Improving Students Learning Through University/Industry Collaboration

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Abstract

In recent years, the engineering and technology accreditation bodies have been putting more emphasis on enhancing students' learning through engagement in "real-world" practices. There is also emphasis on means of evaluating the learning outcomes resulting from students' participation in such practices.

Preparing students for "real world" practices are an integral part of curriculum for many engineering and technology programs. Such preparation can involve numerous approaches to simulate real-world experiences by engaging students with real world clients who will make use of their results. The results-orientation of external clients can be an asset to students and faculty members.

The focal point of this paper is to share experiences gained from the development and delivery of a business/industry project-based capstone course that integrates research, proposal development, and design experiences based on the knowledge and skills acquired in earlier coursework and incorporating standards and realistic constraints. The required coursework reflects a focus on essential skills which include teamwork, project management, communications, and problem solving. The paper also details the process of project solicitation, including necessary communications with potential project clients. The learning outcomes measurement and comparison against the recommendations and/or requirements of an accreditation body is addressed.

Introduction

Preparing Industrial and Manufacturing Engineering students for engineering practices and specifically for engaging in "real world" experiences has been a major focus of the Department of Industrial and Manufacturing Engineering (IME). In preparing students for "real world" experiences, the IME curriculum incorporates a number of different approaches. One is to simulate the real world environment by bringing it to students in the form of problems drawn from the context of academia or research labs. Another approach is to take the student out into the real world through internships and co-op activities. Another common approach has been, as part of regular course work, to connect students with real world clients who will make use of

their results. Such engagement of IME students in working in teams and on real world projects is not limited to just one course or specific semester. They begin working in teams on various projects as early as their first year and continue such immersion through the senior year. Freshmen work with juniors on modest size projects and sophomores work with seniors on large systems projects.

Whenever possible, many IME courses provide for students to work on actual company projects. The most significant course that requires business/industry project work is the Capstone course. During the senior year students are required to participate in Capstone class which includes engagement of students in real world projects performed on behalf of real world business and industrial clients. Such projects involve analysis of client needs, determination of engineering requirements, design, development, documentation, and presentations addressing clients' needs.

Capstone Course Projects

Capstone students work with many regional firms in developing solutions for company problems that require them to draw upon the integral of the entire curriculum. The projects are conducted during spring semesters and teams of students concurrently work on multiple projects related to various IME subject areas. The process of project solicitation starts in early October with the goal of solidifying a brief statement of clients' problem and needs during early-to-mid December. The project solicitation document sent to potential clients outlines the criteria for project selection, project duration, and clients responsibilities.

Project Selection
Final selection of projects will take place during the first week of the spring semester. Projects will be selected based on the number and background of students enrolled in the Capstone course. The course is multidisciplinary; in addition to IME students, students from various engineering programs, business, and facilities management are also enrolled. The Capstone students use the form shown in Figure 1 to apply for functional and project roles in a matrix form consulting firm. In addition, the students submit their resume and make a brief presentation explaining their qualifications for the projects and functional position they are interested in. Immediately after collection of students' application forms, the Capstone coordinator and volunteer students conduct an exhaustive analysis of all the applicants to form project teams and assign functional responsibilities to project team members. Figure 2 shows an example of matrix organization that is created for the IME Capstone course.

Project Duration
The Project Management/Capstone class begins in the first week of spring semester and the project activities start the following week. The course concludes with the Capstone presentations and banquet on the last Thursday of April.

Client Responsibilities
Clients play an important role in the design of a solution to fit their needs. As part of the project solicitation document, it is stressed that the potential client organization can help to increase the success of their project by:

- participating in an initial meeting to review project background, goals, requirements, timing, budget, review Statement of Work etc.,
- providing the project team with access to pertinent information required for project completion,
- providing access to the client facilities, and
- designating a contact person to provide project team members with timely feedback and help in acquiring information and resources.

The project solicitation document also provides a brief outline of costs associated with a project, which are minimal. The client provides reimbursements for expenses directly related to the client project(s). This includes copies, paperwork, phone calls, and mileage expenses for out-of-town travel. In addition, a modest fee will be assessed. The client pays this fee only if the project team has produced satisfactory results.

Project and Job Preference Form

| Your Name: | Credit Hours Load: |
| Major/Minor: | Outside Work Hours/week: |

Course Instructor

Project and Course Support Team

General Manager

Functional Departments

| Technical and Engineering | Business | Operations Management |

| Director of Projects | Director | Director | Director |

| PM | Member | | Project Engineer | Business Manager | Operations Manager |
| Client Name | | | | | |

| PM | Member |
| Client Name |

| PM | Member |
| Client Name |

| PM | Member |
| Client Name |

Project and Course SupportTeam Positions
You have the option of applying for none or any number of the positions in the Support Team. Below each of the positions you are interested in, show your preferences by writing 1 for your first choice, 2 for the next choice, and so on.

Project Membership
You need to select membership in 4 projects. Write your choice of organizations above the **Client Name**. Next to each of the client names, below the space labeled as **Member**, show your preferences by writing a number **1** through **4**, with 1 showing your first choice and 4 as your last choice.

Project Management Positions
As a member of a project team, you might be assigned the role of project manager. If you would like to be considered as a Project Manager, for any or all of the projects you have selected, mark an **X** below the space labeled as **PM**.

Membership in the Functional Departments
You must select membership in functional departments. Please identify your choice of functional departments by writing a number 1 through 3, with 1 showing your first choice and 3 as your last choice.

Figure 1. Project and Job Preference Form

Program and Project Management / Capstong
Spring 200X Team and Project Matrix Organization

Course Instructor	General Manager, Student					Projects and Course Support Team
			Functional Departments			
			Engineering	Business	Operations Management	
		Director of Projects	Director Engineering and Technical	Director Business Management	Director Operations Management	
		Student	Student	Student	Student	

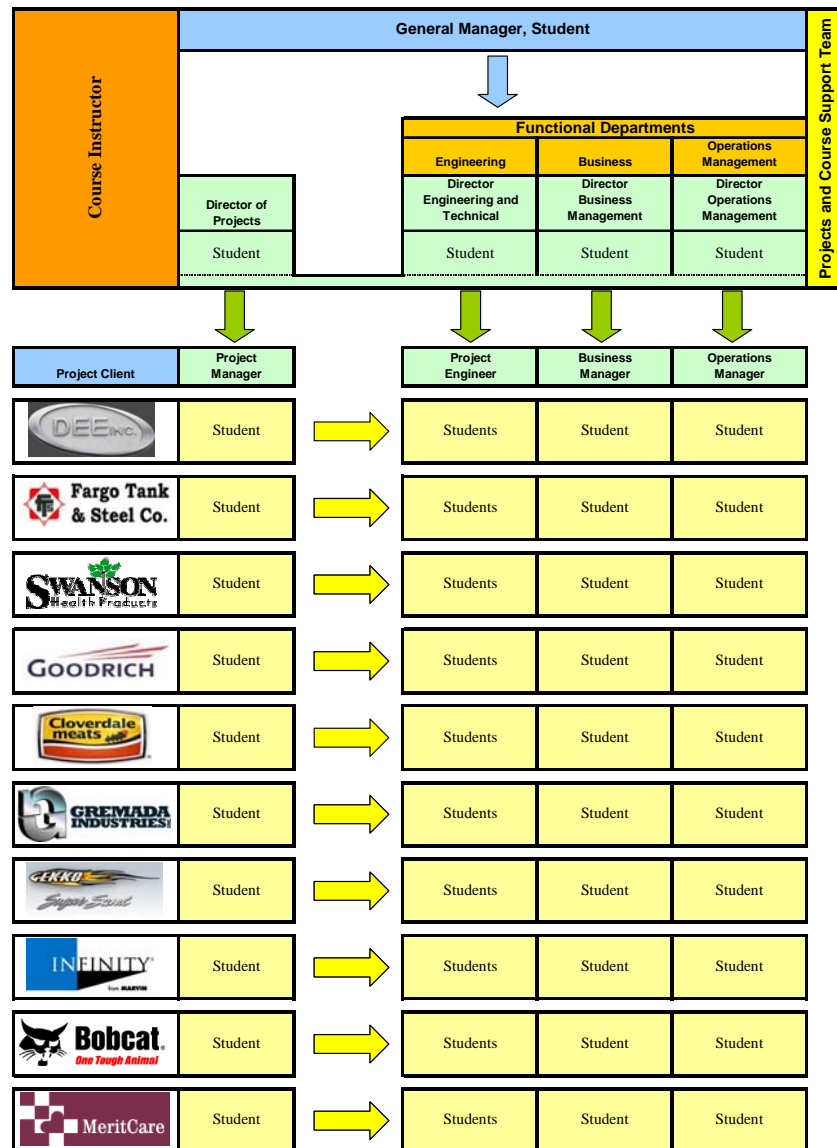| Project Client	Project Manager		Project Engineer	Business Manager	Operations Manager
DEE INC.	Student	→	Students	Student	Student
Fargo Tank & Steel Co.	Student	→	Students	Student	Student
SWANSON Health Products	Student	→	Students	Student	Student
GOODRICH	Student	→	Students	Student	Student
Cloverdale meats	Student	→	Students	Student	Student
GREMADA INDUSTRIES	Student	→	Students	Student	Student
GEKKO SuperSonic	Student	→	Students	Student	Student
INFINITY from MARVIN	Student	→	Students	Student	Student
Bobcat One Tough Animal	Student	→	Students	Student	Student
MeritCare	Student	→	Students	Student	Student

Figure 2. Typical Capstone Team and Project Matrix Organization

Capstone Course Structure

North Dakota State University's Department of Industrial and Manufacturing Engineering has a successful track record of conducting projects on behalf of many regional service and manufacturing organizations. Many of the projects have been conducted by Capstone students as partial fulfillment toward completion of their Capstone course. For IME students, the Capstone experience (course) requires enrollment in IME456, Program and Project Management course, as well as concurrent enrollment in IME485, Industrial and Manufacturing Facility Design, or IME489, Manufacturing Capstone. Collectively, each pair of courses forms the Industrial Engineering & Management Capstone or the Manufacturing Engineering Capstone, respectively.

Concurrent enrollment in pair courses offer students the opportunity to learn project management skills while participating in Industrial and Manufacturing Engineering program-related projects working with industry clients. The process of performing the projects is carefully structured so that the project objectives and the course learning objectives are congruent. Company sponsors interact with student teams during the project work and participate in the evaluation of project teams' work. This practice serves the dual purpose of injecting realism and interest into the coursework and added preparation of students for engineering practices.

Table 1 shows a listing of objectives for some of the capstone course projects that students have participated in since spring semester 2003. The listed project objectives have been abbreviated and slightly modified to maintain client confidentiality.

The ABET Criterion 3, Program Outcomes and Assessment (also referred to as ABET a-k) and Criterion 4, Professional Components provided the framework for capstone redesign and enhancement [1]. The ABET Criteria were also used for developing student learning outcome assessment tools. During fall semester 2005, the Capstone course student learning outcomes were modified and the relation of all of its learning outcomes to ABET a-k were analyzed and documented. In an effort to better link Capstone to the overall IME programs' educational outcomes, the level of potential contribution to ABET a-k was evaluated and documented. Table 2 captures the essence of this paragraph.

The ABET guidelines for Criterion 4, professional component states that "Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political." [1]. The guidelines also specify three subject area components appropriate for engineering but do not prescribe specific courses. Faculty must assure that the program curriculum devotes adequate attention and time to each component, consistent with the objectives of the program and institution.

Capstone provides the students with the opportunity to engage in business and industry projects, thus enhancing their abilities for engineering practices. Table 3 shows a summary of how the Capstone course addresses the considerations outlined in ABET Criterion 4. Explicit student benefits from the Capstone experiences are focused on gaining expertise in the following areas:
1. Experience and confidence for engineering and management practice,
2. Application and integration of concepts and tools from multiple industrial and manufacturing engineering topics,
3. Team work in a multi-disciplinary setting,
4. Presentation and documentation skills, and
5. Interaction with field engineers and managers.

Table 1. Samples Project Objectives

Study, document and analyze the production line including the layout and manufacturing processes and make recommendations to decrease manufacturing lead time and increase throughput.

Develop proposals for improving office layout to help with effective utilization of space and meeting anticipated staff growth.

Redesign the manufacturing cell to help with reducing cycle time and increasing capacity.

Develop improved processes and procedures for packaging and shipping logistics

Analyze and document requirements for a new inventory numbering system that can support operations due to transitioning to a new business model.

Develop proposals to improve information flow to help with maximizing materials yield and more accurate measurement of waste

Develop and document a proposal that can help with increased bottling operations throughput.

Determine and propose methods to improve patient access to healthcare facility

Analyze the current inventory management system and its impact on material handling, storage, and warehousing. Make recommendations improve efficiency and cut material handling costs.

Study and document the feasibility of establishing an on-site, full service childcare center for use by faculty, staff, and students in a university

Make recommendations for improved ergonomics through utilizing improved methods and equipment for material handling and packaging.

Design a centralized "supermarket" facility to be used for storing and distribution of parts in support of final assembly operations.

Analyze, document, and make recommendations for improving access to mammography screening services.

Research and document methods that can help to improve the order picking accuracy rate.

Design a flexible holding device that will aid in improving the cabinet assembly processes.

Develop proposals for improved methods for service work order processing

Develop a proposal for improved material handling methods for loading, transferring, and unloading of parts in a paint line system.

Determine and propose methods to minimize the operating room downtime and recommend ways to improve efficiency and turnover rates.

Research and test various conformal coating materials with the function to protect printed circuit boards from damage caused by environments.

Improve the efficiency of the patient transportation department at a medical center.

Determine the feasibility, cost benefits and requirements for incorporating bar coding system in manufacturing and warehousing operations

Table 2. Capstone Students Learning Outcomes vs. ABET Criterion 3

NDSU IME Program Outcomes Based on ABET Criterion 3 – Program Outcomes and Assessment

Upon graduation, the NDSU IME program graduates demonstrate the following:

a. An ability to apply knowledge of mathematics, science, and engineering.

b. An ability to design and conduct experiments, as well as to analyze and interpret data.

c. An ability to design a system, component, or process to meet desired needs.

d. An ability to function on multi-disciplinary teams.

e. An ability to identify, formulate, and solve engineering problems.

f. An understanding of professional and ethical responsibility.

g. An ability to communicate effectively.

h. The broad education necessary to understand the impact of engineering solutions in a global and societal context.

i. A recognition of the need for, and an ability to engage in life-long learning.

j. A knowledge of contemporary issues.

k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

At the successful completion of program and project management / capstone course, the students should be able to:

1. Understand project management concepts including project attributes, constraints, life, process, and project management benefits. Meets criteria (d) (f) (h) (j).
2. Become familiar with project needs identification, project selection, and the process of developing requests for proposals. Meets criteria (c) (d) (g).
3. Be able to perform needs assessment and develop a statement of work addressing client and project requirements. Meets criteria (c) (d) (e) (g).
4. Use their knowledge to develop proposals for designing or improving a system, component, or process to meet desired needs. Meets criteria (a) (b) (c) (d) (e) (f) (g) (j) (k).
5. Develop and manage project plans by clearly defining project objective, developing work breakdown structure, and developing network diagrams. Meets criteria (c) (d) (j) (k).
6. Have knowledge of project cost planning and project performance measurement. Meets criteria (a) (h) (g).
7. Understand the development of effective project managers and teams. Meets criteria (d) (g) (h) (i) (j).
8. Develop professional project documentations. Meets criteria (c) (d) (f) (g) (h).
9. Use commercially available software to plan and manage projects. Meets criteria (g) (k).
10. Enhance their ability to deal with others, emphasizing functional and project teams, motivation, leadership, integrity, ethics, diversity, and personal growth. Meets criteria (d) (f) (g) (h) (i) (j).

Level of Contribution to Criteria Using the Scale shown Below:										
⑤ very high high average low very low ◯not applicable										

Criteria	a	b	c	d	e	f	g	h	i	j	k
Contribution Level	3	4	5	5	5	3	5	3	3	3	4

Table 3. ABET Criterion 4 Design Considerations Addressed by the IME Capstone Course

Participating in real life problems - All of the assigned projects are real-life problems for real clients. Projects are solicited throughout the year.

Ability to define problem definition – As a part of project solicitation, initially the course facilitator visits with the potential clients and puts a brief document together describing some of the clients' needs. Such documents are then provided to students. Based on the information provided, the students apply for various projects. After the students are assigned to specific projects, they meet with the clients to discuss the situations that gave rise to the client needs. From there, problems are defined and a statement of work is drafted. The statement of work becomes the foundation for the activities that the students will participate in to conduct the project.

Dealing with open-ended problem – The term "fuzzy ball" is used to describe the nature of most of the projects students participate in. The majority of the projects conducted in this course are open ended.

Input and feedback from advisory committee and clients – The Department of Industrial and Manufacturing Engineering has an active advisory board. The advisory board members provide input related to the overall structure of the programs offered through the Department. Also, since most of the advisory board members are graduates of the Department, they provide input and suggestions regarding the effectiveness of the Capstone projects. Some of the advisory board members provide project opportunities in support of the Capstone. The advisory board members are invited to attend the final presentations. Throughout the course and project life, clients participate, through interaction and working with students as well as through the project documents they receive, in evaluating the teams and the projects.

Effective teamwork practices – This is one of the major pillars of this course. The level of students' contributions to teams' efforts become visible during the early stages of the course while conducting the projects.

Addressing health and safety concerns – When and where appropriate, health and safety concerns are addressed. In some of the cases the health and safety factors become critical for proposing and/or developing solutions. Examples include OSHA, FDA, building code considerations, etc.

Incorporating standards – When and where appropriate, various engineering standards such as specifications, test methods, technical regulations, conformity assessment such as UL, etc., are used to propose and/or develop solutions.

Developing alternative solutions – The teams are expected to provide/recommend solutions to given problems or needs. When appropriate, the students are also expected to provide alternative solutions.

Development of a final product – The students always produce a final product. For the most part, in this course the final product is a document detailing the various activities to achieve the agreed-upon deliverables. Due to time constraints, the opportunity to build the physical model or a prototype of the proposed design is rare. The course is only one semester long and for three credits.

Conducting financial analysis – All teams are required to conduct and document financial analysis and economic impact studies of their proposed solutions.

Capstone Student Outcomes Learning Assessment

Many articles are written, some outlining high level generic approaches to course and program learning outcome assessment [2] [3] [4] [8] [9] [10] and yet some provide more specific information about Capstone assessment [2] [5] [6] [7] [11] [12]. The focus of this paper is on describing the structure of a business/industry project based Capstone course and on the tools and procedures used for assessing the Capstone student learning outcomes.

In general, capstone courses are not a specific means of assessment per se, but the experience offers access to a representative body of a student's work. As a result, capstone courses provide an ideal setting for conducting authentic assessments of what students know and are able to do [10]. The IME Department uses the Capstone experience as a major assessment instrument in evaluating the program outcomes. Table 4 shows the breakdown of various activities and associated grade points that are uses to assess Capstone student learning outcomes.

Table 4. Activities Used for Assessing Capstone Student Learning Outcomes

Activities	Grade Points
Chapter Quizzes	210
Job Application • Introduction of Selves – 10 points • Resume (1 Page - follow example format) – 20 points • Preference and Recommendation (complete "Job Preference Form") – 10 points	40
Class and Rehearsal Presentations • First in-class Project Presentation – 30 points • Second in-class Project Presentation – 40 points • Rehearsal Presentation – 50 points	120
Documentations and Final Presentation • The Main Project Document – 100 points • Final Presentation Booklet, PowerPoint Visuals, and Annotated Narrative – 30 points • Final Presentation – 50 points • Team Members Appraisal Form Documentation – 20 points	200
Meeting Deadlines	100
Total Points Earned points convert to %: 90, 80, 70, 60 to A, B, C, D, and F ranges	670

Assessment Tools

Table 5 shows measures used to evaluate Student learning outcomes. As was shown in Table 2, each of the Capstone student learning outcomes are tied to the ABET a-k. Notice from tables 4 and 5 that the majority of Capstone learning outcomes are met through participation of students as teams in projects conducted on behalf of industry clients. The assessment process for Capstone is not solely a self-assessment process.

The development of the "Main Capstone Project Documents" by student teams is an on-going process. The main project document is the final product that each student team produces. In addition to regularly scheduled class meetings, during the semester the instructor meets with each project team six times, each time about 90 minutes. During the third, fourth, and fifth meetings, the instructor evaluates the project report and progress, provides feedback to the students, and assigns a grade. The final Capstone document grade will reflect not only the quality of the final document, but also meeting deadlines to complete various project-related tasks.

Table 5. Capstone Course Student Learning Outcomes Appraisal

Student Learning Outcomes	Measure(s) used to evaluate Students learning
1. Understand project management concepts including project attributes, constraints, life, process, and project management benefits.	• Textbook quizzes
2. Become familiar with project needs identification, project selection, and the process of developing requests for proposals.	• Textbook quizzes • Project job preference application form • Statement of Works document • Client feedback
3. Be able to perform needs assessment and develop a statement of work addressing client and project requirements.	• Textbook quizzes • Statement of Work and main project documents • Client feedback
4. Use their knowledge to develop proposals for designing or improving a system, component, or process to meet desired needs.	• Statement of Work and main project documents • Project documents • Client feedback • Team members appraisals • Class members appraisal
5. Develop and manage project plans by clearly defining project objective, developing work breakdown structure, and developing network diagram.	• Textbook quizzes • Statement of Work and project documents • Client feedback • Team members appraisals
6. Have knowledge of project cost planning and project performance measurement.	• Textbook quizzes • Meeting deadlines for project milestones
7. Understand the development of effective project managers and teams.	• Textbook quizzes • Team members appraisals • Client feedback
8. Develop professional project documentations.	• Main project document • Project poster evaluation • PowerPoint preparation and presentation • Client feedback • Class members appraisal
9. Use commercially available software to plan and manage projects.	• Textbook quizzes • Computer generated project plan documents • Meeting deadlines for project milestones
10. Enhance their ability to deal with others, emphasizing functional and project teams, motivation, leadership, integrity, ethics, diversity, and personal growth.	• Meeting deadlines for project milestones • Team members appraisals • Client feedback

At the end of the semester, the project teams evaluate and report the performance and contribution of their team members in developing the Capstone document. Figure 3 shows the form that is used by students to evaluate their team members' performance and contribution. Relative rankings and narrative descriptions of team performance are collected from this form. This feedback comes from those who know best what each student "had done" and "can do" in the context of the Capstone course and perhaps the entire curriculum.

Team Members Performance Appraisal										
Using numbers 1, 2, 3, …rank contributions of each team member (row) in each category of performance (column). Number 1 means most contribution and the largest number means least in line of contributions. Use each number only once in columns. Include narrative explanation and suggested grade.										
Student Performing the Evaluation:	Quality of Contributions								Narrative: Statement supporting ranking suggested. Examples: absolutely superior, can do anything, most helpful member, put in most time, good writer, kept us moving, made every meeting, ….. never did anything, never came to meeting, wrote only one page, did not edit anything, helpless, always wanted to be told what to do ….	Suggested Grade 1 – 100 Points
	Team Participation and Collaboration				Deliverables					
Names	Sense of Responsibility	Availability	Helpfulness	Resourcefulness	Relationship to Client	Documents	Presentations	Overall Effectiveness		

Additional Comments
Please use the space below to make suggestions to improve the course. Your constructive criticism is highly appreciated.

Figure 3. Team Members Appraisal Form

During the semester, each project team makes three in-class presentations as well as a final presentation. The first two presentations are evaluated and graded by the course instructor and all course participants that are not part of the team. The third presentation is evaluated by the course participants to provide feedback to teams so they can improve their final presentations. The instructor grades the third presentation. Figure 4 shows a typical evaluation form used for in-class presentations.

Throughout the semester the project clients and students maintain contact and provide feedback to each other and keep the Capstone coordinator informed. At the end of the semester and once all the project documents are delivered, the clients complete an evaluation form to provide feedback about the projects and overall performance of their project teams. The condensed version of this form is shown in Figure 5. Project clients use this form to provide input by addressing and rating the evaluation criteria concerning their experiences and impressions during the semester interacting and/or working with their project team. The information gathered from the client evaluation forms do not impact the student grades, and are only used for the purpose of Capstone course and curriculum improvements.

The final presentation audience includes Capstone course members, IME faculty and students, project clients, IME Advisory Board members, other students, and invited members of the business/industry community. The audience except the Capstone course participants is encouraged to participate in evaluating the final presentation. Advisory Board members provide feedback during advisory board meetings about the projects and presentations. Figure 6 shows the condensed version of the final Capstone presentation form. The comments and ratings made on the forms do not impact the student grades and are explicitly used to improve the Capstone course as well as IME undergraduate programs.

The student learning outcomes are also measured using quizzes and/or tests. The quizzes and tests cover material from class lectures and handouts, textbook, supplementary readings, and in-class activities. The quizzes and tests are evaluated by the course instructor.
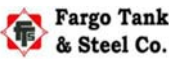
Program and Project Management / Capstone
Project Presentations Evaluation

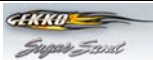| Evaluation Instruction	1 - Circle your name (Do not rate your own team)
	2 - Evaluate team presentations based on:
	   a. Clarity and Quality of presentation (max = 25 points)
	   b. Quality and Unique Features of PowerPoint Slides
	   (max = 15 points)
	   c. Adherence to the presentation guidelines provided by the
	   Instructor (max = 10 points)	

Client Project	**Project Team Members**	**Grade Teams - Scale: 1 - 50** (a) + (b) + (c) =
DEE INC.	List of Project Team Members	( ) + ( ) + ( ) =
Fargo Tank & Steel Co.	List of Project Team Members	( ) + ( ) + ( ) =
SWANSON Health Products	List of Project Team Members	( ) + ( ) + ( ) =
GOODRICH	List of Project Team Members	( ) + ( ) + ( ) =
Cloverdale meats	List of Project Team Members	( ) + ( ) + ( ) =
GREMADA INDUSTRIES!	List of Project Team Members	( ) + ( ) + ( ) =
GEKKO Super Stuit	List of Project Team Members	( ) + ( ) + ( ) =
INFINITY from MARVIN	List of Project Team Members	( ) + ( ) + ( ) =
Bobcat. One Tough Animal	List of Project Team Members	( ) + ( ) + ( ) =
MeritCare	List of Project Team Members	( ) + ( ) + ( ) =

Figure 4. Typical Form Used by Students to Evaluate Project Presentations

FORM B – to be used by clients for Evaluation of Project Team	
Client Organization and Project Title	
Client Representative Completing This Evaluation and Title	

In order to improve our Program and Project Management/Capstone courses and our undergraduate programs, we are asking for your input by addressing and rating the evaluation criteria concerning your experiences and impressions during the semester interacting and/or working with your project team. **These answers do not impact the student grades and will be used only to consider where we can make our program better.** Thank you for your time and effort.

Based upon your observations of and interactions with the team, use the evaluation rubric shown on the right side to rate the project team's performance. Consider all evidence of the team's performance including the written report. Use FORM A for evaluating your team's presentation.	**Rating**	**Rubric**
	5	Demonstrated outstanding level of competence
	4	Demonstrated above average level of competence
	3	Demonstrated acceptable level of competence
	2	Demonstrated marginal competence
	1	Demonstrated incompetence
	NA	Unable to determine/not applicable to this project

Criteria	Rating
The project team understood your problems and needs	
Comments:	
The team maintained acceptable level of communication and provided timely feedback as well as soliciting your input	
Comments:	
The team dealt with you in a professional manner (e.g., on time for meetings, prepared for meetings, courteous, neat, high ethical standards, high technical standards, positive attitude, etc.)	
Comments:	
The approaches used for developing proposals and solutions are clear	
Comments:	
The project team fulfilled all the deliverables as was outlined in the "statement of work"	
Comments:	
The results of the project have value for my organization	
Comments:	
Attention to design and or/documentation details	
Comments:	
The results of the project are of high quality	
Comments:	
This project was representative of activities by practicing engineers	
Comments:	
This project was a challenging engineering project	
Comments:	
This project was a valuable learning experience for the project team members	
Comments:	
Would you consider using Capstone teams for future projects	
Comments:	
Overall satisfaction with the experience and the project results.	

What do you feel were the strongest attributes of the team (e.g., technical ability, learning ability, communication ability, teamwork ability, time management skills, etc.)?

What do you feel were the weakest attributes of the team and need improvement (e.g., technical ability, learning ability, communication ability, teamwork ability, time management skills, etc.)?

What would you change in our process to improve your experience with the team?

Figure 5. Form Used by Project Clients to Evaluate Team Project Performance

<table>
<tr><th colspan="2" style="text-align:center">Industrial and Manufacturing Engineering
Program and Project Management/Capstone – Spring 2006 Projects</th></tr>
</table>

FORM A – to be used for Project Presentation Evaluation	
Client Organization:	
Project Title:	
Please Circle	**I am a:** Faculty Student Business Representative Other ( )

In order to improve our Program and Project Management/Capstone courses and our undergraduate programs, we are asking for your help by rating the team presentations. **Your ratings and comments do not impact the student grades and will be used only to consider where we can make our program better.** Please consider the team as a whole, and not particular individuals. Thank you for your time and effort.

<div style="text-align:center">Please rate each criteria using the scale shown below:
⑤ Excellent   ④ Very well   ③ Average   ② Low   ① Very low   〇Unable to determine</div>

Criteria	Rating
Introduction – Explained who they are/what they are doing/the problems/and the need for the project.	
Comments:	
Technical work – Sufficient quantity/quality of engineering work including why that work was done	
Comments:	
Conclusion and recommendations – Usability of project work	
Comments:	
Presentation organization – Overall flow	
Comments:	
Presentation skills – Overall quality of the presentation	
Comments:	
Q and A – Ability to answer questions	
Comments:	
Rate the presentation for readability of the slides, figures, graphs.	
Provide an overall rating of the presentation.	

If you need, please use the back page to write additional comments.

Figure 6. Form used for Evaluation of Capstone Final Presentations by General Audience

Using Assessment Data for ABET Self-Study Document

The Capstone course structure and assessment tools explained in previous sections made references to ABET Criterion 3, Program Outcomes and Assessment as well as reference to ABET Criterion 4, Professional Element. These Criteria were used to improve the Capstone course structure including the student learning outcomes. Table 2 showed the link between learning outcomes and ABET a-k program outcomes Criteria as well as level of contributions to such Criteria. Tools and methods of collecting assessment data, based on current structure, were explained. The assessment data is collected from internal and external constituents.

Many of the references that were used for the purpose of developing this paper as well as developing a sound assessment plan for the IME Capstone course recommend various methods and tools for collecting assessment data. Some of the references recommend using (directly) the ABET a-k program outcomes for the purpose of collecting data from various constituents

including project clients. While this approach simplifies assessment data collection, it puts the burden on the project clients and other constituents to interpret the ABET (or program) a-k outcomes, hence inconsistent feedback from constituents.

To avoid potential problems from direct use of ABET a-k for collecting assessment data from external constituents, two evaluation forms were developed which were shown in figures 5 and 6. While these forms are more convenient to interpret and complete by external constituents, they lack "directly" providing the data needed to link the learning outcomes to ABET a-k. To address this deficiency, conversion tables were developed that link the various evaluation criteria to ABET a-k learning outcome. These tables are shown in figures 7 and 8.

Figure 7 shows the relationship of project presentation evaluation criteria used by constituents to ABET a-k and corresponding ratings. Similarly, Figure 8 shows the relationships and ratings that were collected from project clients. These figures, once completed, will become part of the IME's ABET self-study document.

Industrial and Manufacturing Engineering Program and Project Management/Capstone Spring 2006	Relationship of Project Team Performance Evaluation Criteria Used by Project Clients to ABET a-k and Corresponding Ratings											Criterion Average for all Teams
	ABET Criterion 3											
Criteria used by project clients to evaluate project team performance	a	b	c	d	e	f	g	h	i	j	k	
Criteria	Shaded areas show the evaluation criterion link to ABET a-k. Average client ratings (5=highest) are shown in the shaded areas											
The project team understood your problems and needs				▦	▦	▦						
The team maintained acceptable level of communication and provided timely feedback as well as soliciting your input				▦	▦	▦						
The team dealt with you in a professional manner (e.g., on time for meetings, prepared for meetings, courteous, neat, high ethical standards, high technical standards, positive attitude, etc.)				▦	▦	▦						
The approaches used for developing proposals and solutions are clear	▦	▦	▦	▦	▦		▦		▦	▦		
The project team fulfilled all the deliverables as was outlined in the "statement of work"	▦	▦	▦	▦	▦	▦		▦		▦		
The results of the project have value for my organization	▦		▦	▦	▦			▦		▦		
Attention to design and or/documentation details		▦	▦	▦	▦	▦		▦				
The results of the project are of high quality	▦		▦	▦	▦			▦		▦		
This project was representative of activities by practicing engineers	▦		▦	▦	▦		▦					
This project was a challenging engineering project			▦	▦	▦	▦		▦				
This project was a valuable learning experience for the project team members				▦	▦	▦						
Would you consider using Capstone teams for future projects												
Overall satisfaction with the experience and the project results												
Percent Ratings of Project Team Evaluation Criteria with Respect to ABET a-k Program Outcomes												

Figure 7. Relationship of Project Team Evaluation Criteria used by Clients to ABET a-k and Corresponding Ratings *This figure is incomplete*

Industrial and Manufacturing Engineering Program and Project Management/Capstone Spring 2006	Relationship of Project Presentation Evaluation Criteria Used by Constituents to ABET a-k and Corresponding Ratings											Criterion Average for all Teams
	ABET Criterion 3											
Criteria used by project clients to evaluate project team performance	a	b	c	d	e	f	g	h	i	j	k	
Criteria	Shaded areas show the evaluation criterion link to ABET a-k Average client ratings (5=highest) are shown in the shaded areas											
Introduction – Explained who they are/what they are doing/the problems/and the need for the project.												
Technical work – Sufficient quantity/quality of engineering work including why that work was done												
Conclusion and recommendations – Usability of project work												
Presentation organization – Overall flow												
Presentation skills – Overall quality of the presentation												
Q and A – Ability to answer questions												
Rate the presentation for readability of the slides, figures, graphs.												
Overall rating of the presentation												
Percent Ratings of Presentation Evaluation Criteria with Respect to ABET a-k Program Outcomes												

Figure 8. Relationship of Project Presentation Evaluation Criteria used by Constituents to ABET a-k and Corresponding Ratings. *This figure is incomplete.*

Summary and Conclusions

This paper provided the framework for design and delivery of a Capstone course that when properly executed, can provide the goal of *improving students learning through university/industry collaboration*. As part of this paper the structure of an integrated Capstone course which includes the engagement of students in business/industry projects was reviewed and the process of project solicitation and assignment of projects and functional responsibilities to students was outlined. The relationship between the Capstone student learning outcomes and the guidelines provided by ABET Criteria 3 and 4 was addressed and the procedure and tools used for assessment of such learning outcomes was explained and examples of assessment tools was provided.

The activities students perform to fulfill Capstone learning outcomes provide "hands-on" "real-world" experiences while working in frequent contact with their client representatives. This Integrated Capstone course creates a crucible for the evaluation of accumulated learning from an entire curriculum and tries to draw upon various combinations of all intended academic knowledge and skill outcomes. To succeed in this course, students must demonstrate professional competence through the accomplishment of work activities. Students are required to handle together widely diverse knowledge, thinking, and activities while facing many of today's competitive challenges to industry, business and government.

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Biography

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