GOOD EDUCATIONAL EXPERIMENTS ARE NOT NECESSARILY GOOD CHANGE PROCESSES

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Abstract *¾ Design, problem solving, and scientific discovery are examples of important processes for which engineers and scientists have developed exemplary process models, i.e., a set of widely accepted procedures by which these functions may best be accomplished. However, undergraduate curriculum transformation in engineering, that is, systemic change in pedagogy, content, and/or course structure, lacks a widely recognized process model. In other words, engineering faculty members do not widely and explicitly agree upon a set of assumptions and flow diagrams for initiating, sustaining and integrating curriculum improvement. The two-loop model that is described in conjunction with the EC2000 criterion (http://www.abet.org/eac/two_loops.htm) provides a flow diagram that integrates assessment, evaluation and feedback processes. However, the two-loop model does not provide a set of assumptions and flow diagrams for quantum actual change or improvement. To initiate discussion of models for the curriculum change process, hereafter referred to as change models, this paper examines three change models and advocates the organizational change model.*

Index Terms ¾ Curriculum change, educational experiments, change models, faculty change

BACKGROUND

Partner schools in the Foundation Coalition [1-3] have been initiating major undergraduate curricular restructuring efforts since 1988. (Note: In this paper, curricular restructuring and curricular change refer to changes in content, pedagogy and/or course structure.) Some efforts have created significant change at partner institutions; others have had less, though productive, impact at other partner institutions. For example, Rose-Hulman Institute of Technology, as a partner in the Foundation Coalition, has been offering an Integrated, First-Year Curriculum in Science, Engineering and Mathematics (IFYCSEM) to volunteers among the entering students since 1990 [4]. Although built upon several promising ideas and carefully assessed with promising results, IFYCSEM has not led to the scale of curricular change that was envisioned when it began. The purpose of this paper is to discuss underlying beliefs about how to initiate and sustain significant curricular change and relationships between these beliefs and success or failure in curricular change.

INTRODUCTION

Too many change efforts fail. In businesses, where more data is available, less than 35% of the change efforts produce enduring, significant change in the operation of the company [5]. Although much less data is available for academe, exchanged anecdotes among faculty suggest that the percentage of curriculum changes that produce enduring, significant change in undergraduate education is much smaller than the commercial sector success percentage. In engineering education, many faculty members point to changes made in response to the Grintner report in 1955 as the last change effort that had significant, community-wide impact. What is responsible for the high failure percentage among curriculum change efforts and what would improve the success percentage?

We believe that the slow rate of curricular change in higher education is due, in part, to the change models that provide the foundation for most curricular restructuring efforts. A change model is a set of assumptions and processes that guide the transition from an old curricular structure to a new curricular structure. This paper examines three change models. The first change model will be called the *current change model*, as it is model that is used by most faculty innovators. The second change model will be called the *espoused change model*, since it is the model advocated by many faculty and organizations that support of large-scale curriculum restructuring initiatives. As this paper will attempt to show, both of these models have significant problems. The third change model will be called the *organizational change model* since it is based on ideas from the discipline of organizational change. We propose that using this model in future change efforts may increase the probability, as detailed below, for success in generating systemic curricular change across the engineering education community. As described herein, two of the authors are involved in a current project at Texas A&M University that has used this model. Although the results are still out, they believe that the model will indeed lead to faster, lasting, systemic change.

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CURRENT CHANGE MODEL

The current change model describes the process by which faculty members in higher education currently go about changing classroom practice. It is based on the authors' informal observations of and discussions with higher education faculty. It reflects the culture of individualism and autonomy in higher education. The current change model consists of the following steps:

1. Recognize dissatisfaction with an element of their students' performance or participation levels
2. Do an informal search for a solution
3. Choose and implement one or more curricular or pedagogical changes to address the problem
4. Gather informal feedback on the success of the innovation, e.g., observing student reactions and asking for student comments
5. Decide whether or not to continue using the innovation, and if a decision is made to continue, decide how to modify the implementation
6. If the implementation seems effective, possibly attempt to disseminate this innovation through informal methods

The current change model is unlikely to promote widespread change for multiple reasons. First, it doesn't seem to incorporate sufficient scientific rigor to convince skeptics. Second, motivation for the change arises from the dissatisfaction of an individual faculty member with an element of student performance or participation. Other faculty, who do not have the same attitudes, beliefs and values of the individual faculty and who do not have access to the observations that convinced that individual faculty member, are not necessarily convinced about the need for change. Third, in this model the faculty member acts individually and research on the institutionalization of reform initiatives indicates that sustained change is more likely to occur when innovations are supported by a coalition of committed faculty, rather than the efforts of isolated faculty [6].

The slow rate of curricular change based on the current change model has encouraged some to advocate a different model that is based on the scientific method, the model we call the espoused change model.

ESPOUSED CHANGE MODEL

The espoused change model is based on the process model for all scientific discovery, that is, the scientific method. Faculty and many organizations that fund educational reform efforts (such as NSF) often express that this is the model that should be followed in curriculum restructuring efforts. However, like the current change model, this model has significant problems.

Curriculum change based on the espoused change model consists of the following steps: 1) conceive curricular change aimed at improvement; 2) pilot a new curriculum to test the idea: 3) assess and evaluate results; and 4) adopt if supporting results support change. The crucial underlying assumption in the espoused change model is that results from the pilot curriculum will convince other faculty members to change if the assessment and evaluation plan has been rigorously conceived and implemented and the results are sufficiently compelling. However, the espoused change model ignores at least five important elements in change: motivation, difference between ends and means, difficulty of replicating results, necessity of providing help and support for faculty who are willing to change, and the element of competition between faculty involved in comparative studies. Below, we discuss each of these problems.

First, enduring, significant curricular and/or pedagogical change requires people to change their behavior and, quite possibly, their values. Results of educational experiments, even when they establish the efficacy of an alternative learning environment, may not motivate a faculty member to change. For example, consider the assessment and evaluation of the structured active learning (SAL) approach in a freshman chemistry course at the University of Wisconsin-Madison [7-8]. It is difficult to conceive of a more carefully developed and implemented evaluation plan and the findings strongly suggest that the efficacy of the SAL methods. However, short-term anecdotal evidence suggests that these positive results did not motivate widespread change among faculty within that department. In short, scientific validity is insufficient to motivate people to change their behavior. As a contemporary example, the negative impact of smoking on health is well established, but millions of people have not quit smoking. In higher education, faculty members frequently cite lack of time, lack of reward, or insufficient knowledge of alternative learning environments as reasons for not changing their classroom management behaviors. In particular, faculty members cite the reward system in academe and its emphasis on research, often as measured by publications and grants in their technical specialty.

Second, education involves two distinct components: ends and means. Ends describe intended outcomes of educational experiences, for example, learning objectives, while means describe how educational experiences are constructed, for example, learning environments constructed of curricular and pedagogical elements aimed at facilitating achievement of objectives. Significant curricular change often involves changes in both intended outcomes and learning environments.

Educational experiments are often promoted as the key step in achieving educational change, however they are ill-suited to this task. Although these experiments may help demonstrate validity of means to achieve specified ends, they cannot assess the value of intended outcomes. Determining the value of intended outcomes, such as particular learning objectives and attitudinal goals, is a question of values and priorities [9]. As such, educational experiments have significant shortcomings when encouraging faculty to make significant changes in their pedagogical practices [10]. Hiebert [9] describes the relationship between research in mathematics education and the NCTM standards in the following way.

Standards are not determined by research. Standards in mathematics education, like those in other fields, are statements about priorities and goals. In education, they are value judgments about what our students should know and be able to do. They are chosen through a complex process that is fed by societal expectations, past practice, research information, and visions of the professionals in the field. The process is similar to the one that operates in selecting standards in other professional fields. Research can influence the nature of the standards that are adopted, but, in the end, research is not the sole basis for selection of the standards. Standards, ultimately, are statements about what is most valued."

As a result, it is not appropriate to use the results of educational research as the final arbiter for choosing educational practices. Educational research can inform the process of educational change, but ultimately, the individuals or community in question must establish intended outcomes as a matter of values clarification.

Further, in considering the value of educational experiments as a means to achieve curricular change it is important to note that even among well-defined departmental courses great variation in emphasis on particular intended outcomes can be found. Similarly, learning environments are considerably varied. Thus, when designing educational experiments to test the "efficacy" of the educational environments by comparing two versions of a course, it must be recognized that the intended outcomes and the means of achieving these outcomes may be different for the two versions of the course. Applying the espoused change model to curricular changes in which both learning objectives and learning environments are different requires significant thought and resources to establish a basis for comparison.

Third, scientists rarely accept the result of a single experiment, no matter how rigorously conceived and executed. Several researchers are generally expected to duplicate experimental results. Usually, scientists wait until the experiment and the results have been duplicated at several other sites. Since curricular restructuring is expensive and time consuming, it is difficult to duplicate curricular restructuring experiments and confirm results. Differences between schools prevent replication of curriculum pilots to test the efficacy of an alternative learning environment. Therefore, it is almost impossible to obtain the replicated data that is typically required for confirmation of results as in other scientific fields experiments. As a result, the espoused change model is unlikely to yield systemic change.

Fourth, results of educational experiments do not necessarily support a faculty member who is motivated to change, but uninformed. The focus of the espoused change model is the validity of the hypothesis that the new or alternative learning environment is superior. The focus is not on helping or supporting faculty who are motivated to change but may be uncertain about how the make the change. Some faculty may want to make changes in the learning environments that they create, but they are uncertain about how to proceed. They need advice, materials, suggestions and support. Since validity, not change, is the focus of the espoused change model, these support elements are often not provided to the degree required by the faculty member who wants to change.

Fifth, when conducting an educational experiment in which the performances of students of two teachers are compared it is highly likely that one teacher will look inferior to the other. Since faculty are intimately associated with the learning environments that they craft, it is easy to transfer preference between learning environments into preference between the persons that crafted the learning environments. Therefore, an education experiment may provide data that indicates one learning environment to be superior for a given set of learning objectives. However, the same experiment may, intentionally or unintentionally, disparage the efforts of the persons who crafted the inferior environment. This is a challenge inherent in the espoused change model and this phenomenon has the potential to create resistance to pedagogical changes that are the subjects of comparative experiments.

These five reasons illustrate why educational experiments, motivated by the espoused change model and elegantly conceived and implemented, may be poor methods for achieving change. In summary, ignoring the human element in change is the most important reason why curriculum change based on the scientific method fails to create significant, widespread improvement.

Schein summarizes the situation in another way. He states "For change or learning to occur we can state the following very general proposition: Anxiety 2 must be greater than Anxiety 1. Somehow I must reach a psychological point where the fear of not learning is greater than the fear associated with entering the unknown and unpredictable." In his model, Anxiety 1 is the "fear of changing, based on a fear of the unknown" while Anxiety 2 is related to the "uncomfortable realization that in order to survive and thrive I must change, and that unless I change and learn how to learn I will fail." [11] Establishing the superior efficacy of an alternative learning environment may increase Anxiety 2, but it does not guarantee that Anxiety 2 will then be greater than Anxiety 1.

ORGANIZATIONAL CHANGE MODEL

If the current change model (used frequently by faculty innovators) and the espoused change model (based on the scientific method) tend not to result in success in creating systemic change, what change model might lead to greater success? The authors suggest that a change model based on theories of organizational change may lead to greater success of curricular restructuring efforts. The organizational change model is based on the eight-step change model developed by Kotter [5]. The parallel steps advocated by Kotter for a business organization are shown in italics.

1. Establish need and energy for a curricular change (*Establish a sense of urgency*)
2. Gather a leadership team to design and promote the curricular change (*Create a guiding coalition*)
3. Define and agree upon new learning objectives and a new learning environment (*Develop a vision and strategy*)
4. Discuss the new objectives and environment with the college and revise based on feedback (*Communicate the change vision*)
5. Implement new curriculum using a pilot, if necessary (*Empower broad-based action*)
6. Conduct a formative evaluation of the program, investigating strengths and weaknesses of the current implementation, and indicators of short-term gains (*Adjust for growing pains and generate short-term wins*)
7. Decide how the new approach may be used for the entire college and prepare an implementation plan (*Consolidate gains and produce more change*)
8. Prepare faculty and staff for the new implementation, implement, and follow up with improvements (*Anchor new approaches in the culture*)

It is noteworthy that a similar set of change processes was identified by evaluators observing a major curriculum reform effort at UW-Madison in the mid-nineties [12].

As previously mentioned, two of the authors have been involved in a systematic curricular change effort at Texas A&M that is based on the organizational change model. Below, we discuss this process using the eight steps of the model as a framework.

Step 1. Establish need and energy for a curricular change 1992/93: Several faculty members are concerned about attrition of women, minorities, and other qualified students. Also, they are concerned about the quality of the first-year learning experience, and the less than desirable level of student retention of information from first-year courses as they progress in the curricula. They, with faculty members from other institutions, write a NSF proposal that is funded.

Step 2. Gather a leadership team to design and promote the curricular change 1993/94: Every engineering department, as well as the Physics and Mathematics Departments, appoints a representative to the team to discuss desirable new changes. Team representatives visit Rose-Hulman Institute of Technology to explore their integrated first-year curriculum.

Step 3. Define and agree upon new learning objectives and a new learning environment 1993/94: The team presents their idea for a new first-year experience in engineering to the executive committee of the college and the industrial advisors.

Step 4. Discuss the new objectives and environment with the college and revise based on feedback 1993/94: Based upon feedback from these groups, the team designs a pilot program, which also includes English, that is presented to the undergraduate advisors before being offered to incoming first-year students. Based on feedback from the advisors Chemistry is added to the effort. The advisors from four departments will select students for the pilot effort.

Step 5. Implement new curriculum using a pilot, if necessary 1994/1995: Pilot effort is initiated.

Step 6. Conduct a formative evaluation of the program, investigating strengths and weaknesses of the current implementation, and indicators of short-term gains 1994/1995: During the pilot data is collected on student performance. Evidence shows that the pilot effort was a success; however, the feedback from the Physics, Mathematics, and Chemistry Departments confirms that despite success the current pilot format would not be institutionalized due to prohibitive expenses.

1995/1996: New pilot effort is run to address the primary concerns of the non-engineering departments. Data from this pilot shows success similar to the first pilot. Some concerns about the ability of most faculty members to engage in this new learning environment are raised. In 1996/97 and 1997/98, Texas A&M repeats the 1995/96 pilot with minor modifications and involves several additional faculty members.

Step 7. Decide how the new approach may be used for the entire college and prepare an implementation plan 1997/1998: All of the engineering departments, and the Physics, Mathematics, Chemistry, and English Departments contribute a faculty member to a committee to review the first-year curriculum and to propose any changes that should be institutionalized in the first-year curricula. Only two members of this new committee were previously involved in the pilot efforts. This committee proposes and ranks five alternative implementations of a new first-year curriculum. Feedback is gathered from all of the departments and the College Curriculum Committee. A separate standing committee chooses an implementation and initiates appropriate catalog changes for all students who will begin engineering in the Fall of 1998.

Step 8. Prepare faculty and staff for the new implementation, implement, and follow up with improvements Spring/Summer 1998 and after: Several workshops that prepare faculty for the pedagogical techniques used in the new curriculum are provided for faculty in the engineering departments, and the departments of Physics, Mathematics, Chemistry, and English. (All engineering faculty members who will teach in the new curriculum are required to attend these workshops.) These workshops are institutionalized and offered every summer, for all faculty, whether or not they have taught previously in the curriculum. Improvements are continuing as the engineering college is introducing themes for first-year student cohorts in the 2000-01 academic year. The themes are hubs to which first-year concepts can be attached.

Underlying Assumptions

Deficiencies of the espoused change model have been described above. The underlying assumption of the espoused change model is that demonstrated superior efficacy of an alternative learning environment will motivate faculty to change. It focuses on the validity of the hypothesis, not on processes that will motivate people to change in the event that the hypothesis is proven. On the other hand, the organizational change model focuses on *changing people's attitudes toward ongoing curriculum change and equipping them to continually change*. Its focus is on people rather than validity. The organizational change model is derived from the change model advocated by Kotter, a pre-eminent researcher in the area of leadership and organizational change [5]. The organizational change model is not necessarily widely used in business but it is advocated as the model that has guided a number of successful organizational change efforts. Below, we discuss the rationale behind many of the steps in this model.

Discussion Points

In the organizational change model, the underlying assumption is that the need for change must be well established and nurtured before the rest of the change process can succeed. Thus, step 1 involves investing substantial time in establishing the need for change. There are at least three reasons why step 1 appears to be crucial in initiating and sustaining systemic change. The first reason is to prepare compelling answers to the question of why change. One of the prevailing maxims in engineering education is "If it isn't broken, don't fix it." Therefore, one of the first questions that many faculty members ask when presented with a curricular innovation is "Why change?" Often, faculty innovators working from the current change model are convinced that when they see the need for change, then the reasons that motivated their willingness to change will be sufficient to convince other faculty. Instead, the organizational change model suggests that time invested in establishing the need for change and building a sense of urgency for change will reap significant benefits in implementing the subsequent steps.

A second reason that step 1 in the organizational change model is important is the vital role that faculty play in the classroom. Faculty members need to be convinced that the innovations will work before trying them in their classes [13] because they have great potential influence on students' motivation. Faculty members are much less effective if they begin a class with a skeptical or experimental attitude about innovations that they are going to try. For example, if an instructor conveys an attitude such as, "I don't really think this is a good idea, but I'm going to try it just to see what happens," then it is reasonable to assume that students will pick up on the instructor's attitude and adopt a negative attitude toward these innovations. Thus, time should be invested up front to establish the need for faculty to change.

A third reason for step 1 in the organizational change model relates to changes in learning objectives. Once teachers are convinced about the value of changing objectives, they may spontaneously work to improve their learning environments. As argued above, efforts to convince people to change learning objectives cannot rely solely upon research.

As an illustration of the importance of step 1, consider the change in engineering education after World War II. Many engineering faculty members point to increased emphasis on mathematics and science as well as the development of the engineering sciences as the most significant change in engineering education during the twentieth century. Why did the change occur? As Grayson portrayed the situation, one reason was the widespread recognition of the need for change.

> *In spite of the success, involvement in the war revealed weaknesses in engineering education, particularly in electrical and electronics areas. The United States previously had depended almost completely on European scientific research to act as the source of ideas and principles for exploitation by the American industrial capability. When the flow of European scientific information was cut short by the war, American engineers reacted as well as they could. But the wartime demand for new and advanced knowledge in almost every branch of engineering and science showed the shortcomings of engineering education. While engineers made contributions to the development of ships, tanks, planes, and armament, it often was the physicist with advanced fundamental training who took the initiative in creating new devices and systems. It became obvious that in order to cope not only with the wartime needs but with the postwar problems and meet the changing technical needs of industry, new developments in engineering education were required. This stimulated a change from a strong emphasis on subjects that emphasized engineering practice to a stress on scientific principles underlying the technology. [14]*

Here experiences in World War II perceived through the eyes of engineering practitioners and educators established the urgency of change.

Step 2 in the organizational change model recommends forming a guiding coalition to shepherd the change process. Members of the guiding coalition should include faculty and staff who are convinced about the need for change as well as faculty and staff who are open-minded skeptics. Skeptics will be able to pose questions that challenge the need for the innovation and the process proposed for the innovation. Again, research on institutionalization of reform initiatives indicates that sustained change is more likely to occur when innovations are supported by a coalition of committed faculty [6]. Through these as well as other steps, the organizational change model takes into account the culture of the organization in which change is being promoted.

Step 3 recommends establishing new learning objectives. After objectives have been selected, educational research can indicate which of two learning environments will be more effective in achieving the selected objectives.

Step 6 in the organizational change model recommends formative evaluation and checking for short-time gains. By formative evaluation we mean evaluation for the purposes of helping the "formation" of a program. In contrast to summative evaluation, which is focused on documenting outcomes of fully formed programs, formative evaluation works to maximize the potential of curricular innovators through real-time feedback for use by implementers to adjust program elements. The LEAD Center at the University of Wisconsin has the following recommendations for formative evaluations. They advocate for the using

> *"a mixture of qualitative and quantitative methods in order to reach an understanding of a program and its impacts. Which methods are used in any given evaluation is influenced by what type of information or evidence will be most useful to our clients. With formative evaluations of pilot reform programs, qualitative data gathered through observations and interviews with program participants is often superior to quantitative data in allowing our clients to see exactly what works or doesn't work about their program--and why. In the less tightly-controlled contexts encountered in a real-world learning environment, quantitative (numerical) data may be useful in determining how much of an impact was made by a complicated network of factors or how many participants seemed to be affected by something in the surrounding context; however, these numbers do little to explain what actually happened in that context or why. This is where qualitative data, with its rich descriptions of contextual factors and their perceived impacts, becomes invaluable. In formative evaluations, qualitative data has the further advantage of providing greater detail about what needs to be done in order to make a program more effective. The average score on a given scale may tell the reformer whether a pre-specified and easily measurable goal has been reached, but it will not offer guidance on how that goal may be reached-or whether it is even worth reaching!" [15]*

CONCLUSIONS

This paper has presented three change models: 1) current change model; 2) espoused change model; and 3) organizational change model. This paper has argued that curricular change efforts based on these two models are unlikely to cause systemic change. The authors argued that the organizational change model would be superior to either the current change model or the espoused change model since it focuses on a process of building a coalition around a recognized need rather than efforts of individual faculty and/or the sufficiency or research data. Currently, the Foundation Coalition is studying its curricular change efforts and the authors believe that the results, based on the early evidence from the experience at Texas A&M, will indicate the superiority of the organization change model.

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