three years. So there is a lot of resistance to doing most of our grad students have come back
three to five years later and say you know what the class was actually useful. We also know
that it is important for the profile of the college.

Why should a student do a company sponsored project?

Fa6 – I think a big advantage in client sponsored is you get a realistic industry experience. When they are dealing with the client they have to give outcome and results while faculty teaching the course are interested in the process. So to be successful they need to satisfy the clients, faculty advisor and technical consultants. There is something about the real world the uncertainty, managing that uncertainty within your team and workflow that you can’t really teach and you have to experience.

Why should a client sponsor a project?

Fa6 – The first reason is to develop that employment pipeline and then as a vested interest just as a professional responsibility. The projects that they solicit are not in their critical path either the projects are the things that annoy everyone in the company but just not have the time and resources to fix. So let us fix to make you a better company. We are cheap engineering in reality we help the company reinvent itself so capstone design become investment of the company profession, investment of company in its performance and process that’s why they should sponsor the projects.

Do they come back again?

Fa6 – Yes, we get clients coming back every year or every other year. It depends on the business cycle and business condition of their company. When the companies were tightening on things and couldn’t do engineering they came to capstone design as it is cheap
and then some point the projects were going down because they went lot more tightly and
were not able to allocate funds for capstone program.

What about the past experience with the program?

Fa6 – I think what really takes is someone in the company saying this is valuable.
And to articulate that within the company we cannot really do that we come in and serve
as parachute professors and we drop in and say hey come to senior design and see what
you get out of it, they are excited and then run off to their next meeting and two meetings
later they forget about it. Hence you need someone in the company who buys into it and is
going to bring up in every meeting. It is a transitional thing, you have to keep selling the
program that you get someone in the inside that says this is valuable. To be a good client
it is not actually just writing a check for ten to fifteen thousand dollars and go do this
project, they have to spend tie identifying it, interfacing it with us, spend time with the
team. They have to make investment and if they don’t make that commitment to help the
team there is a very little chance we could do.

Have you done any far distance projects?

We did a project with a client in Antarctica for several years in a row we worked in
developing a system for monitoring the supplies being arriving and off loaded from the
planes in Antarctica.

How was the experience?

Fa6 – It was a good client it invested time and money for the project, we had to
come up with creative ways to do things we were able to do lot of meeting virtually with
Skype which was good, we had to do things like we went to national ice repository near
the school where they have lockers that operate at certain of warm Antarctica conditions so now we are talking about 50 but it is cod enough to test of systems students had to all bundle up and they realized the gloves were very thick and it was difficulty with their gloves and if you are creative and you got a client to work with, than you have a great experience even if the client is not here. We have done projects with Asia, Europe, South America, and Central America, various parts in North Dakota and Arizona.

What are the challenges with the far distance projects?

Co6 – Logistical challenges when you are doing a teleconference there is a 10-12 hours difference people have to be flexible getting them a fuel of what’s like taking calls in the evening or early morning that’s a challenging in we did not send anyone in the Antarctica. It is not easy but you have to work with them.

Do you want to add any other information?

Our program is fairly unique because it is interdisciplinary and that came out largely because we started as a department of engineering so we all are together. Design does function differently across different departments and that makes teaching a bit challenge

Transcript 7: Interviewer - Varun Rawal, Interviewee - Mason Morehead.

How many projects have you done so far?

Co1: We started in fall of 2010 and I think we have done every semester from then, may be one.

How do you feel working with the undergraduate students in the projects?

Co1 It is good, mostly almost always very positive. They have a similar question every year above the scope of the project and what we expect, for the outcome. I think it is
almost a wakeup call for the students for all the unknowns of the project even the sponsor meaning Parker does not know about then we have to rely on them to make assumptions and then we have to give them our opinion if we think they are valid or not so it is not as clear cut as a ‘textbook problem’.

How is their ability to work as deal with the open enabled problem?

Co1 It is really pretty straight forward. I think a lot of times the questions that they have depending upon the project, it is a lot easier if they can come to our faculty and plant and actually see what they either modifying or creating from scratch. It’s just only so much you can do with email and phone call.

1: Is it good to take more volts to the company?

Co1: Yes, it adds a benefit to the project outcomes if they occasionally visit and come to see it. We have done some more of design projects where it is an actual product design so they are not really working into a piece of manufacturing argument. So, those are kind of different story but most of the ones we have done hard manufacturing or process of a project.

1: The incentive behind sponsoring the project to undergrad students.

Co1: These are couple of reasons that we do it. First reason – Why we sponsor the project was that in 2010 we were just short on full time engineers here at parker, we kind of viewed this is a way of outsourcing the projects to students that would allow us to get our designs done without having to hire a full time engineer and the other one is the relationship with the University. Parker in general, it’s not a very good with past experience with other divisions, it hasn’t been a lot of cross functional collaboration with Universities
and I think this is how we are active in a co-op program that certainly helps. We are funding to that we are getting a lot of requests from other decisions of parker that are interested in their program and now they can either partner with the University or do something similar.

1: Have any of the projects made any remarkable changes in your process system.

Co1: Yes, probably these are three of them that we have used that are pretty much variations are currently being used on our manufacturing floor. One of theirs was probably three years ago and then the other two were been from the past two semesters and we have our other engineer Gary that helps out on their program and he has been more recharge of the implementation on our plant for some of our designs. But it is almost always a positive feeling. Gary and I were talking about this actually on Monday that it is almost always a combination of the different group ideas coming together for our final piece of equipment. So, we will take bits and pieces from different groups and come up with an optimized solution.

So what do you think about multiple teams working on the same project?

Co1: Yes, absolutely and we had projects with four teams we have projects with two team is what we would prefer and what we feel like works the best.

What is the incentive here for sponsoring projects every year and keep coming back? Did the past project add some value to motivate you to sponsor projects every year?

Co1: Yes, absolutely, we really had it was our second project that we sponsored where we really at the end of the semester realized that the project scope was too large for the students. We learned a good lesson there students did a good lesson there students did a good job but I think that what we tasked here to do it was just too much on their plate, so
we decided to scale it back. We were just asking automate this, automate that. You know it has to handle a huge size range capability under numerous temperatures. We should have just turned it down and made it simpler.

What about the challenges during the projects?

Col: Picking a project is always difficult and there are things that we have to balance one of them is the overall scope of the project and whether it is reliable for undergraduates to complete the project and give us a good result. Another one that you know the advisors or professors, help this on and especially Dr. Mocko is normally the one that picks helps us pick the projects but does it essentially utilize the skills in a theory that an undergraduate engineer has learned. Couple of projects we have had has been great. Automation doing essentially turning something that we do here in our factory from a person doing it to a machine doing it and sometimes it’s really good. The basic theories of an undergraduate’s mechanical engineering curriculum. We do not want to pick one that demands a lot of a students for programming control systems or things like that because we know that is not in the scope of curriculum. Really, the biggest reason why we take projects is what financially make the most sense for parker.

How do you find the professional skills of the students?

Col: It is good I think presentations almost always a very good presentations. It is obvious that the final presentation they are practiced and prepared. It is never too long. It is never too short, the presentations I think of them are spot on. Some teams usually use a lot of videos. Some of them rely more on the prototype. I think that is then very positive one thing that we have seen in the past which is being I think mostly our fault which is
forget to get all of the students copies of their electronic drawings and presentations, and things like that. While we are at the presentation, their drawings and all that, and then we went a month or two later and we have to find the students after they graduate and things like that. That’s kind of a challenge for us certainly been our fault, something that we can improve on.

Challenge in maintaining the documents?

Co1: Yes, after it is complete, we go there, we love the presentation, we love the prototypes but lot of times we just forgot to get electronic copies of them.

Did any other group evaluate the project? R&D group or so.

Co1: Gary is the one that does the manufacturing type project and I am the one who has done the product design type project but we also have two other process engineers that have certainly helped implement them as well.

As an industrial liaison was your time and sponsorship worth with all the projects you did with Clemson mechanical engineering student?

Co1: It has been a positive experience. I went to the program, 10 years ago, then I was a design coach for a BMW tem in graduate school. It is always positive. It is good publicity for Parker and Clemson and whenever we present what the students have done to our management, it’s always positive and as I mention we got numerous requests from other decisions within Parker on kind of how the projects work and how they can do a similar project with other University.

I am done with questions and thank you for your time. Do you have any questions?
Co1: No, we actually just scheduled, this will be new for us this semester but we are going to have the students to do their final presentation to the plant. So they will be coming to Spartanburg April 23\textsuperscript{rd} with which they will be able to actually try the prototype on our equipment and we will be able to have lot more of our management available for the feasibility of the solution.

Are the solutions deal with real world scenarios?

Co1: the students only have 500 dollars budget. We always tell them upfront if they need more money or order equipment for them we would be happy to do that. Generally, that’s not a problem.

**Transcript 8:** Interviewee: Gary Carpenter, Interviewer: Varun Rawal.

How many years of experience?

Co2 – Thirty years of experience, background is automotive I graduated from a school called general motors institute back in 1987 and spent until this past in automotive manufacturing, assembly and primarily assembly plants in automotive supplier plants and most recently I have been in parker for about a year now. So primarily that was in automotive process and equipment robotics, automation and that’s what brought me here. We do not have a lot of automation here and the company feels the need to get themselves involved in that because it is primarily labor intensive and they can automate processes and that’s my job to figure out what to automate.

How many academic projects have you done?

Co2 – Two projects.

How do you feel working with the undergraduate students?
Co2 – We picked some very good projects and again because of my background and in the end due to the company I saw several opportunities I felt right. The unique challenges with our processes in the plant is that we do not produce the same part every day. We produce whatever the customer calls and asks us for so it is a general process and we have a lot of different processes within the production of the part. And some part have several parts so we have to be prepared to do just about everything because when a customer calls we want this it is up to us how to make it and my job is more involved with how to provide with right tools and equipment and the processes you need to meet these different requirements we are able to produce parts with quick turn around and that is the other thing because if customer calls and they want part tomorrow while it takes three days to get to our process here and that means we have to interrupt everything, scheduling in able to incorporate new parts into the process and coordinate priorities so it is critical that we are able to produce as much as possible and as fast as possible from manufacturing side. The Clemson students we had some good projects and the first project we had both teams were here every week and were very involved in it. There was one team or the other at least once a week sometimes both teams were here because we had to gather data I was pretty much involved in it, because it was a piece of bigger puzzle that I was working on and the project was kind of what I wanted to do so I needed a specific piece of machinery to do job and depending on success of that determined what I can do with the rest of the process so it was something I was personally interested in and that kind of how I got involved in it. It was interesting and it was fun to see different teams coming up with different ideas because we were trying to provide equal information to teams starting out but then as when we saw
each team kind of developing their own thing we didn’t want to share that information within teams. We wanted to keep the competition going. Interesting was that for both our projects, each project had two teas so it was interesting to see different team work and different solutions.

How do you find solutions from different teams?

Co2 – For the first project they were similar but quite a bit different on the second projects and they little bit closer. Second project was more driven by our requirements than anything else we had some restriction that they can do.

What do you think about the ability to cope up with the real word problems?

Co2 – In the end each team had four members of all the projects so far and you could see I guess for the first project we did I felt that each team was really well balanced because all the member were here if they came, there were at least three from four people involved and if the other was not here because of some other conflict or schedule felt there was very equal sharing amongst the team members as far as responsibility and involvement in the last project. I felt it was a little bit of less than that, they had some of other students we had one guy in a team that obviously had more industrial manufacturing experience his background as he had thirty years of experience, he drove that team and the other team had one guy never came throughout the plant visit. We had one time when everybody came together advisors came both teams came and even the graduate advisors cam so that was kind of a first visit, everybody came and then each teams coming back with prototype as the project required them to bring prototypes to run in our equipment. I was really surprised with the first team because I have dealt with these types of projects before many a times
you get more people on them there is one guy who wants to lead and one guy who wants to follow changing the team dynamics, while in first project teams were very well balanced and that was the thing that impressed me. In the presentations everyone was involved obviously aware of what is being going on in the project

What are the incentives as a company to sponsor the projects to ME 4020?

Co2 - I think both teams got excellent real world exposure of the things and again we have unique situation here I think heavily this area is automotive based because of BMW we are not producing the same product every day so there are some unique challenges that we offer that I think we provide some real world exposure to both teams. The last presentation both teams came and they learned a lot. We were able to see some places where they could apply some of their undergraduate courses and theoretical analysis of the issue but at the end turn around and see the actual application during the plant and all that played out in actually building the product we offer some guidance from our side because it is part of the analysis I guess the evaluation of their solution a lot of times they were so excited that they had something to actually work with. They kind of lost focus in the process gathering information to prove what they made was effective because that was a big thing on the last project they both got so excited to bring their prototype in here and after they run first batch I said so what did they tell you so they answered well our things worked and that is now you know. But they did not run any controls sample against your product that you made your product looked good but how do I know it wouldn’t have looked good without your product in the process. It is an inexperience but that were the
things they learned be open minded and do not stay focused on one thing look at other options.

How about the presentation and professionalism.

Co2 – Yes, we kind of guided this semester based on what we learned before, we requested upfront to provide a little bit of more documentation each team provided USB sticks with just about every data collected. A lot of trouble going back previous projects before that I started and I wanted to see what was done proposals and suggestions they were making it was kind of hard for me to dig out their information and kind of got the general idea of the concept but there were lot of little specific things that were key to making the thing work I need to have necessary information. One thing that we had on our last project was they had to have a special air cylinder and I said one of the key piece of information that I need is what is unique about this cylinder and I said one of the key piece of information I need is what is unique about this cylinder give me some specific part number, so what you bought from and why you selected and if I wanted to actually put this thing in production what would you recommend to do to make that happen. The specific information and both teams this last time of break gave us full reports, solid works modelling and everything and analyzed the other things. I do not necessarily need drawings of things if they made a prototype and helps me to have a solid works model to start from. The one thing that we learned with two teams involved when they present I say I like this about this team’s proposal and now I want to combine them. I might get models of that problems that make easier to work with, I can seek and choose out of each one and combine them. Especially the first project that were involved and it is really hard when both the
teams agree in their proposals but we still felt some specific parts of one was little bit better than the others and one team did a great prototype so we used that as the base of our machine and continue to evaluate it we got to change pieces and parts.

What drives you to sponsor projects to the same department?

Co2 – It has been a good experience, Mason Morehead is our application engineering manager and a Clemson grad. He has been driven it, we are like staffed here and gives us the opportunity to pursue something. It will be nice if I have some time to investigate this and that is kind of what this last semester project was it was not something that we were focused on right now but it is something we will like to do in the future and we kind of toyed with the idea of it, there is a lot of restrictions that make it difficult but they as we proposed the project it was expected as a project and we had two teams and it saved me a lot of time because here is why we have not done it as it is not easy otherwise we would have done already and here are the restrictions we have and here is your challenge how to figure out a way to get around.

DO you recommend some change to the program or suggestions?

Co2 – The biggest thing is last semester was the report that was critical to our pursuing this thing, right now we are not jumping on board to pursue this project. It is kind of a back burner project there are some other things going on now that become a higher priority we still think we want to do it at some point. So we put them at this point or we just kind of set it over here and wait. We are going to wait for a while and we have data available and I have high level of confidence when we are ready to do it, I will be able to go back and open up the data and have a good starting point and that is key to me. Because
in the past projects the prototypes were misplaced and if I have presentations that would help. It is frustrating to know that we had some work done and a lot of time we are into it and now we have seen the other projects. I know that there is probably some good information that was gathered but we need to be able to use it so transferring that information from the team to the company in order to use in future. As the projects were going this semester we express that to the students and both teams did a great job not just they produced hard copies for the presentation and they provided a back top USB stick all their data collection that they did through the semester evaluation what they wanted to do and photos, videos and CAD models, part list those are the material were very helpful to go forward with it.

How was their work what was the considerations that they took?

Co2 – The first project that we were pursuing because it is a key part of what we are doing in this cell and our intention is to take the prototype that was developed and kind of build that into a production machine, this will give is more time to evaluate work because day by day we have different processes running through the same equipment so to me I need a long term evaluation to see how effective this is and where the weak spots are what part numbers do we run that were going to cause issues for what other factors over time that we are going to determine need to be addressed to the machine and long term we will build official machine what we learned out of the prototype and so a great information.

As a liaison, was your time and sponsorship worth working with the students?

Co2 – Yes, the teams come in and say you do not need to stay with us we are going to do this and I said anything you guys want or questions you have. I like to be here and
involved and just to help them along with the way because even I was a co-op student and that is where I learned the most because in school you got the theoretical side of it sitting in lectures watch the videos and then when you get in the real world you see here is what I really need to know and here are the things probably are not as applicable what I am going to do in working world. I just enjoy working with co-op student because I was at one point, I think it is a great experience and would like to share anything I can at the same time, it gives me out side view we are kind of focused day by day on what we do here and do not think about other opportunities and they came up with some good ideas just outside the box and may not think of based on what we do every day. Parkers willingness to provide financial support, it is one that we tell all the teams on every project I have been involved in at the midterm report, if they get at the point where they want to make a prototype that’s probably the project and give them what they need. This last semester couple of teams came and wanted as to get the materials and we said you did not use your $500 budget yet. It is important for me to know that you guys are talking advantage of that because there are specific things that they need to buy and I think it gives them really good experience to figure out what it takes to research were I can get cheapest, what will it take to buy it, that kind of things I think it is a good experience of buying something on your own so I encourage both teams to use budget. If you need air cylinder we got lots of them, if you need two inch stroke, three inch bore certain configuration to if you and you guys go buy that make that part of the $500 budget and we will do the rest. Both the times we have provided materials and support on all of our projects they bring all of the stuff back, it gives a starting point to kick off what we can do.
Transcript 9: Interviewer – Varun Rawal, Interviewee – Johnson Stephen(Co3)

How many years have you worked in G.E

CO3 - 32 years

Since how many years have you been doing projects with undergraduate students?

CO3 - Only done one project. Did back in 2011.

How did you feel working with undergraduate students?

CO3 - The only challenge was my having enough time to spend working, talking with students and giving them, responding to their questions. I do not feel like I have put enough at the time, we had many things we were very with the things going on and I do not felt like I gave as much attention to the students I would have like to given them. The ability of the undergraduate to deal with the open ended problems. So, I actually went back to get out the report and went back and worked at what they had submitted and I thought they all had good ability, they had some different interesting and creative solutions to our problem and thought their reports were understandable and I thought they had good content, they all did a certain amount of finite element analysis, some stress analysis and looked well done and captured the problem they were trying to solve very well.

So what about their professional and presentation skills?

CO3 - It was certainly. We had 4 teams working, tackling the problem and there obviously was a range of presentation skills but I thought that they all prepared well and they made effective presentations. I thought for the age of the students, from the experience that they had operating in that environment, I thought that they did a very good job of presenting their results of their analysis and their approach in a professional manner. And
again I thought highly of what they did given their level of maturity to speak their level of experience in the project like this.

Regarding sponsoring the projects to the capstone program, what is the incentive behind this?

CO3 - Incentive in doing this way that we had a specific problem, I had a specific problem which we were trying to solve and we our self-had run out of ideas. Some new approaches to our problems, we had been in a mode of recycling old ideas within GT, without seeing any significant change in our approach, we had a specific problem with one of our ways, we were looking to try to see some new ways of transport and so my motive was I thought this right for some outsiders thinking, somebody coming from within no details of some of our problems and issues. Typically the teams worked into the problem in different ways, came up with some pretty good solutions and I thought some outsiders look at it definitely generate some new ideas.

Did you take any of their ideas or did their ideas helped?

CO3 - We had a very light scope. Challenge was how we improve shipping of our wind turbine blades. We ship blades in a number of different ways today and each of the team. Looked at it little bit differently they did not try to tackle the same problem. I couldn’t say that they all tackled the same problem and we saw solutions on a focused basis. So one team worked at the rail transport, one team worked at improvements on our road future using automotive style. Springs and dampers, one team worked at our-the way we ship on our marine shipping future and each of these different approaches of shipping drives you to look at it, bit differently resulting in a little different look at the problem. So what I got
out of it was insight into some thinking along the practicality of using of our cushions size
during the course, concerned the cost of the cushion that are associated with using shipping
fixture and the result of them hearing me say that couple of teams worked at specifically
could they replace cushions with spring and damper systems to provide the kind of
movement we were looking at the kind of protection if you will, it goes back to some old
challenges of how do you ship egg and make sure it doesn’t get damaged, so they developed
creative approaches, we haven’t take a hard look at some of this things ourselves and that
kind of confirm that there are some practical approaches we could go look at.

Did you adopt any of the solutions?

CO3 - We did not adopt specifically any of the proposals that were made and not
that there was anything inherently defective about any of the proposals. They were all good,
I would say there was only one that may be did not look at it and have a solid practical
methodology just related to construction of the fixture. I think they may be did not
understand the complexity of the design that they proposed. But three of the four were I
thought quite practical, we would, we could have found our way towards getting the design
or ideas that were proposed and putting them throughout own design process and they
could have resulted in good concepts. What happened really is that we make some
adjustments to some of our existing shipping systems to allow us to solve some of our short
term problems and then one of our blades at the length we were looking at 40 m length
which was so the primary are that they were looking at was sort of 40m length blade what
our customers were using for moved out significantly to needing 50m long blade and so
some of the challenge is some of the things that students were looking at became a little bit
of a point as we go from 40m to 50m it becomes physically impractical to put two blades into one shipping system so we had to put that aside. But that made it unfeasible to use certain parts of that but I still hold out some hope and some thought that there are aspects of what was thought about are still very usable and practical from my standpoint we just haven’t had an occasion to go through and build new shipping fixtures and develop shipping fixture designs we know we are keeping in mind some of the concepts that were presented.

After the projects, did you get any confidence to sponsor more projects or research projects?

CO3 - I would, one of the issues I had as that I am actually in the supply chain, my department is supply chain so we do not ordinarily see any significant challenges from a mechanical design standpoint and so I haven’t had any new things and challenges that come to my attention or come to me that I think would be worthy of sponsoring, certainly I would be interested in doing it again but GT would actually be more beneficial if the student were working on a project under our engineering organization as suppressed under my manufacturing engineer team. So that’s not that I think the results were not good that I saw differently. I don’t think I can present or good enough challenge as a supply chain guy. I was even concerned about the time they were working on the project that I was giving them a significant enough challenge to work on so I felt like good results, the following year I did not have a good project to put in front of students.

After your experience, are there some improvements to be made by the academia?
Co3 - I would say the main thing would be tighter integration of the sponsor with the faculty. Probably as much as anything and I go back to the issue my first issue which was I don’t think I spent enough time and I don’t think I allocated enough time to interface with the students and I would say the same thing applies to interfacing with the faculty and making sure things are on track from a faculty stand point. Again the end result was very good but I think I would have benefitted spent more time working or having more periodic dialogue with professor that would have been more beneficial from my side. I am not sure how GT would have benefitted the team but we could have been more responsive on our side in answering team questions and helping them move through along smoothly that was again from my side I think that is the key to this kind of things as having a good dialogues so the teams understand but they are not left with any questions unanswered as they try to work through the problem. After we were through, I did not get a lot of feedback from the faculty on how well we did on our side where we were efficient, do we gave a good scope to the problem, the challenge that we gave the team. You can lay out what the problem is but sometimes you don’t know how long the problem was going to be or whether it is a good problem for a semester worth of activity. Having some feedback after the thought afterwards might have been good for me to say. The faculty could have given feedback and saying the project was too long in scope or too small in scope or right and presented a right kind of challenge which fit well within mechanical engineering discipline or that kind of stuff just having a little bit of feedback on those stuff might have been good for me to just to see whether we did it right. It is a backward looking and sometimes you do not know the scope, how well you characterize the problem until after you finish it.
Do you feel that program is adding some value?

CO3 - yes, I think it is a great thing I have to say. It was not something I had the opportunity to do when I was undergraduate. It is a great now a days. It is much more about teams and team building and working as a team in engineering environment and I think it is great exercise gives the students real world problem to work on. So I think it is a great program wish I had something like this 40 years ago.

Transcript 10 Interviewer - Varun Rawal, Interviewee – Michael Lail9 (Co4)

Transcript provided on the interviewees consent.

Transcript 11: Interviewer – Varun Rawal, Interviewee – Siva Chavali (Co5)

How many years have you worked in the industry?

Co5 - This is my eighth year, completed seven years with Square D and Schneider.

How many projects have you done?

Co5 - What we do is that we have small projects and big projects. Small projects have duration from six months to a year and the big projects have duration from two years to three years. We had eight small projects and one big project.

What about the project you sponsored?

Co5 - At the time, what we had was that we were there was a transformation. It is a copper transformer. So, for the cost we wanted to change it to aluminum. We wanted to see how much heat the aluminum can generate related to copper. So, we requested a calorie meter to measure the produced heat.

How was it working with the students?
Co5 - Actually, they did a good job. There 3 or 4 groups who worked on this project, and they came up with different proposals and ideas and which was good. Finally, they submitted a prototype for us so that we can do our testing internally. What happened was that we did all the investigation and then we had a question, “How much heat generation would take place?” We gave this assignment to Clemson students. They went back and created this calorie meter, so that we can house the transformer. Then from our side, the project was put on hold. So, I think that the project got kicked in and we changed it one and a half year back.

Was the prototype efficient? Did any other department assess it? Did you implement any of their ideas?

Co5 - I need to go back and talk to other people because I was not in charge of it. So, my understanding is that they did some studies, though not much on that one.

How do you find the undergraduate student presentation skills?

Co5 - The presentations skills were good. I think they presented well.

What was the motivation?

Co5 - It all depends on the company policies and the things that are happening. Example: When we sponsored the project, we had a different management. So, different management was in Seneca which was ten miles away from Clemson. So, it was useful and they wanted to have more interaction with the next generation so that they can absorb it in the companies. Now they have some other things going on to make sure that the cost comes into picture. We have it with a global platform. We have faculties in India, China, Mexico, and Canada. So, what they want is that instead of bringing new resources, make sure you
work with other resources like your counterparts and try to get some more knowledge on
the product itself, like cross pollination. So, it is basically all company dependent and we
had a 3 year plan previous. Now, it is a 5 year plan. In this one company programs, they
have these new plans on how to cross pollinate and to speed up projects. I cannot tell you,
but one thing I am sure of is the undergrads who did the project. They were very
professional. They had presented the PowerPoints and presentations, and then they
submitted the final report. It was all very professional.

Was your time worth as a lesson?

Co5 - Yes, I was one of the members and there were other people who spent lot of
time with my other counterparts but I had probably two to three sessions with them and the
final presentation. So, to be honest I did not spend more than 4 hours of my time in six
months. I did not significantly contribute to the project.

As you were not involved in the project?

Co5 - It was good collaboration within the team trying to see what they can do and
everything. So, overall it was a good one but unfortunately we were not able to do some
more. As I said there was a company policy change and we moved from Seneca to Savanah.
So, the distance basically changed.

Do you try to make them aware of the ‘industrial need’?

Co5 - It is a primary focus so that the students who are graduating understand the
real industry problems and implement some solutions to help solve the issues. Yes, it was
a real challenge and it was helpful to take some information from students and let them
solve the problem.
Do you have any generalized suggestion for the undergraduate students?

Co5 - What I noticed in my 8 years of experience is that when you come to work, it will be an on the job training experience. You can be good at Calculus or Matlab, when you join any company, first thing you will notice is that it is completely new. They have some policies, some procedures. They have something that you don’t know. Information will be unlike black and white thing, use their equation to solve this problem it is cumulative. So, what I can suggest you people own the problem and go step up to solve it.

Transcript 12: Interviewer – Varun Rawal., Interviewee – Porter Whitmire (Co6) and Bob McCraken(Co8),

How do you feel working with the undergraduate students?

Co 8 - Over the last 5 years we have done several ME 4020 projects like anything. Each team and it’s not the whole thing we enter into the expectation to get something big thing but it is typically bring the nuggets that come out of these that we have used and some of the things work.

Co 6 – I think in general they have been pretty good. We got some cool things out of it. We got a patent out of one we did about two years ago, they got a patent rather we bought from them. I would say that they come across as like bob said there are some better than others but they come across as very technically adapt from the most part less adapt at standing up and giving presentations most of them are pretty bad at it to be very honest. They are pretty bad they like to read off the power point that drives me crazy because I can read.

Motivation behind sponsoring the projects?
Co6 – They have been pretty good do not think we have about any complain and the fact that that we keep doing it every semester say something. There are lots of motivations the biggest one is that we are here to make money so we want to get something out of it and so we structure we give them an important project that if they come up with something we would be able to make money out of t so that is our number one goal and we won’t give them a project that we think it is just never going to go anywhere. It should be something we think that would pay.

Co8 – We have a vision.

Co6 – On the other end I went to Clemson and I like working with students and really excited to see the different ideas they come up with. It’s all forest with tree thing we live breathe power tools and we use them every day, we get some new minds untainted minds to look at something. It’s always good they always some up with something and even if they don’t do it perfect job executing they always give us new ideas.

Co8 – A thing about influences and possibly enhances other things that we are doing here that come up down the road, may be two years and three years later.

What protocol they follow when you go to sponsor the projects, what is the approach?

Co6 – We kind of know what the ME 4020 program is, what kind of help we get what kind of problems to present. I think I did the first program with Clemson in 2005 probably and we have done it every semester, but we have not done last three years, we have probably done ten projects. No they do not come up telling us what to expect because we already know I guess.
How about your expectations when you give out projects?

Co8 – The most important thing is we give it to them because we want an out of box thinking and viewpoint.

Co6 – We expect and we have always been as clear of working prototypes at the end which are the actual deliverables. Because to us until you build a prototype all your theory means nothing it is okay to do all the calculations but at the end of the day I can’t sell a calculation to my president there’s got to be a prototype. There should be something that people know or understand so we expect that we go into expecting a prototype or it’s not a working prototype than a conceptual prototype something I can hold in my hands.

Co8 – Proof of concept kind of thing may not be durable enough to do exactly what it’s supposed to do but it shows the functionality of the concept along with their calculations saying we could do it.

Can you recall any particular project?

Co6 – Yes, the last one we did where we ask them to improve the output torque or speed of our impact drivers, one group created the best conceptual prototypes I have ever seen out Clemson which was I wish I should have brought it. So, it is a two impact drivers one side they modified just a standard one and had a crank one and second one they had an idea which was a nested thing and it is awesome and we are working on it now.

Co6 – And they had a crank that showed exactly how it worked that’s perfect because you can show in four seconds how it works that was great
Co8 – Right now we are going a nest step forward to confirm feasibility of the SM and hopefully into development.

Co6 – What do we do after we get the projects finished we have an internal meeting and we usually of three groups we pick pieces of each one and we usually from three groups we will pick pieces of each one and will write the necessary document in house study to take it to the next level to prove that it can work and so we have a set program of what to do once we get student output it goes right into the pot brain.

How about multiple teams doing the same?

Co6 – usually we have three to four teams doing the same project, sometimes we split it up, in general the competition between the teams work I mean there is always one group whose output is subpar and there is always one group whose output is outstanding and then there is usually one in the middle, it has always been other formats that are better may be usually for us it is hard enough to think up one project much less three. We always want to do project that is valid that we think we can get something.

Co8 – We do not want too big.

Co 6 - We can’t have a project that takes it needs to be finished in a semester so I think the current format works we are open in exploring other formats works we are open exploring other formats.

Co8 – Something that could be considered I don’t know it is ever be practical but there is something that’s a dual semester start on it is a little bigger piece of apple.

Co6- You can do other formats too like you could identify say a tool in several aspects that you may want to improve and have different groups working on different
aspects of one project. I think the current format not guarantees but increases the likelihood of usable output because you have all the brains working on the same project, but we would be open for other formats.

What do you think about the duration?

Co8 – Kind of what I would envision from where we end up with a way it is now and the past it expands the same thing and they were able to explore further

Co6 – Right now we usually get conceptual prototypes they are out not working prototypes. It would be cool to do a yearlong format but we will have to be very clear at the end of the year, we need and we would have very high expectations for a yearlong project for instance if I get bob runs the advanced Anderson concept engineering group which is right behind the wall. I expect usable working prototypes in several months like three months. They are professionals ad they do it all the time but the problem with yearlong project besides that is we had asked you a question bow for the next semester it’s really hard by the tie a year goes sometimes that, question we answer is no longer valid in the market we just don’t react quickly and get something on the market our competitors who are sister companies come out with it first so a yearlong format will be tough.

Co8 – It would really need to be the initial thing like if we used it would have to be something we are very confident that it is out there we believe can really be done. We have done ME 4020 and creative inquiry program and then we also have a graduate level student projects, so we got a pretty long sponsor stuff.

Why do you sponsor the projects again to the same department? Are there any challenges with the ME 4020 projects?
Co6 – Certainly what we found is the more we involved are the better the outputs. So we have committed to requiring the students to come up here once they have an idea what they want to do and speak with applicable engineers so if it’s a program dealing with gear boxes and whatever we have to sit down with one gear box engineers and get feedback now we don’t allow the engineers to tell them what to do, we make students as questions and will answer that. That way the vision is without having an influence too much but at the same time we want to make sure what they are dealing with makes sense, so we do that. Managing all that is a burden, bob does that it is a pain but it improves the output.

Co8 – We set down some rules which is good for them to learn like get their time management, make sure you don’t waste your time. WE are a business here and that’s they have done a pretty good job but something that improves the thing is a little bit more emphasis on faculty on the fact that okay they are kids that’s not a school time any more you are dealing with the real world and real business and time is money. Being on time all those type of things that you don’t want to waste such people’s time.

Co6 – That’s a really good point we had students that show up two minutes late and that’s unacceptable, you are not wasting my time.

Co8 – I do not want people flying down the hallway because they are late.

Co6 – Students planning their time this is why ME 4020 is great because they learn how to plan a project out. So we see every group’s every time at the last minutes asking us to help them with the prototypes and we tell them no as we told them beginning of the semester, if you want us to help with the prototype you need to come to us no more than a month after the project starts. We are not going to be able to do that for you, so they learn
a lot. I think about planning projects and we always feel bad that it is like we told you this is the real world you are not going to get your stuff done though us, do it some other way so these are some difficulties again there are good and bad groups. There are some groups their sit right there and come up with ideas call us a week after semester starts give us drawings and some groups we never see they never come up and we nail them at the end.

Co8 – We can’t possibly do this things without taking advantage of that at the same time they don’t want to be totally dependent on us either.

Co6 – The way we stand is that if you are a student and by a company you are given a project where you are asked to redesign a gear box and then you do not go there and talk to gear box engineers, don’t give me your resume because that is stupid.

Co8 – which a thing you needs to be impresses at the beginning.

Co6 – It really is an opportunity for them to get in front of the company that could hire them and we look for potential hires. We have hired Essam and couple of guys.

Co8 – And this is an audition.

Is that another motivation, searching for potential hires?

Co6 – Sure.

Co8- You are looking for that. It’s not something necessary but we do. Anytime you work with us Michelin or whoever it is you better out your game face on, because that can be a potential employment in a great company to work for and how you have done here can definitely influence the possibility of you having an opportunity.

Co6 – We do it informally, if I have seen a student I think would do well here and impresses me I will ask for the resume but rarely, but most of the time I depend them to
ask me to show some interest, so that tells me this is the person that I want to work for, someone who actually has some initiative I usually wait and one and twice I have asked for resume.

Do you have any questions or any further additions?

Co8 – We had a good meeting.

**Transcript 13:** Interviewee – Warren McAlpine, Interviewer – Varun Rawal.

How many years have you worked in corning?

Co7 – 31 years.

How many undergraduate students project have you done in the past?

Co7 – Just one, me personally

How was it working with the undergraduate students in the project?

Co7 – There were quite of few student involved in this there might have been as many as 24 students and they were divided up into four groups and then each group generated a solution for the problem and then presented that solution, one thing that we try to do was also get them their parts manufactured, fabricated so we would test their solutions and so I thought three of the four groups really did well and may be one of the group was exceptional the level of effort they put into it.

Did you take any of the solutions or ideas? Did any other group evaluated the project?

Co7 – What we did is we turned over the results to manufacturing and we did test one of the solutions and I do not know if we ultimately implement that solution on the plant the one that I did not test I wish I still would like to test is one of the approach should be
different in manufacturing and I did not really understand his perspective on it but I did want to try the solution but I am not on that department I did not test it. This guy I do not remember the name began his PhD at the University of Texas, but he was really into talking to us. I think that one of the things was all the students I felt like proposed themselves very well and for the most part except for the one group I think it depends on who is leading that group, they put a reasonable effort towards solving the problem. I think that one of the group the one person who seemed most interested in was probably had a unique solution to the problem. They came down maybe on a Saturday and additional trip down made an additional effort to look at the equipment and really try to understand how the process worked.

As a company liaison what is the motivation in sponsoring the projects to the undergraduate students?

Co7 – I think that there are couple of things one is it is an opportunity that you might be able to identify students that are good candidates to work in your company. I think the interview process is a very difficult process because people are doing that may be over a few hours or at most couple of days and you don’t really know that the person has a good intuition what you are trying to accomplish or not so this gives you the chance to see students working in this environment and see if they have a interest in what they are doing and also gives the company I think some positive exposure to students that are graduating and just as a good public relations effort by the company. The other thing is there are projects in our plant we could use this system more extensively than we do but it’s hard because I see the issues I am no longer a manager so I do not really control any budgets so
it is hard to make a case all the time to come up with five to six thousand dollars which is not that much money in the big scheme of things but it’s still difficult to give every time you want to do this you have to spend a lot of time convincing managers that it is something value added but within the manufacturing plant that’s because its where I spent my life that’s where I know what most about there are lots of small projects out there that I think it is hard to ask sometimes justify putting a person that works for the company on that project because of the return on investment but it is still something that could be improved. I think that it is going to be hard to get a group and ask them to deliver something which is huge breakthrough for the company that’s not what we are really after I don’t think that’s really practical so I think what we are after is exposing students to problems where they can apply their engineering skills and also get some small benefit for the company.

Is it to prepare the students for current industrial needs?

Co7 – I think it exposes them to the real world problems in the plant they can kind of see the opportunities in the plant and can see what manufacturing is about at least manufacturing in our locations and then is an opportunity to assess situation so you have an opportunity of continuous improvement project and it is up to you to define the project, it is little more open ended than a problem out from a book or a school project which is pretty well defined for you so that you have a known outcome that you are looking for. We still typically run across things, there are some issues in the plant that I think people don’t recognize the cost of it so in one process I think we can consume a lot of energy. One group from NC State never really addressed the energy consumption issue and I think it is not
spending a little energy more, it is not a lot of money but there is a lot of wear and tear in the compressor in this kind of plant.

Is it all about students getting exposed to manufacturing and potentially interview them?

Co7 – I don’t think that’s all its about, it is a lot about a good will and I do not know if we have hired anybody that was in one of these groups I don’t know that but I think that you are exposing the company to the students and students talk about the companies if they like the company they will go and tell other students. When you go on campus to interview I think you are more likely to get a better interview scheduled. I am not in the position to know I think has a positive outcome and the other thing the reason that I want to do it was because I still think back on that project a lot of times and say well for example my first project experience I feel it is really the first time that you really try to put what you have learned in school and try to apply it using the principles that you have learned in all the classes. So I do not know what the word for that is, it is close to interdisciplinary.

DO you feel any challenge with any topics when the students do project that you feel the program should improve?

Co7 – I do not know about particular on the project but I think that probably I can just give you an example from a recent project that I worked on so we were using resource from another facility and this piece of equipment and it was not usable in its current state because there was no force analysis in the equipment. First thing I do is establish what you are trying to accomplish the course and then you are going to establish the geometry for your power transmission and then analysis on the shafts and that wasn’t done. Another
example was on the same project in my senior design my advisor had thirty years of experience but he was completely lost in determining cooling capacity of an equipment. One thing I would have liked in the schools was better experiment and design skills and they have opportunity to learn that type of work.

How do you find the idea of multiple teams doing the project?

Co7 – In this case what was kind of difficult for me was that these were four teams and I felt like I like to try to give a lot of energy to something if you going to do it then let’s just do it and I think for me to keep up with four teams was a little bit of time consuming, especially at that time but I do think because we were far from the campus I think that a little bit of disadvantage for the students because we were two and a half hours away but I do think in that situation having two groups it does set up a competitive environment and it motivates them to do a little above than the other team. So let’s say if you have twenty groups working on twenty projects than you are not necessary comparing apples to apples in that case you know it’s a little bit more subjective if they really did as good on a project if they put a little bit more effort, did they put as much effort as the other team. I think competition makes you better.

What was your role in the project?

Co7 – what I tried was getting them to understand what the piece of equipment was doing and I was trying not to give them what the solution would be what I was trying to give them was I thought underlying principles were and what simple equations would take them to a deeper level of understanding in that might help them with the solutions and I felt like it was a little bit too much just to walk up to a piece of process that has been
running for a 100 years and for them in a few hours to figure out what’s going on I think it’s always a difficulty with these things, if you really have expectations then somebody is going to deliver a real solutions you got to put some energy to it to bring them up to speed without hollering their solution in other words we are not going to change the fact that wrapping a piece of metal in cable, we won’t change that but we would like to change or understand how to better calculate that issues. I think there is a little bit of magic involved in this piece that wraps around the metal and in Georgia facility there are seventy lines tom make this wrapping. I was hoping that the students could take that challenge and pursue that a little towards more scientific.

What was the confidence in sponsoring the research projects?

Co7 – I do not think the value we got from the project had any impact one way or the other because I am not in the management I felt really positive with what they did and I felt that we got way more than in return than what we invested. I think we got a good return on it but the problem is you have to get to a different level in the company to get these projects going all the time and I think that is what needs to happen you need to get to the engineering manager level or it needs to be maybe for example there are so many levels in corning now and that time we were owned by corning and now we are corning, so to get the projects going there needs to be somebody In the management and has budget and somebody that sees the value. Somebody incapable of technology that what we call the director of cable technology and I think they just don’t know where to do it and they are not conscious of it I think if they were conscious of this projects of what they can
accomplish I think they would have a list of those projects and you would have a continuous list could you work on this and that. It is part of our continuous improvement effort.

**Transcript 14: Interviewee – Joerg Schulte, Interviewer – Varun Rawal**

How many years have you worked with BMW?

Co9 – Since 1996, so 19 years.

How many of undergraduate projects have you done?

Co9 – Few in California and here did plug insertion, sound analysis for the AGV, four projects.

Can you describe the project that you did it in 2014 the AGV one?

Co9 – It was basically request from a business side from the VP of assembly to build low cost AGV to compliment the AGV that we have on the shop floor and basically the idea is to be able to expand the usage of AGV’s to new areas which currently have not done economically, to invest into towards vehicle you need to set up one of this delivery cycles and if you run that twelve to fifteen thousand a piece for these vehicles than it is not necessary economical to do that but if run at a $1000 a piece than it changes things so the idea was to investigate, if we can be build that in house make use of production parts to cut cost.

What was the incentive behind sponsoring this project to the undergraduate students?

Co9 – Helping to get this design worked out.

Why the undergraduate students and why not a graduate or contract out with local companies?
Co9 – It is not really a research projects so that is something I guess can be ruled out. The format of the senior design projects I thought it was conducive to do it in this kind of things so we never really thought about any other alternatives I guess so contracting out we end up with the same companies building the other ones in the same place.

What do you feel about the professionalism and team dynamics?

Co9 – It was good, we only see them three times at the beginning for a kick off midterm and then at the finals. And so far these three occasions they made a very good professional impression and may be little bit of the records Clemson is making appreciate, I had first experience with Georgia tech senior design classes this spring that was not professional not by a long shot and it makes me appreciate Clemson more. It is really the students or faculty briefing them I do not know but it is a professional presentation, so that’s good. what we do see I guess more than see of any that, though the student teams work together better than others and that is directly reflected also in the results that we achieve. So teams that work together get great results and teams that don’t, go nowhere.

What do you think about the multiple teams doing a project?

Co9 – ON the one side the competition element is nice it is interesting and on the other hand it is a bit of a waste of resources so you could conceivably sort of divide the work up a little bit more in a way to get overall better results. So I mean the three months is not a really long time so designing the AGV it takes a long time and you tend to get stuck in mundane things like finding welding shop that can weld the frame and so on, so more people working in parallel compensate this to some extent.

How are the results? Did you implement any of those?
Co9 – It we talk about the fall one we were very impressed with the winning team that were very good results. The other two teams were okay but they did not meant into achieving the objective of having working prototype at the end of the project, so various reasons we had a competition out here in K-platz, we had tracks laid out for the AGV’s and only one team had it running and the other two teams were struggling.

Is it good to have a final solution?

Co9 – It is mandatory, absolutely. But we did follow up in a way that we said this should be good but let us do it another round that is why we did another class this spring on AGV’s.

Are you doing any project now?

Co9-Yes, we just finished one in this spring so that was a phase two of that one and now we just had a meeting this week we will hand it over to BMW scholars, students from Greenville tech, tri-county and technical colleges and they will build three of them until end of September. So the idea is that the students are in mechatronics scholars so for them it should be right up the alley to do something like that. It has got everything in it that is mechatronics all about so the idea is that’s part of their curriculum to deal with this things with more experience and we can also use the product.

Do you have the documentations provided by the students and did any group evaluate within the company evaluated the project?

Co9 – I as a liaison person I always have to go to whatever department there is to get the buy in from them and get the money. So, in this case with AGV the vice president
of the assembly who put the money so in that way of course I go to them and present this is what we can do.

Is there a reason to keep coming back to the same department?

Co9 – Yes, we are happy with the results.

After the project what about confidence in sponsoring the research project?

Co9 – General level that we can see in Clemson mechanical engineering can do the job but no specific cross over. Good general impression sort of reflects over another activity.

While sponsoring the projects what were the expectations from the students from your side and did the students met any of those?

Co9 – So the way it worked we out the requirements in the beginning of the projects and said we want you to build and AGV or AGC and then ad whole list of requirements like the cost should be thousand dollars, speed, safety feature and its quite a long list, features and elements they have to have and as I said the team pretty much met all the requirements in that way we were happy and the other teams were close because in the end I guess they did not start testing early enough and so ran out of the time.

What were the problems that made the other two teams lack?

Co9 – WE only see them three times hence it is really hard to tell as I said before there is feeling that teams have worked together and also produced better results which lead to the impression of whether or not suggestion I guess about including some sort of team management, team building exercise type of component into the projects to be able to really enable to put to work together.
Do you have any other suggestions?

Co9 – other big request that we have to Clemson is that it would be very good to open this up to interdisciplinary teams from different departments coming up together and work on this things. So, conceivably we could have this AGV project, we could also have somebody from electrical and computer engineering join that team and work on some of the programming stuff. I think that would be all around and will yield better results an also in a lot of ways more reflective of the actual real life environment because in the end in the company you will not necessarily have just mechanical engineers on the team but you will assemble a team also having other field people. One other idea would be going back to the Georgia tech experience what they do well is that they have this design expo and it is very interesting to bring all the projects together and have a little bit of fair to walk around as see other prototypes for the company.


How many years have you been in the industry?

Co10- 34 years

How many projects have you done with the undergraduate students?

Co10 – I would say more than thirty probably twelve universities in USA and Europe.

How do you feel working with the undergraduate students?

Co10 – What we found you need to have, because there is a short time period three months you need to make sure you are responsible, your investigator in the company side needs to be present. He cannot take vacations or travelling. It needs to be something that is
valuable to the company but it is not time sensitive meaning that is one semester class has a problem does not do it or has not achieved it, you could wait and have the nest semester do it then it needs to be a project of small size so that students can do it. so for mechanical engineering projects we tend to like ones that are something related for safety equipment for example tell me a nice size and you are making something and you suspect that may be a quality risk and so that is a good example of the students can analyze it, they can do some design, they can do some prototyping and give you an idea what to do not what they can’t do is design the final product and install in a manufacturing run- that’s too big. So in general they cannot make finished industrial products but they are really good about creativity, new ideas, engineering calculations and finding new approaches also we did some in workshop organization some in new methods of manufacturing, new methods of testing for an example one really successful project it was cutting sections of tires and then polishing them so you can make measurement on how it is built and standard method had been to cut it with a band saw and then to go through severe grinding, polishing steps and to cut a floppy tire on band saw you have to mount it on a particular form which used to be cut out of woods but these days it is cut out of plastic and so it was expensive making the form mounting on the band saw cutting and so on and that is one where the students we gave different teams (4 teams). The four teams each approached a different aspect to it so one team replaced the band saw with a grinding blade they can both do the cutting and polishing in one step and another team had a very clever way of mounting it and holding so you did not have to make a form every time you can have an adaptable device, so those are things that really worked. One project we did was trying to come up with technology for tire
wheels to run on moon or on mars and that’s when we understood the basic physics on how to make it out of earth bound materials but we did not know how to make materials that could work in space and to be honest it is a real hell on students, this things are really hard they really pushed but out of that one I think there were three patents issued and the winning team was invited to present their results in Korea at a capstone project competition and three of the four teams went to a NASA event in Houston so it was kind of a big spectacular one.

Were they from Clemson?

Co10 – Yes, that was in 2003. If you look at that Michelin took it and if you google it Michelin lunar wheel you can trace it back. So the summaries are what we found did work are small projects, you need creative ideas it is not time sensitive you cannot expect a finished professional engineering product that what work for us.

What about multiple teams doing the same problem?

Co10 – it depends on the bi semesters, if we had several ergonomic projects safety issues so then we give each team a different one and so I like to fund the entire class and may be selfish it is okay to have another company in these but typically if there were four teams than to fund one team and I it was something having a lot of creativity, we really needed new ideas, new approached then we had better luck assigning all the team the same project. Student hated that because it was just like competition like crazy and in that atmosphere they work like crazy competing with each other.

How do you find the professionalism and their team dynamics?
Co10 – It varies a lot so and that’s a part of the educational process and important part. It is important for the students to present to the faculty and the company and they talk and so on typically. If we sponsored four teams we would deliver a value and one of them would probably have something spectacular and that’s kind of our assumption and that’s one reason why we like to sponsor several teams it is that way. If you happen to get a team and had problems or couldn’t figure it out, could not work wasn’t successful you still got your problem solved.

What do think about their presentation skills?

Co10 – So, Michelin Company was with at the time heavily biased towards technical results, so and less impressed by fancy slides and fancy movies do if a tem was mostly presenting image and really didn’t have data and facts and so on wasn’t good. The best teams are one they have done great presentation but having worked with lots of grades and undergrads and so on I am more tolerant of a less quality presentation and good technical results.

As a company sponsor what is the incentive behind sponsoring the projects?

Co10 – So, we found a class of problems that were too small for engineers to do like safety problems. A severe safety problem Michelin had immediately if this was a long term potential or someone improving a work post or so on there is a whole class of a problems were the manufacturing couldn’t buy an off to shell solution and it wasn’t really important enough for research to denote project to it so those small projects there is a certain range of those that were a great solutions to undergraduates because it was cheap, relatively quick one semester-two semester, they have creative ideas and they will bring
something forward but then either an internal engineer or you can contract out to somebody to finish it up and deliver the final project. So, that things worked. The things that didn’t work is asking to do really hard in-depth research really hard in-depth research really deep science, computation, massive amount of experimentation those are for a graduate project where they have time and more resources, you cannot give projects where they have to travel to vendors needing a huge budget but that was part of our learning was just finding the projects that weekend well with undergrads and it was about the same across universities and across departments. So we sponsored industrial engineering material science and so on.

Is it to check for potential hires?

Co10 – No, in our case we hope that people might apply to Michelin later but we had no link with being hiring and that was something I insisted on and pushed hard in Michelin we had no link between hiring and capstone projects. So we did not put any restriction on schools whether it was former students without a green card or students that already had a job we clearly kept that separate. I think that participating in capstone projects, undergraduates would tell other undergraduates about what a great experience it was so I am sure it helped hiring but it was indirect by word of mouth and company reputation and so on.

Can you recall any particular students or teams that did a commendable job?

Co10 - So most spectacular example was coming with the concepts of lunar wheel where there were three patents and three of the teams were invited by NASA to Houston
and one of the teams got to go to Korea. Michelin took that work with NASA and really
developed that several years later on.

Did any other group evaluated those projects and R&D inside Michelin?

Co10 – So one thing that worked at Michelin is there is a specific coordinator it
was myself for six years and I had a separate budget and so I could fund projects myself I
intend not to do that but I intended to find a champion inside Michelin engineer with a
problem but then I had a separate budget and could fund them so it made it really simple
in Michelin to handle the capstone projects. The profit the students have not to worry about
writing proposals and purchase orders and stuff like that.

Did any other group like R&D evaluate the project?

Co10 – In Michelin, it was a larger the coordinator and then I always had an
engineer scientist somebody in Michelin that requested the project and they eventually got
the results and so they would evaluate in terms of, did it meet their needs, and is it
something they can put in production or carry forward. Typically those engineers would
attend the presentations and certainly read the reports and they would typically be working
with the student teams giving input and so on so yes they evaluate the results. I mentioned
we did not linked it to hiring. We also did not link it to upper management so it wasn’t
upper management reviewed and approved we always kept it a low level kind of
commensurate with the cost and size of the projects and so kind of individual engineer
level or first level manager.

After this experience how was your confidence in sponsoring the research projects
to department and was your time worth?
To Michelin and Clemson starting in 2002, we tried to partner very aggressively and kind of University-Company level. So we partnered in four areas: Hiring, (Michelin career center), government relations-working with the state capital and federal capital research, community relations in our community services, community service duration and so on. In research we split activities among undergrads, sponsored graduate research and in terms of coops working in Michelin and so the program I mean we continuously for from 2002 to 2008 we helped build ICAR and in that I think they are still active in sponsoring projects now. I think it was highly successfully it continues to be highly successful but part was learning what worked so the capstone projects were piece in a big program one thing I would have liked one weakness there were certain projects we couldn’t do as they were multi-department so we always had to decide are we doing a capstone project in industrial and chemical engineering and material science or mechanical and so if it would have been a multidisciplinary we would have done other types of projects, so most projects at Michelin you will have materials people, mechanical engineers and may be electronics, manufacturing specialist, may be industrial engineering and there were some projects that we knew by nature to be successful they need to be multidisciplinary and you just couldn’t do with capstone. So, and we talked about that they need to learn mechanical engineering and do mechanical projects. So, capstone mechanical engineering is good on the other hand when you go to graduate school I think grad students have to be able to work interdisciplinary and work with people in multiple department disciplines and I would recommend about a multi-department capstone projects but in things like
undergraduate research, creative inquiry there are multidisciplinary project but yes capstone
it is a weakness as it is only departmental.

Transcript 16: Interviewer – Varun Rawal, Interviewee – Tracy Crews

Transcript not given on interviewee’s consent.