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## **AC 2011-625: MISSOURI S&T ENGINEERING MANAGEMENT CAPSTONE SENIOR DESIGN: LESSONS LEARNED AND CHALLENGES TO COME**

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Stephen A. Raper, received the B.S., (1985) M.S., (1987) and Ph.D. (1989) degrees in Engineering Management from the University of Missouri-Rolla. Stephen graduated from Republic high school in 1978 and enlisted in the United States Air Force, serving 4 years and also began his higher education pursuits on a part-time basis. During his transfer enrollment visit to UMR, he met Professor Bernie Sarchet and quickly knew that he wanted to study Engineering Management. His experiences outside of the university and the military include an internship with Anheuser Busch, a faculty position at Sinclair Community College in Dayton Ohio, a developmental leave with Fru-Con Construction and Consulting Engineering where he was assigned to Mead-Johnson in Evansville, Indiana. He spent 9 months in Japan as a Japan Society for the Promotion of Science faculty fellow, and recently was the first faculty member to take a sabbatical leave in Wal-Mart Logistics organization. He has received outstanding advising awards, received the Merl Baker award, is a founding member of Epsilon Mu Eta, and also participated in the Missouri University System Presidents Academic Leadership Institute. He is currently an associate professor and the Associate Chair of Undergraduate Studies in the Department of Engineering Management & Systems Engineering.

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## **Abstract**

A more traditional, capstone senior design course was recently added as a requirement for Engineering Management undergraduates in the Engineering Management & Systems Engineering Department at Missouri S&T. The case studies course that had served that purpose was deemed to be insufficient for ABET accreditation purposes by department faculty. The most recent 2008 accreditation visit for the department verified this belief and caused the department to launch the new class earlier than anticipated to prove the class would be taught and that it would meet required standards. Thus, no weaknesses or concerns were noted in this area in the final ABET report.

This course has been offered for four consecutive semesters and has provided much useful information related to the departments overall curriculum and how it prepares students for entry into industrial work settings. This paper will discuss the development of the course, the challenges that were faced and will be faced as the course continues to develop, and lessons learned thus far. The paper will also discuss how department alumni can be essential partners in this process both in terms of identifying projects, and in assessing student strengths and weaknesses. Final conclusions will be offered that may be beneficial to other Engineering Management programs.

## **Introduction and Background**

Engineering Management as a discipline at the Missouri University of Science and Technology has followed somewhat of a unique path, championed by Professor Bernie Sarchet. This path began in the mid 1960's when the program was originally housed outside of the school of engineering. However, Professor Sarchet saw the need to develop the degree into one which could be accredited and allow graduates of the program to pursue professional engineering licensing and registration. Thus, the program was moved into the school of engineering, and the curriculum was developed such that it could be evaluated for engineering accreditation. The first such visit occurred in 1978 and the program received its first full 6-year accreditation in 1979. Subsequent visits occurred in 1984, 1990, 1996, and 2002 also leading to full 6-year accreditations.

As stated above, the program did receive the full accreditation, but that is not to say that there were not challenges and that changes to the curriculum were required due to recommendations made during the various accreditation visits. Under the old ABET guidelines, which generally looked at programs in terms of counting math, science and engineering design credits, curriculum changes were made. Also, suggestions for providing students more structure in terms of program options, lead to the development of five internal emphasis areas and the more traditional general engineering emphasis. The department and faculty felt "reasonably" good about the direction the program had taken thus far in its history. Although curriculum changes

had occurred over the years, there had not been any major threats that might have lead to any curriculum weaknesses or concerns as defined by ABET.

### **Curriculum Challenge**

As stated in the previous section, the engineering management undergraduate program did receive the full 6-year accreditation after each visit. There had been some ABET concerns noted, and those were addressed in an appropriate manner. However during the last three visits, the program evaluator would always look very closely at Criterion 5, and more specifically, the culminating design experience. In the engineering management program at Missouri S&T, the culminating design experience was addressed using a strategic management class that combined theory with case analysis. The instructor for the class would assign cases to teams and thus analysis of the case would occur. During the last three accreditation site visits, and prior to the 2008 visit, the course instructor would meet with the program evaluators, and would persuade them that the course met that particular criterion. However after the 2002 visit, and in reviewing ABET requirements from that point on, it was clear this course would no longer suffice as the culminating design experience. The department knew that this situation must be addressed. However, culture, location, personalities, history, etc., caused this to be a significant challenge.

The program had a long history of success, so the adage “if it ain’t broke, don’t fix it” applied here. Strong resistance to change for that fact alone was encountered any time discussion of developing and implementing a more traditional senior design course was made. Certain faculty were adamant in their view that strategic management and cases would address Criterion 5. However, they were not aware of the changing requirements of ABET, in particular driven by the original ABET 2000 criteria. Given that programs would now be evaluated based on objectives, outcomes, and evidence of continuous improvement, it was essential that the “capstone” course take into account real-world standards and constraints. Case studies, while useful, provide little information that addressed that particular need. In addition, because engineering management is a discipline that focuses on big-picture design rather than specific design, it was obvious that the program would have to work with industry partners in the development of projects suitable for students. This last factor amplifies the problem with the location of the Missouri S&T campus. The campus is situated in the middle of the state in a rural location with a very limited manufacturing base. Thus, the program would have to reach out and go to industry partners rather than bring problems into a laboratory environment.

The department knew a course which met ABET requirements must be developed and added to the curriculum in the form of a core, required course taken during the last semester. As stated above, significant challenges to development of this course existed. However, the department used the ABET requirements as the primary catalyst or driver for change.<sup>1</sup> The department relied upon the ABET constituent driven approach to overcome at least the cultural, personality, and historical barriers to change. There were several major changes to the core curriculum, including a more traditional capstone experience. These changes went through normal campus processes,

and were slated to be implemented in the Fall 2008 catalog year. The new capstone course was to be offered for the first time during the Fall 2009 semester. In other words, a promise to start the course in the Fall 2009 semester was made.

### **Fall 2008 ABET Visit**

As noted previously, the engineering management program had received the full 6-year accreditation each time the program was evaluated. As noted, minor concerns were cited and addressed in the appropriate manner. It was felt that the program was positioned to receive another 6-year accreditation after the Fall 2008 visit. With the promise to launch the more traditional senior design course, the department thought a potential weakness or deficiency in the program had been addressed. However, this was not to be the case. The initial report of findings from the program evaluator cited a weakness related to Criterion 3 – Program Outcomes because the program had passed only 3 of 11 outcomes, and that the program could expect a weakness for the capstone senior design experience, even though it was slated to begin in the Fall of 2009. The evaluator indicated that the team desired to cite the lack of a capstone senior design experience as a deficiency, but he convinced them to cite a weakness instead.<sup>2</sup> During the time between the issuance of the initial findings, and the final ABET report, both cited weaknesses were removed, and no concerns were noted. The department was able to collect more assessment data, and to launch the senior design course during the Spring 2009 semester in order to allow the ABET team to evaluate the output from the course.

### **Engineering Management Capstone Senior Design**

Engineering management is a “big-picture” type of discipline. The degree combines engineering, mathematics, science, business, and technology into one degree. Therefore, a culminating capstone design experience must seek to address big picture issues. This is very different from perhaps the design of a circuit or design of a gas control valve which are more typical for electrical and mechanical engineering students. Therefore to find design experiences that meet the needs of the program, industrial partners, and applications would need to be identified. The actual course description is as follows: “Open-ended design projects will be addressed with small teams. The emphasis will be on solving industry-based projects that are broad in nature and which will require the students to incorporate knowledge and skills acquired in earlier course work in the solution of the problems.”<sup>3</sup>

The main requirement for the course is for the students to work in teams on industry projects. Given the location of the Missouri S&T campus, and the previous acknowledgement that local opportunities for industry partnership would be limited, a significant challenge in the initial Spring semester 2009 launch of the course and in each of the semesters to date was present. The engineering management program knew it would be essential to find industry partners that are willing to allow access to their organization and be willing to allow evaluation of a “problem” that may or may not lead to a working solution.

Finding industry partners for other engineering management programs may not be so challenging. For instance the program at West Point Military Academy has ready access to military and government projects. Whereas Stevens Institute of Technology, and the University of Arizona have programs that have much larger industrial applications in close proximity to the campuses. The approach taken here at Missouri S&T has been and will likely continue to be reaching out to alumni that work in industrial settings and request their participation as industry partners. To date, the engineering management program has chosen not to charge a fee for companies to participate, which many other engineering programs on campus do require for participation. Of course if a fee is required, a potential industry partner may have higher expectations. In this case, it was more important initially to launch the course and demonstrate to ABET that the capstone experience would meet their expectations. Fortunately it did, and the program continues to reach out to alumni in seeking industry partners.<sup>2</sup> There may come a point in time that the program will choose to “sell” this service. But until that time comes and perhaps after, Missouri S&T engineering management alumni will play a leading role in capstone senior design experiences.

### **Experiences to Date**

The capstone course was initially offered in the Spring semester of 2009. Twenty three students, who were not actual graduating seniors, participated in this course. This was necessary as no legitimate Fall 2009 catalog year students were slated to graduate. The industry partner was a manufacturing facility, Invensys Controls, located in West Plains, Missouri. The approximate distance from the Missouri S&T campus and their facility was 100 miles. Kristen Beckmeyer was the key contact and department alumnus who developed the projects/problems for five teams. Her main goal in this activity, rather than find working solutions to the problems, was to make sure students experienced real world challenges and problems. In addition to plant visits by the course instructor and students, bi weekly phone conferences were held, a mid semester progress report was made via tele conference, and final presentations were made on campus. Invensys Controls also participated with one team during the Fall 2009 semester and four teams during the Spring 2010 semester. During the Spring 2010 semester, students teams were paired with plant teams that had been assigned problems based on lean/six sigma initiatives. Invensys Controls did not participate in the Fall 2010 semester even though a request was made. This was due in part to Kristen moving to a corporate position in Chicago, Illinois. Even though Missouri S&T alumni continue to work at the facility, their interest level in partnering was not as great as Kristen’s. This supports the notion that alumni contacts are essential in this type of activity.

During the Spring 2010 semester, another industry partner, Aerofil Technology Incorporated, a contract packager of aerosol, granular, and liquid products participated in the design experience. Aerofil is located in Sullivan, Missouri, a community approximately 44 miles northeast of the Missouri S&T campus. Greg Wilke an engineering management alumni worked with three student teams on projects in that facility. The relationship and approach was similar to that

encountered with Invensys Controls. Of particular note in this case was that student teams made final presentations to the entire facility during their bi-weekly “check-out” meetings. In addition, Greg asked to see dry runs of the presentations on campus prior to the site presentations.

Aerofil participated again during the Fall 2010 semester using two teams to work on the same assigned problem. It was further instructed that the teams were to work separately on their solutions. A third industry partner participated in the Fall 2010 semester, championed by a department alumnus, Eric Foster, a process engineering for Synergetics, Inc. Synergetics is located in O’Fallon, Missouri, approximately 105 miles northeast of the Missouri S&T campus. Three student teams worked on three different projects during the semester. Communications between the teams and partner were less formal, but a final presentation at the facility was required.

During the Spring 2011 semester, Aerofil is hosting two teams, and Synergetics is hosting one team. A new partner, Multi-Pack Atlanta, a contract packager located in Winder, Georgia, will host two teams. Winder, Georgia is approximately 700 miles away from the Missouri S&T campus. The American Society for Engineering Management has also asked for a team to analyze their business processes. No driving will be required in this case, but extensive documentation review and phone and personal interviews will be essential for the project. In the case of Multi-Pack Atlanta, student teams will visit the facility once with the course facilitator and all other communications and interactions will be handled in electronic fashion. Two department alumni work at the Winder facility and will facilitate the interactions between the teams and the company.

### **Lessons Learned and Conclusions**

The engineering management program at Missouri S&T has been successful to date in preparing its graduates for success once they leave academia and enter the professional workforce. Professor Bernie Sarchet’s decision to move the program into the school of engineering and to then seek accreditation might be the key reason for this success. Five consecutive successful accreditation visits helped to establish the legitimacy of the engineering component of the degree. ABET’s desire to “absolutely” require a culminating capstone senior design experience that included real world constraints and standards forced the program out of its comfort zone and broke through cultural and historical barriers and strong personalities that sought to maintain tradition. This breakthrough has illuminated several course operational issues, but also a significant broad curriculum issue that is fundamental to engineering management, more so than other traditional engineering disciplines.

Operational issues or things that one should do to run the course successfully for the benefit of the students and the industry partner can be offered based upon experiences to date. Certainly finding industry partners willing to participate is essential. This has occurred for this program, by reaching out to department alumni who are willing to allow access, and to establish

communications methods and processes. More to the latter point, some means of predictable communications must occur to ensure progress is being made and in a direction suitable to the industry partner. A lack of adequate communication lead to disappoint and frustration for both Synergetics and one of the student teams during the Fall 2010 semester. If an industry partner is in close enough proximity, then the teams must visit as frequently as necessary to collect information, analyze data, and in some cases, perform “rapid-experiments” which was the case at the Aerofil facility. In general, the industry partner must allow adequate access to the facility and information in order for the team to succeed. Conversely, the team must engage fully (visit, communicate, etc.) in order to find a solution to the problem. Lastly, the course facilitator plays a leading role in guiding the students, providing time lines, and in motivating the students.

The broad curriculum issue referred to above can be stated in the following manner or way: above all else, engineering management students should be critical thinkers that can apply a broad approach to problem solving in a wide variety of settings or situations. That is, the curriculum should prepare them to grasp a problem that lacks definition, get their hands around the problem, then deploy the tools and methods necessary to solve the problem. In working with the industry partners to date, the choice has been made to not explicitly define the problem, rather, state it loosely, and let the student teams develop the focused problem statement. The results to date have been mixed at best. Those teams which had more success had the common characteristic where at least one team member had coop or internship experience and had already worked on open ended projects and assignments. In general, the teams to date have not shown a great ability to define the problem and then work on an appropriate solution. This presents a challenge here in the engineering management program at Missouri S&T as compared to other engineering management programs. This capstone course is a one-semester course, versus a two semester course. In the two-semester course, much more time can be spent in defining the problem, understanding who the stakeholders are, etc. In a one semester course, this has to occur rapidly.

The statements might seem negative as far as the program is concerned, but in reality, they are pointing to a need for some type of curriculum revision to address the curriculum shortcoming. If the capstone course is to be considered the culminating experience, and is used to evaluate the skills and abilities of the students from several perspectives, then it clearly can be used as means for continuous improvement as required in ABET Criterion 4. In the case of the program here at Missouri S&T, another curriculum change will be made to the core set of courses. The program will be adding a course that addresses problem solving and critical thinking broadly. It is anticipated that the course will initially be offered during the Fall 2011 semester.

In conclusion, the development of a more traditional capstone senior design course was necessary as required by ABET. ABET provided the push and incentive for the program to overcome barriers which had delayed the development and launch of the course. The experience has also shown how alumni can play a leading role in establishing program and industry

partnerships. Lastly, the effort has pointed out that further changes to the curriculum are needed and will occur.

## References

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