Enhancing the Undergraduate Engineering Curriculum: A Collaborative Process

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Abstract - This paper describes a process of reviewing and taking action to enhance an undergraduate engineering curriculum. It presents a number of issues associated with defining and implementing change while being sensitive to practical constraints. It addresses issues of organization, goal setting, data gathering and consensus building. Since the process of encouraging change may be more universally relevant than the specific elements of change, the goal of the paper is to outline a specific set of experiences which may be instructive for others.

Introduction

The challenge of undergraduate engineering curriculum review and change is one that faces all colleges and universities. There are many forces that motivate these activities. Curriculum change takes many forms. There are evolutionary changes that can occur within an individual course and these are typically instituted by the faculty responsible for the course. More significant changes in departmental, collegiate or university curriculum typically result from the activities of groups of individuals and in these cases it is often more difficult to choose new directions and establish new programs.

Changes in administration such as the appointment of a new Chair, Dean, or a Provost always brings to an academic community an opportunity for change whether this be a course, curriculum programs or facilities. In the lifetime of the academy, there are small windows of opportunity, which must be exploited to the fullest. In each instance these opportunities for change depend on the many factors in the local community, as well as the larger academic environment in which it exists.

At the University of Notre Dame, major university-wide curriculum reviews have occurred approximately every decade and recently these have not generally influenced the individual programs within the College of Engineering. With a somewhat recent appointment of a new Provost and the appointment of a new Dean, the College has been presented with a window of opportunity. This paper documents certain aspects of the process whereby the College of Engineering reviewed its undergraduate curriculum and began to institute the changes resulting from that review. It is hoped that by presenting in this forum a number of issues associated with this review that other institutions that will undergo a similar process may benefit from this experience.

Rationale for Change

It is an understatement that significant change has taken place in engineering education. At the end of World War II, engineering education moved from a technology base to a science base. This model was much like the German model of the late 1800's and early 1900's and was the result of the tremendous science and engineering knowledge base developed during World War II. This model ushered in a new era for universities with engineering programs. In many ways, it was the Golden Age, the beginning of our present electronic information and other technologies. Theoretical areas such as control theory, information theory, cybernetics, aeronautics, and others, developed quickly and flourished. The transistor was discovered and many other innovations appeared.

The ensuing paradigm for undergraduate engineering education served the country well for almost 40 years despite the ups and downs of funding and students. Through the 1980s, the many significant societal changes began to have a serious effect on the engineering education system. These included:

- End of the Cold War
- Continuing, swift technology growth
- Drastic changes in industry needs
- Expansion to a global economy
- Changing attitudes about higher education
- Changing attitudes and preparation of students

Each of these could have made a difference, but considered together they require serious reconsideration of the engineering education process. As a result of these influences, a flurry of studies were performed beginning in the '80's for both general education and engineering education. Many of the reports directed towards engineering education came from agencies such as the National Research Council, the National Science Foundation, ASEE, ABET and called for major changes in education. This has been followed by changes in the accreditation process, demands for assessment and
Rethinking of scholarship, and how it relates to the education process. A small number of these reports are cited in the References [1-10].

**Framework for the Process**

Approximately five years ago, the Engineering College Council at the University of Notre Dame (an elected faculty group representing all departments and chaired by the Dean) established a number of goals for the College and a significant number of the goals were related to the undergraduate engineering programs. During the ensuing years a number of changes were introduced into various departmental programs, but one might view these as fine tuning rather than major innovations. This may have been due to the fact that although there was an apparent need for more drastic change, there was no significant impetus for action. Much of this was due to the success of many aspects of the individual programs and demands associated with other important issues in the College and University.

As mentioned above, with the arrival of a new Dean, the opportunity and motivation to make more definitive changes was present. One of the new Dean's first steps was to form a Curriculum Enhancement Committee to review several aspects of the College of Engineering academic programs. He was particularly interested in targeting the First Year of Studies, the gateway to the College of Engineering at Notre Dame.

All undergraduates in their first year at Notre Dame are enrolled in the First Year of Studies - not in a specific college or department. They take courses in a number of areas; humanities, social and physical sciences and mathematics, as well as they have the opportunity to take a course or two related to their intended program of study. Upon completion of the First Year, they are enrolled in the college of their choice. College of Engineering intents have in the past taken the same sequence of courses regardless of their intended major and, as will be noted later in the paper, the goal of maintaining a First Year experience which would allow a student to enter into any of the programs in the College was an important consideration in this curriculum review process.

For the past fifteen years there has been a single three-credit course in the First Year taught by the College of Engineering in one large section with weekly small-group meetings. It introduced some basic concepts and contained a small design project. Most recently, the C language was presented and used and UNIX was introduced as the operating system of choice. A number of sessions were also devoted to MATLAB since that is an application language used rather extensively in many College programs.

Because students at Notre Dame are enrolled in the First Year of Studies, the College of Engineering has no direct influence on academic advising for first year students. The student's selection of a major is deferred by at least one year with the intention of providing them the chance to make more informed decisions. On the other hand, since the College of Engineering had very little influence on the First Year students (either by coursework or advising) there was considerable concern as to the effectiveness of the First Year experience for engineering intents.

The Dean also asked the Committee to consider how all of departmental programs in the College of Engineering could achieve academic distinction by any measure in the national community. Noting that Notre Dame is a national research university, the Dean was explicit in his recognition that teaching and research are both important elements to be acknowledged and totally integrated into both the life of the student and the life of the faculty member.

The Committee was appointed by the Dean and included a representative of each of the five departments in the College. Each of the members of the Committee was tenured faculty who had been recognized for their contributions to teaching, curriculum development and research. An Associate Dean of the College was appointed to chair the Committee. This group of six people appeared to provide good diversity of opinion, represent most of the College's programs, was small enough to allow for effective discussion, and large enough so no individual was overburdened.

The Committee embraced the challenge of defining and recommending innovation without disruption of those elements of the curriculum which were very effective. One additional daunting aspect of the charge to the Committee was that a report with a plan of action was to be prepared in approximately four months. This paper documents various aspects of the process whereby this Committee worked to meet these goals.

**Beginning the Process**

The Committee began its efforts with the beginning of the Fall 1998 semester. The group was brought together by the Dean, provided its charge, and its subsequent activities were coordinated by the Associate Dean who chaired the group. The Committee then established its own working rules and these are summarized below.

- Any issue or proposal was open for discussion regardless of its apparent feasibility.
- No constraints were to be imposed in terms of resources required to achieve the goals set forth. Proposals should be developed and put forward whether or not it appeared that resources would be available.
• Research into both effective and ineffective approaches tried in the past was required to insure that all approaches would be given consideration.
• Open discussion and candid interaction were encouraged.
• Members should represent their individual programs but set College goals above departmental goals.
• Members should not try to reach consensus outside of the Committee discussion or generally discuss recommendations prior to the completion of the Committee's report.

With the ground rules in place the first task was to establish a structure and set the goals for this committee effort. This required the group to focus their efforts and to establish a common perspective to begin the project. Since innovation and progress can have different meanings for different people, arriving at a collective understanding of the Committee's purpose was imperative.

One particularly effective tool used during the preliminary discussions was the whiteboard. Often the group was able to focus discussions and establish lists of important issues or items of concern during its earliest meetings by writing them on a board and organizing them using post-it labels. This was used to find common elements and identify conflicting ideas. These initial discussions of the goals resulted in the identification of four areas for Committee action. As was subsequently realized, the selection of these goals had a great impact on the remaining deliberations of this Committee. These were:

• Pedagogical issues in teaching innovation including information technology, experiential learning and support facilities.
• Means by which the entire faculty could be enabled and encouraged to support curriculum innovation including resources, time and leadership.
• Specific learning experiences that should be "targeted" for change, in particular the First Year, capstone activities and interdepartmental efforts.
• Methods of assessment must be established to evaluate the influence of proposed changes.

The Committee was tasked with establishing its own organization. As one might expect the simple issue of finding a common meeting time for six faculty was difficult considering everyone's teaching, travel and research commitments. This led to the situation of breaking the Committee into two subgroups. It was agreed that the subgroups of three each would take on two of the four major issues identified above. This turned out to be an important decision because it allowed those who were most interested or experienced in a particular topic to have the time to consider it detail. At the same time, the simple task of finding acceptable meeting times for the subgroups was much easier. The formation of subgroups also lead to other interest issues that are discussed below.

Establishing a Schedule and Data Gathering

The next step was establishing a timeline for the process. The Committee began to work in earnest the last week of August, after the fall semester had begun. It was agreed the Committee would have most of its fact finding and data gathering accomplished by mid-October. Subsequent to this fact-finding phase several weeks would then be devoted to formulating recommendations and drafting a written report to the Dean and College. The report was to be due to the Dean by the end of the calendar year. Due to the anticipated time associated with the process of review, approval and implementation of curriculum changes, this Committee was required to establish a plan and achieve consensus in less than four months.

A schedule was established at the onset with the deadlines indicated:
• Establish Committee Goals (by Mid-September)
• Collect Data (by Mid-October)
• Develop Curriculum Innovation Concepts
• Establish Specific Recommendations (by Mid-November)
• Achieve Committee Consensus
• Prepare a Report (by Mid-December)

Sources of information for the fact-finding phase were a variety of reports cited earlier, campus curriculum development specialists, individuals responsible for the First Year program, catalogs and web sites for other programs and personal contacts. There was also strong support from the Dean to visit any schools that were deemed necessary to gather supplemental information.

During the data-gathering phase Committee members were encouraged to exploit individuals or specific resources with which they were familiar. During this period there was much exchange of information and discussion via e-mail between all the members of the Committee. Comments and notes were exchanged on almost a daily basis, as information became available. This use of electronic, asynchronous meetings was very beneficial as it allowed members of the group to reflect on issues and write out comments for consideration by all the members of the Committee.

Since extensive changes in the First Year of Studies were being considered, it was prudent to evaluate a number of peer institutions, particularly those that had recently modified their First Year of Studies. Information from a
number of these sources was reviewed including the web sites of the various NSF Programs. Further, a number of documents prepared by NSF were reviewed. This proved to be very valuable in setting a certain tone for the way the Committee report would ultimately be written and the kinds of recommendations that would eventually come forward. The insight and experiences of other institutions were used to help justify the subsequent recommendations.

Finally, visits were made to several sites to review unique programs. Northwestern University was in the process of making some extensive changes in the way they approach their introduction to engineering. There was also interest in the development of new facilities to implement a learning environment. The University of Colorado, Boulder had recently developed a learning center for the Engineering College on that campus and two Committee members made a visit to that facility. While the information on the web sites was helpful, it turned out to be far more useful to make a personal visit as it provided better insight into the various issues associated with developing this facility and the effectiveness of the center now that it is in place.

Unfortunately, in each of these situations, it is difficult to extrapolate extensively, or copy programs that have been put into place in other Universities. One can only adapt ideas and thoughts to the unique situation within one’s own setting. Clearly, the gathering of data, though limited, was not selective to the point of only hearing the things that one wants to hear. Effort was made to establish a process that was open enough to put new thoughts on the table, and then, of course, to adapt them to the local situation.

During this period consultation took place at times with the Dean to keep him informed of the progress and issues of concern. This was not to imply that the Committee was not independent in its thinking, but it was essential that both the Dean and the Committee agree on the final recommendations so that he could act as the advocate for the recommendations. He would thus be able to provide resources and achieve support at all levels within the academic community.

The annual meeting of the College of Engineering Advisory Council took place during this period and presented another valuable source of information. These are individuals from outside of the University, most from industry, who have supported and provided counsel to the College. They too were used as a resource. The Dean made a presentation to the entire group in which he described his intentions regarding this effort. During the two-day period, two sessions of Advisory Council were scheduled. One was a meeting of the Committee with a subset of Advisory Council for a brainstorming session related to what they felt were important issues associated with undergraduate curriculum development at Notre Dame. A written summary of this session was prepared and distributed to all members of the Council and a second session was held on the second day with the entire assembly to discuss the conclusions and recommendations and to gather further input. After the meeting, the Chair wrote a summary of these discussions that helped provide additional guidance for the Committee’s deliberations.

Subgroups

The purpose of the subgroups, already mentioned, was to concentrate efforts in areas that committee members had the most interest and expertise. While this is an effective working tool, it also introduced certain problems. One of these is that at some point, the two groups would be required get together to explain what each is doing and to resolve any conflicts in goals or approaches as well as identify any overlap in perceived areas of responsibility. Maintaining the independence of the subgroups while still providing effective direction to the entire effort at times was a challenge, but there seemed to be no easy way of overcoming this working arrangement considering the time and scheduling constraints that were in place. The Chair frequently made notes of each of the meetings both from the large group, and the subcommittees, and shared this information with all, so that there was not only a record of work, but also a resource to fall back on in future discussions.

Preparing a Report

The writing of the report took on a life of its own and proved to be an extremely interesting and dynamic process. One could easily make an analogy with a trial jury, individuals who have some things in common, but also many differences, and must ultimately come to agreement and consensus on a decision. This too, was the case. Each of the two subgroups was asked to write independently a set of recommendations. Each recommendation was accompanied by a written rationale.

At this point in the process (mid-November), the groups came together and met as a full committee to discuss and review their individual subgroup recommendations. Each of the recommendations was discussed in detail to consider and assess the rationale behind each. This became an iterative process as they were rewritten and resubmitted two or three times using the above process of present, discuss and restate. In the meantime, the chair had written an introduction to the emerging report including some history and the justification of the need for change in order to put the entire process in context.

After reasonable consensus had been achieved on individual issues, it then became necessary to formulate a
singe document. Initially, this was achieved by simply combining the introduction and individual recommendations. It became apparent that greater structure had to be provided to effectively link and provide continuity for the complete document and this was accomplished by a "reorganization" of the recommendations.

With this revision in place (mid-December), the committee then got together to discuss this final form of the report. With a reasonably acceptable final draft in place, the task of achieving complete consensus became necessary. With the typical end-of-semester rush this became impossible to achieve and thus one of the initial goals of closure by the end of the year was not achieved. Thus, in January, at the start of the new semester, finishing the report became an essential task and turned out to be more time consuming than had been anticipated.

The final steps of the process began with a meeting with the Dean to discuss his thoughts on the draft. The Dean basically accepted all of the recommendations after discussion with the Committee. At this point it became apparent that to produce a final set of recommendations that had the possibility of acceptance at all levels within the community, extreme care and attention to detail would be required. An attempt was made to "leave no stone unturned" in preparation of the final form of the report. The committee then had five meetings, each three hours in duration, to go through the report, line by line, word by word to clarify amongst ourselves and for the potential readers, the recommendations and rationales in a concise yet thorough manner. With a laptop computer in the room at all times, changes were made on-line. It proved to be a difficult but very interesting process and the dynamic of six engineering faculty working on a report of this nature in this way, proved to be a great challenge. In almost all cases it provided each the opportunity to think through every issue and express their individual concerns. Since these were the individuals who would be responsible for explaining this report to their respective faculty groups, their individual understanding and acceptance was critical. Eventually, all became of like mind (either through exhaustion or sound reasoning). Certain issues were challenged, but consensus was ultimately achieved. It would be interesting to note that though there was general agreement with the draft document, it was only after extensive and detailed discussion that a true consensus was achieved. By the end of January the report was finished with the full approval of every point by all committee members and presented to the Dean.

As indicated earlier, the actual content of the report was not the subject of the current paper. Though process was the primary concern it is of interest to note that the final report contained four main sections.

- Introduction and Rational for Change
- Recommendation for the First Year Experience
- Development of a Learning Paradigm
- Issues of Implementation and Assessment

(Copies of the report would be available through this paper's authors.) It is important to note is how the final results were influenced by decisions regarding goals, schedule and Committee organization that occurred very early in the process. This should not be a surprising conclusion as this is the same dynamic present in many engineering projects!

After the Report

The Dean had already arranged to have meetings with the Provost and other officials at the University, including those in the College of Science to discuss the report. As soon as it was available, it was sent to these individuals so that they had an opportunity to review it before his meeting with them. Formal presentations were also made to the Dean's Executive Council (all departmental chairs) as well as the Engineering College Council of elected faculty and administrators. The report was distributed to all faculty members with a letter from the Dean indicating his support and a general faculty meeting was held in which the recommendations were presented and general discussion of issues took place. There were several important and constructive comments expressed in the open faculty meeting.

The immediate result of this activity was the appointment of a second committee to begin the process of developing the curriculum for two new engineering courses recommended by the committee for the First Year of Studies. These two courses will be taught as pilot courses in the coming academic year and are to be taught to all engineering intents in the First Year of Studies in subsequent years. In addition, the Associate Deans have begun meeting with officials in the College of Science to address issues resulting from other recommendations that influence course offerings in Physics and Mathematics.

During these initial discussions with the faculty and College of Science, one question was common: Why was there no direct consultation with faculty in both the College of Engineering and the College of Science during this process? With regard to the Engineering faculty, input was solicited from the faculty at large, but no direct discussion took place. In regards to the College of Science, no dialogue took place. In both cases this was a deliberate decision on the part of the Committee. It was the intent of the Committee to develop a set of recommendations, totally unbiased by feedback or the typical roadblocks which often appear when one attempts change in academia. The
committees evaluated the curriculum that was in place at this time, and given their experience in the College, it was felt that a significant discussion before a report was issued would be unproductive. The Committee's goal, with the support of the Dean, was to develop a plan and associated recommendations that provided the best academic program and then to begin the process of open dialogue to develop support and consensus in a larger faculty group.

Role of Administration Leadership

It cannot be emphasized strongly enough that leadership in this kind of endeavor is of the utmost importance. In this case, the Dean was completely supportive of the efforts and worked closely with the Committee. Though he did not attempt to bias the recommendations made by this group, by being part of the process he was able to establish an understanding of the goals and rationale necessary to champion the cause. This is important because it is through the Dean, that resources will come to the College to implement many of the recommendations. This is important, because the immediate action resulting from the report will be key in actually achieving change. It is not sufficient to put the recommendations on the table, but to see that they become implemented in an orderly and appropriate fashion.

As mentioned above, this process has begun. Since the First Year of Studies was one of the prime focuses of the committee's work, this effort is moving ahead. Much of the onus here is placed upon the individual departments working with the Dean to see that these changes are implemented.

Final Comments

This effort has proved to be fundamentally important for the College of Engineering. It has brought together a number of people across the spectrum of disciplines to cooperate in a collaborative and collegiate way. All are aware that the next steps in the process of change are most important. The Committee's role in encouraging willing and enthusiastic participation is critical. While as always there is some reluctance to change on the part of certain faculty, the fact is that most are in agreement with the recommendations and the rationale behind them. It is this aspect of the process that appears to be quite important and provides justification for the care and time taken in preparing the Committee report. It will be a combination of the College leadership, the effectiveness of the recommendations and the support of those involved in implementing the recommendations that will eventually determine if the College can meet the challenges ahead.

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References