Curriculum Integration at Arizona State University

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Abstract

The freshman and sophomore integrated curricula developed at Arizona State University under the auspices of the NSF-funded Foundation Coalition are briefly described. The freshman program is currently in a second generation pilot while the sophomore program is in a first generation pilot. Problems encountered in designing and implementing such curricula are discussed as are possible solutions where they have been found.

Introduction

The most exasperating words in teaching, "Will this be on the examination?" carry with them a stereotype of the engineering student as one willing to acquire carefully-controlled and sequentially presented knowledge only if it will be of benefit in the short term. This stereotype can be extrapolated to the next level where the student memorizes information without fully understanding its relationship to other bits of knowledge that are acquired in other courses. Whether this is a completely valid stereotypical image is perhaps debatable, but those faculty who teach senior capstone design courses see an all-too-often pattern of students not being able to use, in new contexts, the knowledge they have been exposed to earlier in the curriculum.

Engineering education programs must cultivate new attitudes in students - educational programs can no longer afford to allow these stereotypes to be indicative of students. The vision of the engineering education for the next decade has to be the production of new engineers who, among other attributes, possess [1-4]:

- An enhanced capability to solve the complex problems of modern society as individuals or on teams,

- An improved ability to utilize appropriate technology,
- An understanding of the interconnectedness of all knowledge,
- A deep commitment to lifelong learning.

In order to produce students who have acquired these attributes, new curricula with new pedagogies will be needed. The integration of what is now considered to be disciplinary material must be at the heart of any curriculum reform effort. In addition, the educational experience developed must catalyze the talents and capabilities of all students, including previously under-represented groups, through immersion of students in active-learning environments using appropriate technology.

The concept of separating educational subject matter into separate and distinct discipline areas was first promoted by the NEA in the late 1800s and has since grown to where the different disciplines are the near-exclusive property of separate and somewhat self-serving departments that often compete against one another for resources. This atmosphere has led to the growth of barriers or walls between subjects, departments, and colleges within the university - even between institutions - that are now difficult to overcome when addressing curriculum improvements. These walls perpetuate the perception among students that each subject is unrelated to any others. With technology growing more complex with time, this separation of subjects has perhaps outlived its usefulness as the need for students to become more cognizant of the "interrelatedness" of all knowledge becomes more critical.

Curriculum integration is now a much talked-about concept in education; it is currently being tried in many elements of the K-12 system and to a lesser extent in higher education. The intent of curriculum integration in engineering education is to take the subjects that have traditionally been taught as separate entities, such as communications, calculus, physics, chemistry, and beginning engineering, and deliver them to students in a way that makes their interrelationships more obvious and their concepts better understood. Curriculum integration is one of the four thrust areas central to the Foundation Coalition's primary mission.

The Foundation Coalition is a union of universities, colleges and community colleges consisting of Arizona State University (ASU), Maricopa Community College District, Rose-Hulman Institute of Technology (RHIT), Texas A&M University at Kingsville (TAMUK), Texas A&M University (A&M) - the lead institution, Texas Woman's University (TWU), and the University of Alabama (UA). These seven institutions are working together to develop engineering curricula that incorporate curriculum integration, active learning strategies, and strong technology thrusts. The *Coalition* institutions offer a diversity of size, age, financing, dominating ethnicities and gender in the student body, and experience in educational reform - all requirements of the sponsor, the National Science Foundation Engineering Coalitions Program.

This paper addresses the ASU experiences and problems in designing and implementing its experimental integrated curricula. Both a freshman program and a sophomore program are currently being piloted. Faculty from the College of Engineering and Applied Sciences (Mechanical Engineering, Electrical Engineering, and Chemical Engineering), the College of Liberal Art and Sciences (Chemistry, English, Mathematics, Physics, and Psychology), and the College of Business (Economics) are involved in the design and delivery of these curricula.

The Foundation Coalition Models for Integrated Curricula

Several levels of integration can be achieved, beginning with just a well-coordinated set of discipline-specific courses and extending to a fully integrated mathematics-sciences-engineering-composition-humanities-social studies courses in which the boundaries of each discipline are seamless. The level required for significantly improving student capability in the desired attributes is a topic of research being explored at the current time.

A major part of the Coalition’s model for freshman engineering integration is the RHIT Integrated First-Year Course in Science, Engineering, and Mathematics.(IFYCSEM), a set of three, sequential, 12 credit courses which have been in place as an option for about three years [5]. The assessment data collected on student performance show that students who have participated in IFYCSEM demonstrate an improved level of cognitive ability; these data provided the basis on which the Coalition’s curriculum integration thrust was established. A smaller part of the Coalition’s model for freshman engineering is the ASU first-year engineering design experience [6]. This program has been required of all engineering students at ASU for many years and currently gives students exposure to engineering design in a highly computerized environment. The Coalition model for the sophomore program is the TAMU/NSF integrated engineering science curriculum [7].

However, for both the freshman and sophomore programs, each institution in the Coalition must accommodate the conditions that are unique to it in order to have any chance of achieving sustainable programs by the end of the Coalition funding period.

The ASU Integrated Program in Engineering

The Freshman Integrated Program in Engineering (FIPE): The ASU version of the Foundation Coalition’s freshman curriculum consists of 15 sem hrs of course work in each of two semesters. The new curriculum, like those of the other Coalition schools, was designed during the 1993-94 academic year and piloted during the 1994-95 academic year. A second-generation pilot is being offered during the current (1995-96) academic year.

The fall semester integrates English (3 sem hrs), calculus I (4 sem hrs), physics-mechanics (3 sem hrs), physics laboratory (1 sem hr), and introduction to engineering design (4 sem hrs). Although a student takes all 15 hours as more-or-less one large course, the faculty team that designed the program opted to stay with individual course numbers so that students would not be burdened later with having to explain what was in an all-encompassing, single identity course. The courses were formally scheduled so that the contact hours are all bunched together as shown in Table 1.

The second semester of the freshman year consists of English (3 sem hrs), calculus II (4 sem hrs), physics-electricity and magnetism (3 sem hrs), physics laboratory (1 sem hr), and chemistry (4 sem hrs) . This semester is scheduled in a time block identical to the first semester.

Faculty from the chemistry, physics, mathematics, English, and psychology departments join with faculty from the engineering departments of mechanical, electrical, and chemical engineering in teaching the FIPE curriculum. In the year prior to the start of the first pilot course, these faculty members met several times per week in planning sessions; once the first pilot had started, the faculty met for about two hours per week to consider the upcoming topics and make any last minute changes.

Although the time schedule gives the appearance of harboring a more coordinated set of courses than fully integrated set, faculty, during the design stage, decided to move material around within the overall boundaries of the time block so that it is delivered in more of a just-in-time (JIT) fashion. The formal course listing in each hour time slot was more for convenience in accommodating the University's infrastructure. A considerable amount of subject migration actually occurred, but not so much as to describe this as a fully integrated package.

A more important technique of integrating disciplines through the use of major projects was adopted early in the design of the package but was successfully carried out only in the fall semester of the first year of offering. Although this turned out to be highly effective, its use in the spring semester was severely reduced due to a number of factors. More information on the freshman program can be found in a companion paper [8]; more detailed information on the projects and other materials can be obtained in the World Wide Web at the URL http://www.eas.asu.edu/~asufc/.

The ASU Sophomore Integrated Program in Engineering (SIPE): Although the Texas A&M/NSF integrated engineering science curriculum has been taught at ASU for about three years as a pilot in chemical engineering, other departments have continued to ignore it as a possible core for their students. As result, the ASU sophomore design team had to work within the constraint that a major share of the engineering departments would accept the final product for students in their major.

The integrated program for first semester sophomores is being piloted at the current time, having been designed during the 1994-95 academic year. It follows a time block similar to the FIPE program and consists of ordinary differential equations, linear algebra, electrical circuits, mechanics, and micro/macro economics. The basic integrating theme for this package is "systems." The economics course significantly differs from typical micro and/or macro economics courses by being much more quantitative; for example, the course uses the calculus concept of rate of change to model economic systems. A spring curriculum offering will contain calculus III, statistics, and materials. At the current time programs in electrical engineering, industrial and systems management engineering, and mechanical engineering have opted to allow the package for students in their majors. Civil engineering is considering it on a case-by-case basis.

Faculty from the departments of economics and mathematics are joining faculty from the electrical and mechanical departments in engineering in delivering the pilot SIPE.

Has it Worked?

Since only one year's data on the FIPE have been collected, it is too early to provide quantitative data that demonstrate if there have been changes in student performance and attitudes. The program was unable to define a "comparable" group of students to track along with the FIPE students, until late in the year, thus negating the ability to make quantitative comparisons other than final grade distributions in courses. A more complete program of assessment is underway during the 1995-96 academic year.

In spite of the lack of good statistical data, the instructors in the program have stated that they could notice a marked improvement in student capabilities over students in the same courses they had taught in traditional formats. Except for first semester English grades, student grade distributions in the FIPE courses were superior to those in traditional offerings and student retention was considerably better. Thus far the results are very encouraging.

Problems and (Where They Exist) Solutions

Students:

The 1994-95 FIPE pilot had 31 students enrolled in the 15 hours per semester it contained. It is unlikely that this program will be sustainable at this class size because of the economic disincentive in terms of institutional resources required. This was realized from the outset, but the size was chosen for two reasons. First, a classroom facility with the necessary environment (technology, scheduling freedom, location, etc.) existed that would accommodate this size class. Second, the pilot course was viewed to be as much a learning experience for the faculty involved as it was for the students. Thus, until the faculty learn what is important and how to do it, scale up to larger sizes is premature. Misunderstanding the important features offers much more risk in the long run than does starting small (starting small does entail some risk because some faculty and many administrators prematurely associate smallness with the program and lobby against its continuation - early perceptions are hard to change).

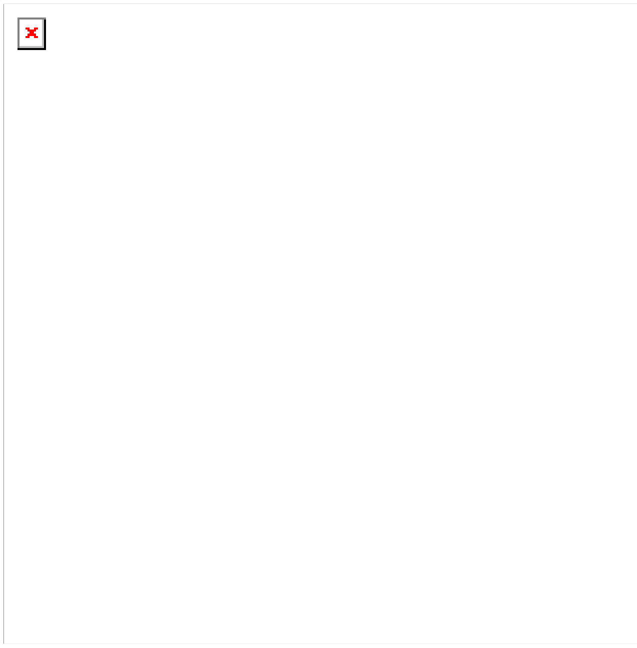
Because of the small FIPE pilot class size and the variety of differences between it and the traditional environment for students, it was important to collect student’s perceptions of the features the instructors thought might be important to retain when scale-up actually begins. To examine these perceptions, the students were asked to rate, on a numeric scale of 1 to 5 (1 was defined as *very detrimental*, 5 as *very important*), their feelings about these features. This data was taken on a survey form near the end of the second semester of the FIPE. Fig. [1] shows the features included in the survey and the average of the students’ ratings. Only five of the 17 features for which data were sought averaged less than a 4 (*important*) and only one of these, journaling (which was required), averaged less than a 3 (*neutral*). High in the ratings were modern technology issues, project-based learning, close association with faculty, and availability of the classroom for non-scheduled periods.

Class size was not an extremely important feature with the students, an evaluation which has not gone unnoticed. As of the present time the teaching faculty feel that this program can, given the proper physical facilities, be scaled to 60 students and perhaps 100. However, class size is an important issue for administrators and is discussed in a following section.

Physical Facilities:

It is difficult to prepare students for the modern workplace environment while teaching in traditional lecture halls with a blackboard and/or an overhead projector. The FIPE class is taught in a room that has, in the center section, eight, 3’ square tables, each of which accommodates a student team of four. Around the periphery of the room are eight tables, each holding one Mac and one Windows-based computer. Each of the latter tables is allocated to a particular team. Non-computer work is done at the square tables, but when the computer is needed, two of the students can swing their chairs around to the team’s computer table and the other two can roll their chairs the short distance to that table. This room has 26 sq ft of gross floor space per student (excluding table surfaces, this reduces to 18.5 sq ft per student) but is currently too congested for good movement by the instructor. The square tables have proved to be a bit small, and their sharp corners a source of constant student aggravation (not to mention damaging to the swivel chairs on rollers).

The SIPE is being taught in another type of experimental classroom setup. Team tables have been custom built (see Fig. 2) that allow a team of four students to interact at a table of 4’ by 3’ size.



Two team members sit along each of the 4’ sides. On the narrower ends of the table are 16" by 16" pads that hold computer monitors (two per table). Under each monitor pad is located the tower case that is the computer driving the monitor above it. Teams of two can each use one of the two computers, or all four students can observe either computer at their table. All computers are Windows-based machines. This room seats 40 students with 24 sq ft of gross floor area per student (excluding table surfaces, this reduces to 19.5 sq ft per student) and cost the University about $130,000 to renovate (almost half was for computer hardware).

Faculty:

It is important to have a critical mass of faculty who enjoy opening up their subjects and relating them to other fields of knowledge. However, this faculty attribute of being able to integrate their specialty is not enough. Faculty must also be able to work on teams with fellow faculty members and students, an attribute that is not necessarily "indigenous to the specie." At ASU, faculty have become a part of the Coalition program by a variety of methods. Some have joined the effort due to their own initiative based on personal interests and beliefs. Some faculty were sought out by their department chair after the campus project director visited the chairs on "recruiting" trips. Both of these methods have yielded successful results, but both can "backfire."

Recruiting beyond this small group of "maverick" faculty can become much more difficult. Plans for scale up must include getting more faculty involved prior to the time they might operate in the new environment entirely on their own. That is, many people should be involved as early as possible so that new recruits can observe successful methods in use.

It seems a fact of life that no matter how much planning precedes the offering of an integrated course, not all of the common points between disciplines get discussed and not all disciplinary language differences for common concepts are eliminated. There are many subject ties that become apparent only as they are being presented in the classroom.

The speed and level of integration achievable is greatly enhanced when instructors are present for parts of an integrated course other than their own. In the case of the ASU FIPE, it would require an instructors' presence for 19 hours per week in order to view the whole package, an impossible requirement considering the other expectations placed on faculty. But it is desirable for faculty to attend more than just their own time slots for teaching their material.

Another problem has been to keep faculty close to the edges of their comfort zone for teaching in the classroom, without forcing them over those edges. When they near the edge, they tend to retreat back inside their comfort zone and to revert to what they did in the traditional classroom. Well within their comfort zone, they may begin lecturing more, resort to fear as a motivator, rely on discipline-specific language which they had agreed to standardize, and give only discipline-specific contextual meaning to concepts. Doing what they have always done will most certainly yield the product we have always generated.

Advisors:

Advisors (whether they be faculty or staff advisors of students, but particularly faculty) are often difficult to reach in getting out the word on new curricula. At ASU this was particularly detrimental to the Coalition program in recruiting students for the first FIPE and first SIPE pilots from some departments. Fortunately, a considerable amount of the first FIPE pilot experience was captured on video. Advisors who viewed a 12 to 15 minute collage of these videos clips became staunch supporters for the second generation pilot.

Administration:

Support of the administration in the departments that should have faculty participating in the integrated program, as well as the upper administration of the institution, is crucial. At ASU the support has ranged from one chair's contribution of a faculty member without the need for release time support to a faculty member being "guided" by his chair through the comment, "I thought you wanted to make full professor before long."

Another potential problem is the "revolving door" on some administrative offices. This has not been a problem at ASU even though the College has its third Dean in the three years that the program has been running, and five of the department chairs (three in engineering departments) have changed. This is probably due to the fact that there are considerable Coalition resources associated with the curriculum design effort. Institutions that attempt to integrate subjects in the curriculum without outside resources may find that changing administrative faces, and thus priorities, cause major problems.

A real problem at ASU that is probably common to most large institutions is the variation of section size and staffing policies of lower division courses across departments. To get department chairs to agree on how the course(s) must be staffed so that cohorts of students can be taught together will be difficult. At ASU, freshman composition is taught by instructor- and TA-level people with student section sizes of no more than 25 (the FIPE program had to pay for a second instructor for its 31 students); calculus is taught by both instructor- and professorial-rank faculty with sections of about 45 students maximum; physics and chemistry are taught by professorial- rank faculty in lectures of 150 to 200 students and by TAs in smaller laboratories and recitations; and the engineering design course has been taught by professorial rank in lectures of up to about 400, and by assorted ranks in graphics laboratory sizes of up to about 50 and recitations of up to about 40. In the scale up that must eventually come, compromises between the departmental administrations involved must be reached, and that will probably necessitate some shifting of resources. Early indications are that this will be one of the more serious problems to be faced, although the upper administration has shown some initiative in helping to solve this problem from above.

It is interesting to note that as department chairs become more aware of the unique and innovative nature of the curriculum which their faculty members are developing, they tend to give the program more credibility and moral support, if not financial. Since the Coalition and the FIPE programs are addressing educational issues that are receiving more and more attention nationally, this credibility is hastened by the publicity the issues are garnering. For example, a chair of one of the departments that has participating faculty has now begun to tout this program as an example (one of the few) of the new and experimental things the department is doing to address needed reforms in education.

Many departments need and demand money for adjunct faculty/graduate students to teach courses that would otherwise be taught by participating faculty during the early experimental and implementation stages. This takes resources. Even though the FIPE had Coalition resources that could be used for this purpose, some of the departments with participating faculty soon realized that money allocated for this purpose was kept in the dean’s office and did not filter down to their local use. This "release time" concept is an important one during the early experimental and implementation stages since more faculty time is consumed in planning and offering courses to small pilot section sizes. Thus, getting money to participating departments has to be addressed at the very outset - it will be a problem in some colleges and not in others.

The "Tie that Binds" Administration and Faculty:

Last in this short list of "hot spots" are faculty reward systems. These systems must effectively put more emphasis on innovative teaching that contributes to the generation of desired student outcomes. Note that this is different from what is often a simple, if not traditional, emphasis on "good teaching." Although written criteria might be changed to reflect this new emphasis (which has been done in the Engineering College at ASU), crucial interpretations in applying these criteria are made at the faculty level. There is a difficult "species conservation" problem to solve when the "fox is in charge of the hen house." Solutions are still being sought in this area.

Summary

There are data that demonstrate that an integrated curriculum in which many of the ties between subjects are made clear, and the material being taught is applied in several contexts, produces more desirable student outcomes than does the traditional, modularized, "disciplinized" engineering education program. However, the culture in which curricula currently thrive and in which essentially all faculty have reached teaching "adulthood," is so strong that it is a major challenge to break its tradition. "Tradition is fine but sometimes it lasts too long," as Tevye said in the play, *Fiddler on the Roof*. This modularized tradition served students and employers well in the 1960s, ’70s, and ’80s, but the world has changed. There is a need to do better.

Members of the Foundation Coalition are making progress in changing this tradition as they refine their integrated pilot courses. Not only are they improving curricula on their own campuses, they are trying to solve problems that are common to most institutions and they will be producing teaching materials that can hasten the implementation of integrated curricula at other places.

Acknowledgments

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