A Need for Developing Continuous Improvement Plans for Capstone Project Management – Both Students and Faculty will Benefit

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Abstract

One of the most important shifts in engineering education, brought about by the adoption of the Accreditation Board for Engineering and Technology's (ABET's) Engineering Criteria 2000, is the framework of continuous improvement. Department-level self-evaluation narratives address using feedback to monitor and improve the education process and thereby improve the students' learning outcomes. Using this continuous feedback loop to improve the educational processes of a department is a great first step. The process of continuous improvement can, and should, be taken much further. Each faculty member of the department should use the process to improve their own skills as an educator. ABET's criterion 5 states that the "faculty must develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes." It is implicit in this statement that faculty members should take the next step and develop their own continuous improvement plans. Often this is more the exception than the rule. This paper presents the educational benefits of continuous improvement plans and uses Capstone project management as an example of how such a plan may be implemented. The following two questions are addressed: 1) How can faculty members develop their own continuous improvement plan to enhance their Capstone project management skills? and 2) How can faculty teach students to develop and utilize continuous improvement plans throughout a Capstone design project?

Introduction

Prior to the adoption of ABET's EC 2000 accreditation criteria, engineering programs were required to show that they were providing the proper curricula to their students. That is, to maintain status as an ABET accredited program, the program had to simply demonstrate that they were delivering the courses needed to provide the proper subject matter to the students. As long as the program presented the information, they could be accredited. It was not necessary to show that the students actually learned the material.

Under the EC 2000 requirements, the focus has shifted dramatically from the *just show us what you're teaching* paradigm. The 2004-2005 Criteria for Accrediting Engineering Programs requires processes to measure how well the students learn, processes to determine whether the alumni of the program have met expectations, and processes to use feedback to improve that quality of engineering education.

EC 2000 criterion 3 requires engineering programs to demonstrate that the students know or are able to perform eleven delineated sets of skills "by the time of graduation from the program." EC 2000 criterion 2 states that an engineering program must work with its constituents to define program educational objectives "that describe the expected accomplishments of graduates during the first several years following graduation from the program." Criterion 2 also states that the engineering program have in place "a curriculum and processes that prepare students for the achievement of these objectives and a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program." Moreover, and as mentioned above, EC 2000 criterion 5 states, "faculty must develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives [criterion 2] and outcomes [criterion 3]." It may seem a bit redundant that both criterion 2 and criterion 5 state that evaluation is required to "improve the effectiveness of the program." The difference between criterion 2 and criterion 5 lies in the audience to which each criterion is directed. In criterion 2, the program is directed to "have in place" …. "a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program." On the other hand, criterion 5 directs the faculty to take the responsibility for the evaluation process. "The program faculty … must have and demonstrate sufficient authority … to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes." Now depending upon whether one interprets the directive to the faculty to be an individual or group charge, the argument could be made that the evaluation requirements of criterion 2 and 5 are the different (the individual interpretation) or that they are the same (the group interpretation). For the purpose of this paper, the author chooses to adopt the individual interpretation. With this interpretation, the author will now pursue the impetus for developing an individual plan for evaluation of the efficacy of one's Capstone project management.

The first paragraph of the *2004-2005 Criteria for Accrediting Engineering Programs* states very emphatically that the main purpose of the criteria is to reform the engineering education community's way of doing business. ABET is attempting to "foster the systematic pursuit of improvement in the quality of engineering education." The criteria further, and quite importantly state the heart of any educational program is the faculty.

Background

In the past 10 years, there has been an increased awareness and use of evaluation procedures to gather data as part a philosophy of continuous quality improvement.[1] Puerzer and Rooney[2] list several universities as early pioneers (dating back to 1995) that have used survey instruments to obtain feedback about the quality of their engineering programs. There were generally two to three constituent groups surveyed at each institution. Benefield et. al.[1] surveyed alumni and industry constituents. Schneider and Neiderjohn[3] and Puerzer and Rooney[2] surveyed graduating seniors and alumni. Regan and Schmidt[4] surveyed alumni, graduating seniors, and incoming freshman. What is common about all the surveys reviewed is that their purpose was to gather feedback data for the improvement of an engineering program or entire engineering school. The improvements that can be made from this type of feedback are therefore at the department or program level or at the school level. The improvements will most probably be changes to the curriculum that is offered. That is, when it is deemed that the program outcomes or objectives

are not being met well, changes in the curriculum will be made. For instance, if a program learns that their alumni are not fairing well in their ability to function on multi-disciplinary teams, it is probable that a program-level change would be made in the curriculum – more interdisciplinary projects would be offered in the curriculum. It is intended that these changes will improve the outcomes and objectives of the engineering programs to better meet the criteria set forth by EC 2000. There is no implied intent that the individual faculty would necessarily be required to improve their delivery abilities. The question arises: Does this alumni and graduating senior survey feedback improve the quality of the educator or his/her ability to affect the students' attainment of outcomes and objectives? Or, does the feedback only affect the program curricula?

Motivation

The answer to these questions gives rise to the motivation of this paper. This author is not certain that program level changes have much effect on the quality of the individual faculty member's ability to enhance the outcomes and objectives of the program. In short, to this author, the answer is unknown. Probably one should not admit that they do not know the answer to one's own question, but not knowing the answer does provide motivation to investigate. There may be literature available to answer these questions. But this literature would probably answer the questions on an average basis and still not satisfy the author's desire to make an individual difference in the outcomes and objectives set forth for the students.

So the next question arises: How can a faculty member make an individual contribution to the continuous improvement effort of the program? That is, what can the individual do to improve the outcomes and objectives of the program? The answer is quite simple: Develop your own continuous improvement plan.

The answer may be quite simple, but the execution of such a plan requires much thought and (no pun intended) planning. There is, however, a wealth of literature about total quality management and continuous improvement to aid in the development of an individual's continuous improvement plan. One such example comes from a 1995 publication by Stedinger.[5] Years before the advent of EC 2000, in 1993 Stedinger employed total quality management (which included data gathering for continuous improvement) in a junior-level probability and statistics course at Cornell University. From this effort, he learned that "he was not teaching as effectively as he could, he did not really know how students learned, he did not appreciate what students were thinking, and he did not understand why he was teaching the way he did." He subsequently used this knowledge to improve his teaching efficacy. One of the main aspects of his paper was the discussion of "taking time to listen." Stedinger used weekly surveys to gather feedback about the course.

This paper will address how to use the ideas from both the program level alumni/graduating senior surveys and the individual level total quality management effort to develop an individual continuous improvement plan. The faculty member's role as a Capstone project manager will be the vehicle for the individual continuous improvement plan. The purpose of the plan is to positively affect the outcomes and objectives of the program by improving the delivery of the Capstone project management. There are many outcomes and objectives that can be affected by the delivery of a Capstone design course. To limit the scope of this paper, research of previous survey results has been performed. The results of these studies show that there are a few

outcomes and objectives that are much more "significant for engineers to be successful in the practice of their profession."[1]

Results of Other Survey Instruments

In 1997, Auburn University published results of a survey of 546 alumni who earned their bachelor's degrees in engineering between 1985 and 1994.[1] In the survey they asked alumni to rate how essential attributes were to be successful in the practice of their engineering profession. 16 different questions were asked, 5 or 6 of which were similar to the attributes in ABET's criterion 3. They also asked the alumni to rank how well the university had met their expectations in 25 different attributes. The study used the relative difference between the average reporting of the expectation and the importance of each attribute to identify the areas that needed improvement efforts. Table 1 adapted from Benefield et. al.[1] shows the five attributes rated with the highest importance, shown in descending order. The * denotes the attributes that were determined to need improvement based upon the difference in reporting between expectation and importance.

Table 1. Auburn University Survey Results on the Most Important Attributes Necessary for Success in the Practice of the Engineering Profession

Attributes of Importance
Ability to learn on their own
In-depth technical knowledge of the student's major engineering discipline
Experience in communicating technical information through written documents
* Experience in communicating technical information through oral presentations
* Experience using or ability to quickly learn existing software such as AutoCAD, Lotus, or dBase to solve practical problems

It is interesting to note that the experience in communicating technical information in written form was very close to the cutoff they used to determine areas that needed improvement. It is worth mentioning that they did not ask the alumni a question regarding whether their expectation of their *ability to learn on their own* had been met. Therefore, based upon the analysis technique, the *ability to learn on their own* attribute could not be deemed an area that needed improvement. It was, however, rated as the most important attribute indicative of success in the practice of engineering.

The Auburn study also surveyed 298 industry representatives to determine what attributes are needed for successful engineers. The survey found that the alumni and the industry representatives ranked the top 16 attributes in almost the same order of importance. In fact, the first four were ranked in the same order. Therefore, both the industry representatives and the alumni said that the *ability to learn on one's own* was the most important attribute of a successful engineer.

The Auburn University study was performed prior to the adoption of EC 2000's criterion 3 attributes and was a survey of alumni and industry representatives associated with a large university. Therefore, to gain another perspective, a second study was reviewed where the surveyed group was from a small engineering school and the survey was performed to measure the EC 2000 criterion 3 attributes. Puerzer and Rooney, from Hofstra University, published a study of the use of the alumni survey as an assessment tool for small engineering programs.[2]

In this study, the alumni graduating in classes ranging from May 1993 to December 1998 were surveyed. The aim of the survey was to determine the difference between the individual's perceptions of importance and preparation for each of the a-k criteria from EC 2000 criterion 3. They also added one additional criterion: *Your understanding of the business environment*. Rather than simply use averages to determine areas where they may need improvement, Hofstra employed a threshold technique to determine whether their graduates felt that they were over-, under-, or adequately prepared in each of the criteria. Using this technique and separating populations into electrical and mechanical engineering majors, they determined that there were two to four areas that required improvement. For the mechanical engineering program, Communication skills and understanding of the business environment needed improvement. For the electrical engineering program, in addition to those two areas, the need for life-long learning and the ability to function of multi-disciplinary teams also needed improvement. In fact, 35.7% and 42.9% of the electrical engineers felt under prepared for the multi-disciplinary team and life-lone learning criteria. Part of the difference between the electrical and mechanical engineering programs was reported to be the increased importance rating that the electrical engineering alumni placed upon the importance of the multi-disciplinary team and life-long learning criteria.

To gain additional insight, two additional studies were reviewed. These employed the surveying of students at the completion of their Capstone design projects. Marin, Armstrong, and Kays surveyed 44 students to determine the correlation between 6 factors and whether the "Capstone design project was an experience that substantially challenged them in a 'voluntary' effort to accomplish something difficult and worthwhile"[6], which the authors defined as an optimal experience. An important part of their work is to define the role of the instructor in helping the students achieve the optimal experience: "The goal of instructor mentorship is to design a learning experience whereby students can productively deal with the critical design issues they will face and to develop a mastery of these issues. The instructor has succeeded as a mentor when students take ownership of the design project."[6] They conclude their study by showing a strong correlation between the students' feeling of ownership and the view that the project substantially challenged them to make a voluntary effort to accomplish something difficult and worthwhile. The study is essentially asking the question, what is correlated with the ability of the students to learn on their own i.e. make a 'voluntary' effort to succeed.

Popov studied the effects of the instructor's role in improving the quality of student learning in the context of the Capstone design project.[7] The study attempted to measure the effects of a change in the instructor's management style on the quality of student learning. His aim was to "stimulate intrinsic motivation, encourage learner activity, and facilitate peer interaction." The methodology of the management change was to use group workshops and tutorials for the first semester, and group tutorials for the first two-thirds of the second semester of the Capstone design course followed by individual tutorials in the latter third of the course. In prior years, the author had "supervised the students individually during the whole life of the student project."[7]

Because the author had a very small sample size the main findings about the outcomes came from observations over the period of one whole academic year. He also assessed the outcomes with the use of a student feedback questionnaire with interview-type questions with the aim of adequately surveying the three areas of intrinsic motivation, learner activity, and peer interaction.

From the observations and surveys, the author reported that "the change in the way the project students were supervised led to a more independent approach to learning on behalf of them, despite the large number of group tutorials introduced."[7] Some, he reported, essentially benefited from peer interaction in their learning, which was explicitly encouraged.

Developing Continuous Improvement Plans for Capstone Project Management

At Western New England College faculty typically manage between 3 and 7 Capstone design projects each year. The engineering school is similar to Hofstra University in size and composition. The Capstone design projects Western New England College are mostly single semester, individual projects. This author's Capstone students, however, are an exception to that rule. In the past three years as a faculty member, the projects have evolved from individual, single semester projects to two semester group projects. A review of literature on the teaching of Capstone design courses[8] showed that a 36% of the projects last an academic year and 54% of the Capstone design projects were comprised of teams of 4 or more students. So, the trend of this author's projects is not contrary to Capstone projects of other engineering schools.

Drawing from the ABET's criterion 5 requirement which states that the "faculty must develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes." And from the literature reviewed above, this author proposes to develop his own continuous improvement plan in the context of Capstone project management.

The project management of the past three years has been similar to that of Popov prior to his change in management style. This year, however, the author has adopted a group tutorial approach similar to Popov's reported methodology. The deficiency of Popov's study was that there was no longitudinal study of the effects of his change in management. So the program objectives, measured by the accomplishments of the alumni of the program, have not been surveyed. The total quality measurement techniques employed by Stedinger suffer from the same lack of longitudinal data. Furthermore, the deficiencies of the program level studies are that there is not an easy way to tie the feedback back to an individual professor's management or delivery of a course or a Capstone project.

In this paper, the author is proposing that a *Continuous Improvement Plan for Capstone Project Management* be developed. The plan will use surveys the attitudes of the students at the end of the Capstone experience and surveys those same students at 1, 3, and 5 years after graduation. The survey will be a treatment of the a-k criteria as they relate to the students' experiences in the Capstone project. It is the opinion of this author that there are 5 main criteria that he can affect by Capstone Project Management style:

(i) a recognition of the need for, and an ability to engage in life-long learning
(g) an ability to communicate effectively
(d) an ability to function on multi-disciplinary teams
(c) an ability to design a system, component, or process to meet desired needs
(e) an ability to identify, formulate, and solve engineering problems

The opinion stems mostly from the overlap in the Auburn University and Hofstra University studies regarding the attributes or criteria deemed most important to successful practice of engineering. In both studies, communication skills and the ability to learn on one's own or the ability to engage in life-long learning were rated as the most important qualities of successful engineers.

The proposal of a *Continuous Improvement Plan for Capstone Project Management* includes using exit surveys to ask the importance of and perceived attainment of all 11 of the criterion 3 attributes. This will be followed by the 1, 3, and 5 year surveys that repeat the same questions. Two aspects of the study are of interest:

1) How do the answers to the questions and the difference between the answers change with time and further education?
2) Does using the feedback to modify management style affect the results of the initial exit survey and the relative change of those perceptions longitudinally?

A second portion of the proposal is to share the feedback with each year's present students to develop a continuous improvement plan for the Capstone project students. The idea here comes from the trite ad slogan: 'An educated consumer is our best customer.' In this case the consumer is the student whom we want to instill a greater sense of the need for life-long learning, ability to communicate effectively, etc…. The idea of the student in a parallel feedback path of the alumni survey is to provide the student another voice, one of a former customer who now has the experience as a practicing engineer. This voice may resonant more loudly and instill the passion for learning, communicating, working well on teams, etc…. that ABET and this author believe are important qualities for successful engineering practice. The management style to be employed here is to require students to review and summarize the feedback of the previous students, and thereby start their own continuous improvement plan.

Networking is an added benefit of performing small sample surveys of one's own Capstone design project alumni. The author has instructed his students that they will be able, through staying in contact with their Capstone project advisor, to be part of a larger network of students whom they don't personally know. They may, however, need each other at some point in the future. Swearengen et. al. states that "As outsourcing captures an increasing percentage of engineering work, engineers will become 'free agents' in a professional services market. Long-term employment at a single company may become an exception. Thus responsibility for career development shifts from employer to individual."[9] The network developed and maintained by staying in touch with one's former students may be beneficial to the students who find themselves in a sudden career change. The sudden career changes give further credence to the students' need for attaining the outcomes and objectives set forth by EC 2000 Criteria 3 and 2.

Summary

The requirements of EC 2000 and the subsequent EC 2004-2005 assessment measurements deem it necessary to survey the constituents of the engineering programs, including the students and alumni. The data from these groups is used in an effort to continually improve the quality of the education provided by the engineering program. This surveying effort is now a ubiquitous task

for all engineering programs desiring accreditation or re-accreditation. It is logical that surveys can be used to improve the quality of Capstone design courses and to help improve the attainment of the program outcomes and objectives.

Literature was reviewed to describe the background and motivation for proposing that faculty develop their own continuous improvement plans with regard to Capstone project management. Surveying the faculty's Capstone project students at the completion of their projects and at 1, 3, and 5 year intervals after graduation was proposed. Requiring current Capstone students to review and summarize the survey results was also proposed. The idea is to create a parallel feedback path to help the Capstone students develop their own continuous improvement plans.

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Biography

Dr. Steven G. Northrup has worked as an assistant professor at Western New England College, Springfield, MA for four years. Prior to his academic career, he worked as a design, production, and test engineer in the automotive electronics industry for seven years. His research interests are humanoid and mobile robotics, signal processing and control theory, and assessment of learning.