Industry/University Partnership in a Capstone Course

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Abstract

Wichita State University has partnered with industry to provide real world project experience for undergraduate students. Industry provides students with ill-defined problems where student teams must define the problem and develop solutions that use tools and methods learned in their courses. Students from this course have won the best paper award from the Institute of Industrial Engineers at the regional and national level. This course also addresses several of the ABET criteria and provides the opportunity for assessment of student ability in these often difficult to assess areas. This paper presents the method of the course and the method used for assessment.

Introduction and motivation

Capstone design projects are common in engineering curricula. In response to industry demands for more practical engineering graduates, many engineering colleges have implemented capstone design projects as well as to respond to emerging ABET requirements[1]. A survey by Todd, et al. found that about 60% of engineering programs use industry based projects for some or all of their capstone design courses[1]. Dutson, et al. performed a literature review of over 100 papers. The survey identified the course duration, format, content, and evaluation as well as a review of team size and method. Amon, et al.[2], implemented a two course sequence in senior design using a specific research focus (wearable computers) that are sponsored by industrial partners and are “cross-disciplinary and inter-departmental.” Finally, Farr et al.[3], claim that the capstone course is the most important course due to the fact that it provides skills beyond design requiring the synthesis of curricula concepts with the so called soft skills.

The motivation for this type of course and the design of the course is due primarily to the unique requirements of industrial and manufacturing engineers to define a problem and solve it. Many other engineering disciplines have the problem defined for them. Although, Dutson, et al.[4] states that the focus of engineering curricula on the engineering sciences produces engineering graduates having difficulty becoming productive engineers. This has led to more capstone courses to develop more immediately productive engineers.

Background and history of course

A commonly used term for these types of classes is ‘experiential learning.’ These have been categorized into two types by Harrisberger et al.[5]: ‘simulations’ and ‘authentic involvement.’ Simulations, as the name implies, are ‘contrived situations’ developed to achieve learning objectives requiring some synthesis of curriculum concepts generally using a laboratory environment or case study. ‘Authentic involvement’ uses industry partners to place the students in a real world environment solving problems that are of benefit to the partner while still requiring students to synthesize curriculum concepts. The capstone experience in the Industrial and Manufacturing Engineering Department at WSU is that of the ‘authentic involvement’ type and somewhat unique in that it requires students to participate in two dissimilar semester-long, group projects in industry. Students are required to enroll in the class in their last two semesters. Therefore, the students take the class twice. Each semester the student works with a different group of students and at a different company in a different type of project.

Course methods

Two faculty are responsible for the course in alternating semesters. This is intended to allow students to observe two different approaches to managing the project as well as enabling different instructional content each semester.

One of the primary ‘features’ of our capstone experience is that students are required to address ‘messy problems.’ This means that the problem is not well-defined. The class instructors work with the sponsors from industry to identify areas for improvement, not problems to be fixed. The underlying philosophy of our curriculum is that a large part of becoming a successful practicing engineer is the ability to properly define the problem, bound it, generate multiple alternate solutions, and then evaluate those solutions to propose the final solution.

As observed by Dym, et al.[6] Rittel[7] describes the design process as “inherently argumentative,” which promotes an atmosphere of constant questioning akin to the Aristotelian approach. Also, Bucciarelli[8] describes “design as a social process” making design in the context of negotiated decisions. Minneman[9] “reemphasized Bucciarelli’s views on the role of ambiguity and negotiation: they are inherent to design and constitute a condition and a mechanism for understanding and structuring design activity” [6]. All of these authors point to the need to expose students to ‘messy problems’ in order to develop them as a practicing productive engineers. Many of these authors point especially to the need to develop this in a group context.

Industry partnership

Wichita, the “Air Capital of the World” is home to major manufacturing facilities of Spirit Aerosystems, Boeing Aircraft Company, Bombardier/LearJet, Cessna

Aircraft Company and Raytheon Aircraft Company. Wichita is also home to a number of ancillary industries including some large companies such as Brittain Machine and Thayer Aerospace. At WSU, many established avenues exist to promote partnerships with the aviation industry. As these partnerships have developed, opportunities for student projects have increased. Students serve as interns and students have class projects with industry. Therefore, the capstone experience at WSU is not the only interaction our students have with industry.

The ability to add value on their first job assignments is a distinguishing characteristic of graduates of the Industrial and Manufacturing Engineering Programs at Wichita State University. Our interaction with industry using industry-based projects in the curriculum is a key enabler of our students being ready to contribute.

In a given semester, the projects are intended to be varied. The variation is in both type of industry and type of project. Although, as previously stated, WSU has access to many aerospace companies, other companies are involved as well. Capstone projects were held in the last two semesters at: Boeing (scaffolding setup and safety in the modification area), Saint Francis Hospital (redesign of an emergency room), LearJet (process improvement in the wire shop), Cessna (tailcone assembly redesign), Air Capitol Plating (control of solution concentrations), Spirit Aerospace (flow though chemical milling preparation), Advanced Industries Inc. (improve flow through machine shop), Wichita Eagle Newspaper (reduce press downtime). The Saint Francis project is an example of integrating service learning into the senior design course. This is similar to the "compassion practicum" in the United States Military Academy[10].

The IMfgE Department has developed a relationship with managers in several industrial partners. The process of gathering potential projects becomes easier with time. Potential industrial partners are contacted about submitting candidate projects for the faculty to review. Industrial partners are specifically instructed to not provide a project plan or even to completely define or scope the problem. A key learning objective of the senior design class is to provide experience for the students to define the problem. Students must define the problem in the terms of the sponsor, in terms of the faculty providing a grade, and in terms of their understanding of the requirements. The sponsor typically provides a candidate area of their facility. After enough candidate projects are submitted, students are placed in teams and on projects. After the first few semesters, more companies propose projects than we have student teams available. This presents a good situation in that the faculty are able to be more selective in choosing projects suited for the individuals and the teams assigned.

The sponsor is required to provide a contact at their company to escort the students and introduce them to key company personnel. This compares favorably with Magleby[11], who found that interaction with an industry contact is key in the learning of engineering practice. A proposal is written to explicitly document the problem as understood by the students. The sponsor and the faculty evaluate the proposal. The sponsor assesses the problem scope and project plans of the student team. The faculty assesses the learning involved and ensures that curriculum concepts are used during the project. At the mid-point of the semester, the student team submits a progress report. Again, the sponsor and faculty assess the progress report. Throughout the semester the team presents brief oral reports on the progress and future plans. At the end of the semester, the student teams prepare a written report and present an oral presentation. The faculty from the department as well as personnel from the sponsoring company attend and assess the presentations.

Course results

There are several possible viewpoints for assessing the quality of a capstone design experience. The most basic is to determine if the organization sponsoring the project was pleased with the result. The sponsor must be pleased as this makes it easier to recruit projects in the future. Also, as the faculty involved, there is an innate desire for a successful project from the class. An important perspective is the amount and quality of learning experienced by the students. As the faculty are engineers as well, there is an intrinsic reward in problem solving and design. However, the faculty can become too involved in the technical outcome at the cost of the quality of educational outcome. Similarly, the sponsor must be prevented from defining very specific expected outcomes for their projects. As sponsors are requested to make a donation to the department, sometimes they expect to get "low cost" consulting (or even employees to take data). The project must be viewed as an educational activity.

In order for deep learning to take place, students must be allowed to fail initially and learn from those failures. Significant educational objectives are to assist each student in developing a professional attitude toward the art and craft of engineering, an appreciation of the power and value of the skills that they have developed, and the confidence to undertake messy real world projects. Typically, real progress on developing a solution begins half way through the course after teams believe that they have developed a series of problem/solution scenarios, each more robust than the previous. The process of open inquiry that takes place as a team (and the set of teams in a class) is the activity that produces the deep learning required for attitude and confidence development.

The program outcomes for which summative assessments are expected for Senior Design with respect to ABET 2000 are allocated to the various course artifacts (see Table 1). Many of these artifacts provide the basis for formative evaluations for both the students and faculty during the course but they may also serve as summative evaluations of program outcomes. Six unique perspectives are incorporated in these assessments; the faculty responsible for the course F, student self evaluation S, classmate peer evaluation C, team member peer evaluation P, the entire faculty of the department EF, and each project's industrial sponsor SP.

By incorporating multiple evaluations from multiple sources for each program outcome the likelihood for bias is reduced.

Table 1 Outcome assessment allocation to specific performance measures in Senior Design indicating those assessments that also have formative components and the source of the assessment.

Course artifact	Assed by	Formative	Number of measures	Program Outcome								
				c	d	e	f	g	h	i	j	k
Written Proposal	F	X	7			X		X				
Oral Proposal	S, C	X	10	X		X		X				
Written Progress Report	F		7			X		X				
Oral Progress Report	F, C	X	1		X							
Final Presentation	EF, SP	X	7		X	X		X		X		X
Final Report	F, SP	X	40	X		X	X	X	X	X	X	X
Peer Team Assessment	S, P				X							
Sr. Exit Confidence in knowledge	S		8	X	X		X		X			X
Sr. Exit Self efficacy	S		7	X	X			X		X		

For each of the rubrics developed for assessing Senior Design artifacts, the relevant program outcomes are identified. An example (Table 2) is the allocation of rubric elements to program outcomes for the assessment of the final written report. This is the most detailed rubric used in the course and illustrates that each outcome is assessed in multiple sections of the rubric.

Table 2 Outcome assessments allocated to elements of final written report **rubric.**

Rubric element	**Points**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
Executive summary / Abstract												
Problem definition	3					X		X			X	
Method/approach	3					X		X				
Result/conclusion	3					X		X				
Definition of Problem												
Defined problem in sponsor's terms and context	**2**			**X**		X						
Explicitly identified limitations and constraints	**2**			**X**		X						
Explicitly identified freedoms and resources	**2**			**X**		X						
Clear problem statement in	**2**			**X**		X						

technical terms												
Specific project objective and aims identified	**2**			**X**		X						
Methods/Approach												
Literature review	**2**									**X**		
Data collection	**2**		**X**									
Measures of achievement of objectives identified	**3**											**X**
Engineering modeling/analysis	**2**	**X**										**X**
Multiple alternatives	**2**			**X**								
Feasibility analysis	**2**			**X**								
Specifications/requirements	**2**			**X**								
Solution Concept												
Developed measures of problem solution effectiveness	**3**	**X**		**X**								
Solution optimization	**3**			**X**								
Description of features	**2**			**X**								
Manufacturability	**2**			**X**								
Sustainability	**2**			**X**								
Environnemental impact	**2**			**X**					X	X		
Social impact	**2**			**X**					X	X		
Political impact	**2**			**X**					X	X		
Ethical impact	**2**			**X**					X			
Health and safety impact	**2**			**X**					X	X		
Explicit consideration of total economic impact	**3**			**X**					X	X		
Global and societal context addressed	**3**			**X**					**X**	**X**		**X**
Plan for implementation	**3**			**X**								
Format/Image												
Attractive professional document	**4**							X				
Effective use of graphics	**3**							X				
Appropriate use of capitalization and punctuation	**3**							X				
Tables and Figures correctly formatted and used	**3**							X				
References cited correctly	**3**							X				
Appendices used appropriately	**3**							X				
Scientific Merit/Value to											X	

Sponsor												
Completeness of alternatives developed (breadth)	3			X								
Development of alternatives (depth)	3											X
Appropriateness of IMfgE tools selected	3											X
Effectiveness of IMfgE tool use	3											X
Appropriateness of assumptions	3											

Conclusion

The senior project experience in the Industrial and Manufacturing Engineering Department at Wichita State University evolves though continuous improvement. This paper presents a snapshot of the current course design. The key characteristics of an industrially based project that make it a learning opportunity are:

- Students are considered project team members and directors, and do not act as consultants or temps,
- Problem is loosely defined as opposed to the problem and solution pre-determined,
- Problem method is open as opposed to the project becoming performance based, required to follow pre-set steps and teams not allowed to design the method,
- Students see themselves as professionals responding to a messy issue with incomplete information, fuzzy objectives, and in the context of an economic, social, and political environment,
- Students are required to deal with a wide variety of issues and constraints, most of which are revealed only through active experimentation on their parts,
- Problem incorporate ethics, economics, and global issues, requiring students to demonstrate lifelong learning, and
- Activity is scalable providing good, highly effective students more than they can handle (force them to make effort allocation decisions) while less capable students have the opportunity to achieve success.

The capstone project in an engineering degree should be just that, a capstone experience providing students with the confidence to practice as engineers. These students should be more ready to contribute to their future employers in terms of both having the ability to synthesize their learning as well as the ability to perform on a team exhibiting the “soft skills” desired by many of today’s employers.

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Biographical Information

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Don Malzahn is a Professor of Industrial & Manufacturing Engineering at Wichita State University. He received B.S., M.S. and PhD degrees from Oklahoma State University. He has over 31 years teaching experience with research interests in engineering education, decision analysis, and project management. He has taught the capstone course for over 20 years and has been integral in its development.