Integrated, First-Year Curriculum in Science, Engineering, and Mathematics - A Ten-Year Process

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Abstract:

The Integrated, First-Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM) restructures first-year courses in calculus, mechanics (physics), engineering statics, electricity and magnetism (physics), computer science, chemistry, engineering graphics, and engineering design to create a three-course, twelve-credit-per-quarter sequence. Rose-Hulman Institute of Technology has offered IFYCSEM to a portion of the entering class since 1990. The present paper traces the process through which the IFYCSEM program has been developed and identifies ways in which the development process may have been improved.

Introduction

One of the most significant lessons learned during the IFYCSEM program is that the process through which new curricula are development, approved, and implemented are at least as important as the curricula which evolve, particularly with respect to dissemination and wider implementation. Faculty acceptance, appreciation for the broad impact of new curricula, and receptivity for future curriculum development all hinge as much on the process as the final product. Evolution of the IFYCSEM program has been described in [2] and [3]. However, the process will be reviewed here to provide appropriate background for the lessons learned.

Origin

During the academic year 1986-87 Brian Winkel, professor of mathematics, organized a series of seminars in the area of parameter estimation. With the support of a grant from The Lilly Endowment Inc., H. T. Banks, Department of Applied Mathematics, Brown University, visited the Rose-Hulman campus and led the seminars. Colleagues from a number of different departments joined the seminar: civil, electrical, and mechanical engineering; physics; mathematics; and chemistry. Encouraged by enjoyable, interdisciplinary interaction, Winkel, in November 1987, invited colleagues to meet and discuss how the first-year curriculum could be improved - both for students and faculty. It was in these meetings that concerns about student weaknesses and ways to address these weaknesses emerged. It was also in these meetings that the idea of combining eleven courses into ‘‘one big course’’

emerged. Since faculty seemed interested in pursuing these ideas, Jeff Froyd prepared a proposal to The Lilly Endowment, Inc. for faculty support during the summer of 1988 to develop a syllabus for a first-year curriculum which integrated topics in science, engineering, and mathematics.

During the summer of 1988 six faculty: Jeff Froyd, Electrical Engineering; Robert Lopez, Mathematics; Andy Mech, Mechanical Engineering; Mike Moloney, Physics; Ed Mottel, Chemistry; and Brian Winkel, Mathematics; developed a syllabus, basic building blocks, and themes. This group learned about each other's perspective and discipline as well as colleague's timing and teaching process. By the end of the summer a syllabus and vision of a new course, a new approach, a new culture of learning had emerged - the Integrated First-Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM). The vision, syllabus, and implementation mechanisms were presented at the 1988 Frontiers in Education Conference [1].

Faculty Approval

During the Fall Quarter of 1988-89 Froyd and Winkel presented the vision, syllabus, and implementation details to each of the academic departments. Presentations were also made to the Curriculum Committee and the Freshman Studies Committee. A motion to approve initial offerings of IFYCSEM was tabled by the Curriculum Committee. Then, a motion to approve initial offerings of IFYCSEM was brought to the Institute meeting in December 1988. In January 1989 the Rose-Hulman faculty approved IFYCSEM for implementation with 60 students in the first offering and then 120 students in a second offering when sufficient resources became available. Froyd, Moloney, and Winkel wrote three proposals to the National Science Foundation. ALL THREE WERE FUNDED for a total of $618,000. Further, a Rose-Hulman Presidential Commission of interested faculty was appointed for the year at the request of Winkel and Froyd. The Commission met throughout the 19988-89 academic year and addressed implementation issues, such as scheduling, course content, impact on student's major, and transfer arrangements. The Commission acted as a sounding board and support group for the infant concept of IFYCSEM.

During the summer of 1989 a faculty team of Jerry Fine, Mechanical Engineering; Jeff Froyd, Electrical Engineering; Mike Moloney, Physics; Ed Mottel, Chemistry; and Brian Winkel, Mathematics, supported by the first phase of NSF curriculum grant, proceeded to define the curriculum in more detail and work on rationale and selection criteria for a computer system. During the academic year 1989-90 Fine, Froyd, and Winkel were given one-third release time to develop curriculum ideas and make a final decision on the computer system. The three faculty devoted time to speaking at meetings about the planned curriculum, selecting and designing the classrooms to be used, and making the decision as to which computer system should be selected. The NeXT computer was selected in consultation with the Administration and Waters Computing Center. The Institute committed over $450,000 for 70 NeXT computers and room remodeling for two classrooms of the future. Moloney selected Zenith 286 machines for the physics lab ILI grant and began development of software and experiments at this time.

Initial Offering

During the summer of 1990 a second grant from The Lilly Endowment, Inc. supported five faculty members (Fine, Froyd, Moloney, Mottel, and Winkel) as they completed preparations for the new curriculum. Each faculty member then received one-third release time to offer the curriculum to sixty

students during the 1990-91 academic year. Over 200 students responded to a mailing inviting them to participate in the new curriculum. Sixty students (roughly one-sixth of the entering class) were selected to become the first IFYCSEM class based on overall academics with a special interest in high verbal SAT scores.

Sixty (60) students began the integrated curriculum in the fall of 1991. Twenty-three (23) students had switched to the traditional curriculum within the first six weeks (twenty students had switched within the first two weeks). Two students were added during the first three weeks and thirty-nine (39) students completed the Fall Quarter.

Several factors contributed to the massive switch. First, professors were overzealous and expected students to acclimate to a new computer environment too rapidly. Insufficient time (only a one-hour class period) was devoted to introducing the NeXT computer environment. Too many computer tools were introduced within too short a period of time. For example, both Mathematica and WingZ (a spreadsheet program) were introduced in the first two days of class. Students with little or no exposure to the use of computers were suddenly expected to use an unfamiliar computer to complete homework assignments; it was a frightening experience. Students were overloaded with too many things to learn about their new environment and the software applications which they would be using.

Second, the jump to more emphasis on problem formulation and problem solving was made too rapidly. For example, on the first day of class, students received a memo via electronic mail. The memo provided them with data which had been obtained from an experiment. It asked them to find a function to fit the data, extrapolate and predict behavior at a time point beyond where the data was taken, and write a report on their findings. For some students, the assignment was intimidating; many didn't know where to begin, and for those who did start, their lack of familiarity with the computer tools caused their efforts to end in frustration. Frustration and endless hours in the classrooms with the NeXT workstations quenched the initial enthusiasm and excitement of almost every student.

After six days of class, class was canceled for two days while students regained their breath and professors attempted to bring their expectations more in line with the knowledge and capabilities of the students. For many students, the pause was not taken quickly enough. They were uncomfortable risking their collegiate career on an untested curriculum.

By the middle of the Fall Quarter, students had become far more comfortable with their new learning environment. The professors, too, had adapted to teaching in a way that took into account the students' growing ability and confidence, as well as their fears and weaknesses. No compromises were made as far as integration and our basic philosophy were concerned. A number of compromises were made as far as pace was concerned. In spite of the early discontinuities in the schedule, and also some later slowdowns to give the students ''breathers,'' the planned amount of material was covered for the quarter, and indeed, for the rest of the academic year. Thirty-nine students completed the Winter Quarter, and all but one successfully completed the Spring Quarter.

The major complaint from students during the remainder of the academic year was the work load. Students perceived that regular homework, laboratory reports, examinations, and design projects were too much work. Professors worked to adjust the amount of homework assigned and the dates on which assignments were due, but comments about overwork continued throughout the entire year.

Parenthetically, it should be noted that two seminars were scheduled during the Winter and Spring Quarters to inform faculty about the initial implementation. Poor attendance diminished the impact of

these presentations and discouraged IFYCSEM faculty from offering additional seminars.

Succeeding Iterations

Seven faculty (Claude Anderson, Computer Science; Fine; Froyd; Howard McLean, Chemistry; Moloney; Mottel; and Winkel) worked during the summer of 1991 to review the lessons learned from the initial implementation and revise the curriculum for its second offering. Then, they offered the second implementation to 120 students during the 1991-92 academic year. These students responded to a mailing and were admitted on a first-come, first-served basis. Sixty-five students completed IFYCSEM in this second implementation.

With support from Lilly Endowment thirteen faculty (Frank Acker, Froyd, Electrical and Computer Engineering; Bruce Allison, McLean, Mottel, Chemistry; Anderson; Rick Ditteon, Moloney, Azad Siamakhoun, Physics; Fine, Wayne Sanders, Mechanical Engineering; Martin Thomas, Civil Engineering; and Winkel) worked on the third IFYCSEM implementation during the summer of 1992. The thirteen faculty would review the second implementation, prepare new homework problems, laboratory projects, and design projects which emphasized relationships among topics, and prepare the third implementation. Also, six faculty new to the IFYCSEM program would learn about the curriculum, its vision, and its experiences. The thirteen faculty did not produce as many interesting problems and projects as anticipated, in part because Froyd and Winkel did not communicate clearly expectations for the summer. Although only two of the six faculty would participate in the third implementation, all would be more knowledgeable and could share their information with colleagues.

Eight faculty (Anderson; Richard Ditteon, Physics; Roger Lautzenheiser, Mathematics; McLean; Moloney; Mottel; Wayne Sanders, Mechanical Engineering; and Winkel) offered the third implementation to 90 students during the 1992-93 academic year. (Sanders only taught during the Fall Quarter because he went on sabbatical for the Winter and Spring quarters.)These students responded to a mailing and were admitted on a first-come, first-served basis. Fifty-six students completed IFYCSEM in this third implementation.

Eight faculty (Anderson; Fine; Froyd; Lautzenheiser; McLean; Moloney; Mottel; and Winkel) offered the fourth implementation to 90 students during the 1993-94 implementation. These students responded to a mailing and were admitted on a first-come, first-served basis. Fifty-seven students completed IFYCSEM in this fourth implementation.

Eight faculty (Anderson; Froyd; Lynn Kiaer, Mathematics; Mottel; Michael Mueller, Chemistry; Don Richards, Mechanical Engineering; Jerry Wagner, Physics; and Winkel) are offering the fifth implementation to 90 students during the 1994-95 academic year. Four of these faculty members taught IFYCSEM for the first time. There was a considerable amount of learning that occurred for both faculty who had taught IFYCSEM previously and those who were teaching it for the first time. The veterans viewed IFYCSEM as a fluid, experimental program and were reluctant to share what previous implementations had done for fear of suppressing alternative suggestions from the new faculty. On the other hand the new faculty were anxious to learn what had been done previously so that they could use the experience of the veteran faculty as a starting point. Gradually, the disparity in approaches was worked out. In general, IFYCSEM was taught using the approach from the previous year. Students responded to a mailing and 94 students were admitted on a first-come, first-served basis. Fifty-nine students completed IFYCSEM in this fifth implementation.

Three of the new faculty from 1994-95 (Kiaer, Mueller, Wagner) will be teaching in 1995-96. Now with one year of experience, they are each working on ways in which the material taught in 1994-95 can be better integrated in 1995-96.

Improvements

There were at least two points in the process for greater faculty participation and consultation: 1) immediately after the initial grant and before the summer of 1988 and 2) the academic year 1988-89. Unfortunately, these opportunities were not well-utilized. In retrospect, these lost opportunities have cost IFYCSEM both valuable input and faculty goodwill. Once the initial grant from The Lilly Endowment had been received, a presentation should have been made to the entire faculty about the vision for the curriculum. Then, a group of faculty should have met during the academic year to lay the groundwork for the efforts of the six faculty who worked on course organization and initial syllabus.

After the six faculty had completed their work, presentations were made to each department, a dinner was held for all faculty during which the emerging curriculum was presented, and a Presidential commission was appointed to provide an external perspective. However, insufficient opportunity was provided to suggest changes in the curriculum. Although faculty were informed, faculty believed that they were provided with little or no opportunity to suggest changes which would be implemented. Since faculty believed their suggestions would not affect the prototype curriculum, they began to view the faculty who would offer IFYCSEM as a separate entity and a ‘‘we versus them’’ syndrome formed. As a result, a large segment of the faculty do not view the IFYCSEM program as a Rose-Hulman program, but as a program offered by a separate group of faculty.

For example, meetings with each academic department could have been structured to both elicit comments and develop responses. Documentation of the proposed curriculum was distributed in advance of the meetings. However, during the meetings no processes were presented to show how constructive suggestions would be used to help improve the proposed curriculum. As a result, faculty may have felt that they must either approve the proposal as presented or state that the proposal would not work. Therefore, some meetings with departments rapidly degenerated. Mechanisms must be provided to allow constructive feedback to improve curricular proposals.

Another resource which was inadequately utilized was the Presidential Commission. The commission was appointed at the request of Winkel and Froyd. These two faculty members talked to various faculty and asked the President to appoint faculty who indicated that they would be interested in serving on such a commission. The Commission met throughout the 1988-89 academic year. Although it was conceived in the minds of Winkel and Froyd as a mechanism through which implementation issues such as student transfer to another institution and scheduling, its charge was not clear. Many of the Commission members believed that they would play a more formative role. They anticipated that their input would impact the vision and structure of IFYCSEM. Instead, only implementation issues were considered.

In retrospect, more consultation with prospective members of the Commission should have been held to help formulate the charge of the Commission. At this point, the desire for greater input in the formation and structure of IFYCSEM would have emerged and the talents, experiences, and resources of the Commission members could have been more fully used.

Greater faculty participation may have changed the curriculum design and structure. For example, IFYCSEM may not have been offered as a sequence of twelve credit courses. Therefore, the ease with which topics were moved may have been decreased and the team teaching structure may have been eliminated. However, the IFYCSEM program may have received increased faculty support and ownership. A graphical representation of the possibilities may be helpful.

The trade-off between the magnitude of curricular change and the acceptance of new curricula by faculty appears to be inherent in the curriculum development process. Assume that magnitude of curricular change can be quantified by a scalar between zero and one which measures the distance between old and prototype curricula. Zero represents no curriculum change while one represents the most radical change imaginable. Also, assume that faculty acceptance can be quantified by a scalar between zero and one. Zero represents no faculty participation while one represents 100 percent active faculty support. If the two scalars are plotted on orthogonal axes, then a square is obtained. Certain regions of the square appear to be infeasible. For example, it does not seem likely that 100 percent of the faculty would actively support the most radical change imaginable. Therefore, the upper right-hand corner appears to be infeasible. Also, it is impossible to imagine curricular change with zero faculty participation. Therefore, a strip along the left-hand edge of the unit square appears to be infeasible. The size of the feasible region may depend upon the process through which new curricula are developed. Experience in the IFYCSEM program suggests that greater faculty participation should have been actively and vigorously sought at crucial points in the process.

Dissemination

Efforts to disseminate and broaden IFYCSEM implementation within Rose-Hulman were complemented by efforts to share the vision and experiences beyond to campus. The first step was to appoint an advisory board for IFYCSEM. Members of the advisory board were Dr. Ed Ernst, Dr. Mac VanValkenberg, Stephen Case, Dr. Carl Erdman, Executive Associative Dean at Texas A&MUniversity; Dr. Tom Davis, Dean of Engineering, Milwaukee School of Engineering; Dr. James Spain, Chemistry, Clemson University; Jim Harris, EE, Cal Poly San Luis Obispo/NSF. The advisory board met twice. Each time the board reviewed implementation details, results of the evaluation processes, met with students, and offered improvements in implementation.

It was through the advisory board that Carl Erdman extended an invitation to Rose-Hulman to meet with and join a group of schools who were in the initial stages of preparing a proposal to the third round of the National Science Foundation's Engineering Coalitions program. Rose joined the effort and became a member of the fifth engineering coalition. The Foundation Coalition consists of seven schools: Arizona State University, Maricopa Community College District, Rose-Hulman Institute of Technology, Texas A&MUniversity, Texas A&MUniversity at Kingsville, Texas Woman's University, and the University of Alabama. The Coalition will create a new foundation for engineering and lifelong learning. Initially, the Coalition is focusing its energy on the first two years of the engineering program. In 1994-95, all member schools are offering prototype first-year curricula modeled upon the IFYCSEM program and the  program at Drexel University [4]. These efforts will provide models of integrated, first-year curricula at diverse types of institutions. In 1995-96, member schools are offering prototype second-year curricula which build upon the new engineering science core at Texas A&MUniversity [5]. In subsequent years, these prototype curricula will be refined and expanded while new upper division curricula are created which build upon the new foundation laid in the first two

years.

In addition to the advisory board, presentations about IFYCSEM have been presented at Frontiers in Education conferences, ASEE conferences, and the joint MAA/AMS meeting. Numerous schools have either visited Rose-Hulman or invited Rose-Hulman faculty to their campuses to learn about IFYCSEM. In June 1994, a workshop was held in Estes Park, Colorado in which 75 faculty from 32 schools either shared or learned about integrated curricular activities across the country. A second workshop was held in July 1995 on the Campus of Wagner College. Here, 27 participants shared details of the integrated curricula which were being offered at their institution. In addition to presentations, participants developed integrated problems, discussed curriculum development and assessment processes, and shared mechanisms through which information about integrated curriculum could be more readily disseminated.

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