Realizing the New Paradigm for Engineering Education

Proceedings

June 3-6, 1998
Omni Inner Harbor Hotel
Baltimore, Maryland

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This conference has been supported, in part, by the Engineering Education Centers Division of the National Science Foundation through Grant EEC-9802123.

Redesigning Engineering Education

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Abstract

In developing the PLAN, WPI sought to address concerns inherent to its then traditional curriculum that was rigid, unresponsive to differences among students, and was compartmentalized by independent departments so that intellectual growth was fragmented.

The PLAN was an entirely new and different educational program responsive to the needs of students and society while nurruring sensitivity to the ideas and values of our society. It included fundamental departures from the traditional elements of technical education including:

A. The achievement of competence rather than the accumulation of credits.
B. Individual freedom and responsbility in planning the program of study.
C. A large component of project and independent study learning.
D. Emphasis on education as a coopera tive venture between faculty and students.

Frequently, changes to engineering curricula involve the addition of new material to a well-established body of knowledge. Deciding which components to eliminate becomes the central issue in curricula reform. To adopt and implement the PLAN, the WPI community necessarily employed a more fundamental approach by focusing on learning rather than information transfer. Additionally, the PLAN has been a dynamic entity undergoing continual and substantive revision in the best spirit of continuous improvement. In the following sections the processes invoked in the adoption and revision of the PLAN by the WPI community are outlined in the hope they may help guide other faculties in embracing substantive revision.

Introduction

The impetus for curricular reform was faculty recognition that "the school didn't have goals for the future."` Debate in a faculty meeting led to the appointment of a planning committee that studied the matter and made reports over an eighteen-month period. This process involved students, faculty, administrators, trustees, and alumni and resulted in a plan, the WPI PLAN as it came to be known, which was voted by the faculty and adopted by the administration and trustees. The faculty vote was not unanimous; one-third of the faculty did not vote in the affirmative.

These same thoughts were echoed in "The Engineering Education Coalitions'" which traces the origin of the coalitions to the late 1980's when senior NSF managers sought to change the prevailing paradigm of engineering education to a comprehensive approach that focused on connecting and integrating curricular elements. The program aimed to establish curricula that would engage students in exciting and fulfilling studies and provide them with a strong foundation and the capacity for lifelong learning.

What WPI has learned as a community about implementing a "change in the prevailing paradigm" may be helpful at other institutions as the coalitions proceed in their efforts to challenge conventional thinking about engineering education throughout the US. What WPI has learned has also aided greatly in repositioning WPI as a broader comprehensive university seeking to define the kind of liberal education needed for the next century.'

Original WPI PLAN

The PLAN consisted of several principal elements along with assessment mechanisms. It was begun in 1971 when WPI was predominately an engineering school. The principal components were:

D Projects and Independent Study- approximately 25 percent of students' time would be spent applying theoretical knowledge to practical problems. It was envisioned, for example, that undergraduate students would work side-by-side with faculty members and graduate students at the frontiers of discovery.
D Internship Centers - students would conduct meaningful work in line with their studies in an industrial setting under the guidance of a faculty member.
Multidisciplinary Approach - combining the study of science and engineering with courses in the humanities and social sciences.
D Intersession - a concentrated time between terms during which visiting scholars would conduct seminars and short courses.
D Calendar - four terms each seven weeks in length plus a summer term.

The degree requirements specified that students must demonstrate competence by applying knowledge to unfamiliar problems. To this end, it was envisioned that each

student would pass a comprehensive examination and satisfactorily complete two advanced level projects (each the equivalent of a term's academic work or one-quarter academic year) and complete satisfactory studies in a minor field. By the time the first class graduated, the comprehensive examination had been implemented as a competency examination. Evaluation consisted of written evaluations of project and independent study work on an "acceptable" or "acceptable with distinction" basis. Competency examinations were administered by the appropriate disciplinary department and were strictly on a pass/fail basis. Problems were original and unfamiliar to students. Typically, students were given a few days to research and work the problem and prepare a written response, which was submitted to an examining committee, much like a thesis committee. Students were then given an oral examination and informed immediately whether or not they had demonstrated competence. Students were eligible to take the competency examination after successful completion of a minimum quantity of academic work. It could be retaken any number of times, but most students successfully demonstrated competence within four years. A few were successful after three or three and one-half years while some took longer than four years.

The structure of the PLAN included a number of significant departures from traditional engineering and science pedagogy. Students were given the freedom and the responsibility for their own courses of study in a non-prescriptive environment with a focus on outcomes. The curriculum was largely project-based with the projects drawn from the "real world." Students necessarily learned to deal with open-ended problems, to learn on an as-needed basis, and to take responsibility for their own progress. The PLAN dramatically increased the advising responsibility of the faculty and was believed to be more cost-efficient. The PLAN recognized that knowledge of human relationships and human need was as important to engineers and scientists as to liberal arts majors. Students were required to conduct substantive study in the humanities and (soon) would be required to conduct one of the project activities at the interface of technology and society. Finally, the PLAN was envisioned to substantively involve graduate students in the undergraduate program and to have undergraduate project activity intimately connected to graduate research. It was planned that the undergraduate student would not only experience multidisciplinary projects, but also would be partners in the excitement of a broad spectrum of collegiate life.

The WPI PLAN at Present

Three projects, distribution requirements and some ancillary elements constitute the present degree requirements. The projects and their principal outcomes are:

The Humanities "Sufficiency" Project, which measures whether the student has achieved a sufficient background in a self-selected area of the Humanities or Arts (for engineering and science students) to be likely to continue lifelong learning in that area;

The "Interactive Qualifying Project" (or IQP) which assesses the capacity of students to reflect on the impacts of science and/or technology on societal values and structures; and The "Major Qualifying Project" (or MQP) which measures the ability of students to begin working on open-ended professional problems at the level assumed of someone beginning professional practice or graduate school.

Collectively, WPI believes these three projects provide students with a learning environment where they have rich opportunities to achieve the goals' the faculty articulated in 1987:

> To lead students to develop an excellent grasp of fundamentals in their principal areas of study.
> To lay a foundation for life-long renewal of knowledge.
> To gain a mature understanding of themselves.
> To form a deep appreciation of the interrelationships among basic knowledge, technical advance, and human need.

Required projects form the core of the PLAN. The curriculum is designed so that faculty spend substantial time working with individual or small teams of project students in a cooperative environment.

First, the Humanities "Sufficiency project. The WPI faculty believe strongly that every student should attain substantive understanding of the humanities through study in a sequence of thematically related courses and project work. The experience was designed to allow students to acquire an understanding of how knowledge is obtained and expressed in a non-technical area. Students, with the support of advisors, select five courses where they must define a thematic or intellectual relationship for example, five courses dealing with aspects of history of science, or theater production, or creative writing. They conclude their sequence of study by writing, with a single faculty advisor, a final project wherein they conduct independent study and a critical or research essay (or original work or performance).

The Interactive Qualifying Project resulted from faculty concern that students needed to develop appreciation of the inter-relationships of science, technology, and society. The objective of the IQP is to enable graduates to understand, as citizens and professionals, how their careers will affect the larger society of which they are part. This project is the equivalent of three courses and is typically conducted in a small team setting under the guidance of one or more faculty advisors. Any faculty member can advise

any undergraduate(s) in this project activity. As such, the faculty, as a whole, clearly has ownership of the IQP and has developed an expectation that everyone ought to participate.

Interactive Qualifying Projects by definition are set in a societal context and are frequently pre-arranged with other organizations such as government agencies, museums, societies, and foundations. Students are expected to prepare a proposal, conduct background research, conduct the study, and prepare a written report. Students make frequent oral reports during the project and many make formal presentations at the project conclusion. The faculty advisor works with the project team throughout the project, finally reading and evaluating the report. Thus, the report itself is the outcome reflecting achievement of understanding of the interrelationship of technology and society in an instance, that usually has broad implications.

The three courses equivalence for the IQP is, in fact, one of the principal reasons WPI adopted a seven-week term basis for the academic schedule. Normally, students take three courses per term, but clearly can pursue the entire IQP in one seven-week term which provides opportunity for of campus project centers. Approximately one-third of WPI undergraduates take advantage of this opportunity to conduct their IQP's at established residential project centers in Washington, DC, San Francisco, Bangkok, London, Venice, Puerto Rico, Costa Rico, and elsewhere.

The final project-based degree requirement is the Major Qualifying Project (MQP). Our faculty wanted to be sure that the students demonstrate, in their major field of study, the application of the skills, methods, and knowledge of the discipline to the solution of a problem that would be representative of the type to be encountered at the beginning of one's career. Typically, small teams are formed to focus the project work on a topic offered by industry, the faculty, or the students themselves. Again, the course equivalence is three courses, but usually spread throughout the year. Both the advisor and students must be in the same discipline, although multi-disciplinary teams are frequently formed together with an advising group of faculty from the represented disciplines.

Students prepare a proposal delineating what, why, where, when, and how they will conduct the project. Frequendy, MQP's involve engineering design so that specifications must be developed, the design conducted, and demonstration of achievement must be made. In this case, oral presentations are necessary in the weekly team meetings and, often, at the project conclusion. The report, itself, is one of the outcomes reflecting the objective. Additionally, written and oral communications are demonstrated as are other desired elements such as teamwork.

In addition, students must satisfy Distribution Requirements, a Social Science Requirement, a Residency Re

quirement, a Physical Education Requirement and achieve a threshold amount of academic credit. For students of engineering, the Distribution Requirement results in one year of study in mathematics and science, one and a half years study in engineering science and design, and out-of-department study stems, etc.

Global Perspective Program

The global economy, fueled by scientific discovery, technological innovation, and instantaneous communication, has produced fierce competition for financial, material, and human resources. Scientists and engineers will be confronted as never before with problems whose solutions require technical expertise and necessitate an ability to understand and work effectively in cultures other than their own.

Ten years ago, WPI launched its Global Perspective Program to provide students an opportunity to pursue projects concentrating on global issues. Presently, there are 15 Global Project Centers where students and advisors pursue project activity. Predominately, the focus has been on Interaction Qualifying Projects but recently Sufficiencies and Major Qualifying projects have been added and plans are underway to include graduate activity as well. Approximately 25 percent of the undergraduate students have participated in this program during the past few years. This percentage is expected to increase to 50 percent during the next few years. WPI minimizes the cost of participating in this program by charging no additional fees, extending full financial aid, and requiring "project fees" from sponsoring agencies. Local organizers arrange housing, board and transportation with an eye toward economy and also arrange projects and sponsors as well.

Change Process

Reflecting on the process of change at WPI, the outcomes that were achieved include:

Academic program planning shifted from faculty to students.

Students create programs of study tailored to individual interests.

Prescribed sequences of courses eliminated.

Focus shifted to outcomes rather than subjects or courses.

Project-based curriculum motivates students to learn both in and out of classrooms.

Significant oral and written communications embedded in projects.

1 Emphasis shifted to learning rather than information transfer. Revised academic calendar to enable flexibil-

ity, off campus projects, etc.

Establishment of non-punitive grading system.

Encouragement of cooperative learning.

The curricular changes at WPI grew out of dissatisfaction with traditional engineering education and concern that institutional direction was lacking. The change process was driven by faculty through a committee structuree with administrative support. Since there are no schools at WPI, all faculty are involved in curricular change. Approximately two-thirds of the faculty ultimately voted to establish the WPI PLAN. In order to ensure successful establishment of the PLAN, an implementation committee was formed to facilitate the curricular changes. The "learning-curve" was very steep as the nature of projects was developed, as competency examinations were administered, and as academic advising matured. Initially, it was believed that the PLAN would be less costly than a traditional curriculum, but it was recognized that transitional costs would be significant. It is worth observing that faculty development was (and still is) an important component of the PLAN. To this end, numerous "retreats" and summer efforts were conducted to refine the curriculum, develop administrative procedures, and establish a strong advising system.

Outcomes

The WPI PLAN includes components which are inherently tutorial and time intensive for faculty. Courses, for the most part seven weeks in length, demand that students learn on their own and at a fast pace. Many students and faculty have initial difficulties with these formats. In recruiting faculty, WPI seeks individuals who can be comfortable with a non-traditional curriculum, who are openminded and adaptable, who are interested in the interrelationships of technology and society, and who are willing to spend a substantial amount of time in project and academic advising activities. Nevertheless, expectations for scholarly accomplishment and research productivity are high frequently causing a time allocation dilemma for faculty. Most faculty members successfully **find equlibria** which enable them to excel not only teaching in the context of the PLAN but also teaching graduate students and pursuing their research obj ectives.

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