Evolution and Evaluation of an Integrated, First-Year Curriculum

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Abstract - *Rose-Hulman Institute of Technology is planning to offer a new first-year program for all entering students in the 1998-99 academic year. The new first-year program will build on seven years of experience with the Integrated, First-Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM). In IFYCSEM, faculty integrate topics in calculus, physics, chemistry, computer science, engineering design, engineering statics, and engineering graphics into a year-long curriculum which emphasizes links among topics, problem solving and teams. These faculty have pioneered innovations in the areas of curriculum integration, technology-enabled education, cooperative learning, and continuous improvement through assessment and evaluation. Rose-Hulman's experience has helped encourage other institutions to offer prototype first-year curricula modeled upon IFYCSEM. These institutions include Rose-Hulman's partners in the Foundation Coalition: Arizona State University, Maricopa Community College District, Texas A&M University, Texas A&M University at Kingsville, Texas Woman's University, and the University of Alabama. The paper will summarize goals of the curriculum, structure of the curriculum, significant innovations, student perceptions of the curriculum, summative assessment data, evolution of the program through formative assessment and continuous improvement, impact of IFYCSEM beyond Rose-Hulman, and development of an Institute-wide first-year program.*

IFYCSEM Goals

Rapid changes in our globally interconnected society, exponential growth of the knowledge base, increased emphasis on cross-disciplinary teams, and increased availability of computing hardware and software require more productive learning and teaching processes. Recognizing these imperatives, the Integrated, First-Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM) has focused on three new characteristics for graduates:

1. an integrated knowledge base emphasizing links between disciplines,
2. improved problem-solving strategies, and
3. enhanced ability to work and learn in teams.

Faculty as well as students must develop these characteristics.

Why is an integrated knowledge base necessary?

Chasms between disciplines are caused by differences in notation, terminology and emphasis. These chasms encourage students to perceive topics as isolated compartments. As a result, they place new instances of the same concept in different boxes with different names. Increased effectiveness and efficiency in the learning and teaching processes require that faculty help students 1) bridge gaps between disciplines and 2) build an interdisciplinary mindset.

Why do we need to improve student problem solving strategies?

Three trends: 1) increasing availability and power of computing hardware and software; 2) increasing demand for improved higher order thinking skills; and 3) increasing demand for design and problem solving processes, require graduates with improved problem solving strategies. Traditionally, first-year courses in science, engineering, and mathematics emphasize mastery of common manipulations. Students lose sight of learning as they become enmeshed within the details of these manipulations. Today, inexpensive hardware and powerful software can perform routine manipulations. Discipline-specific innovations such as calculus reform and first-year engineering design courses have demonstrated value in shifting emphasis to conceptual understanding and problem solving. Faculty, together with students, must change emphases across the spectrum of first-year courses to use computer hardware and software as learning facilitators.

Why do students need to work and learn in teams more effectively?

Companies have empowered cross-functional teams to develop and implement strategies to tackle difficult problems and implement continuous improvement. In academia, researchers have demonstrated the effectiveness of cooperative learning strategies. For instance, study groups have been shown to be effective in improving the retention and performance of women and minority students. Similarly, faculty who have taught IFYCSEM have discovered the value of students learning in teams as they tackle difficult problems and work to build connections. In addition, teams have provided a more supportive learning environment. Therefore, graduates must become more effective in learning and working in teams.

IFYCSEM Structure

IFYCSEM is a sequence of three twelve-credit courses. (Rose-Hulman is on the quarter system.) These courses integrate required topics in the courses shown in Table 1.

Table 1: IFYCSEM Topical Content

Course Description	Credits
Calculus I, II, III	15
General Chemistry I, II	8
Physics I, II	8
Computer Programming and Problem Solving	2
Engineering Design	2
Engineering Statics	4
Engineering Graphics	2
TOTAL	41

Students are prepared to enter any major in their sophomore year. Typically, an eight-member interdisciplinary faculty team offers IFYCSEM to ninety students in three sections.

IFYCSEM Innovations

Five of the most significant innovations which IFYCSEM has pioneered at Rose-Hulman are listed below.

1. IFYCSEM has developed a year-long curriculum which successfully integrates concepts across calculus, mechanics, engineering statics, electricity and magnetism, general chemistry, computer science, engineering graphics, and engineering design. An interdisciplinary faculty team has developed and revised the curriculum.
2. IFYCSEM has developed a positive and flexible learning environment which emphasizes continuous improvement through student-faculty interaction and assessment. Student-faculty interaction is facilitated through a faculty team working throughout the year with a cohort of students, an elected IFYCSEM council which meets bi-weekly with faculty, and plus/delta feedback.
3. IFYCSEM has developed a supportive learning environment through cooperative learning, team training, team projects, sophomore mentors and base teams (teams which exist throughout the entire quarter for learning as well as support) [24].
4. IFYCSEM has helped faculty and students integrate and unify concepts across disciplines.
5. IFYCSEM has helped pioneer learning environments in which students have routine access to computer workstations and software.

Student Perceptions

While in the program, IFYCSEM students report that they feel that they work harder, get less sleep, and have less time for extracurricular activities than the students in the traditional curriculum. They also report they feel that they have: been better prepared for the sophomore year, learned more material in their first year, developed better organizational skills, better oral communication skills, and greater ability to work in groups.

Summative Assessment[1]

All of the students who have participated in IFYCSEM volunteered. To compare IFYCSEM student performance with that of students who take the traditional curriculum a statistical technique, cluster analysis, was used. This technique matched students from the traditional curriculum with students who completed IFYCSEM on characteristics which included: cumulative grade point average at the end of the first year, predicted grade point average, SAT scores, Force Concept Inventory, Mechanics Baseline, Learning Environment Preferences test, and parent’s education. The office of Institutional Research and Assessment has tracked performance of both groups starting with their sophomore year. Comparison data include grades, persistence at Rose-Hulman, faculty assessment of student attributes, and post-testing at the sophomore and senior levels on selected performance and attitudinal characteristics.

Comparative Performance: Retention and Grade Point Average

Overall, summative assessment data show that students who **complete** the IFYCSEM program do significantly better than the students in the matched comparison group both in persistence at Rose-Hulman and grade point average in upper level courses. As upper class students, they were rated more highly by faculty in the areas of their communication skills, ability to integrate the use of technology for problem solving, ability to develop their ideas to appropriate conclusions, and ability to integrate previous knowledge into their current work. The following tables show persistence and grade point average (GPA) for

[1] Summative assessment describes collection of data for the purpose of evaluating the impact of a program.

all of the cohorts (both IFYCSEM and comparison groups) to date. The year in the top row refers to the year in which students entered Rose-Hulman. GPA data on the entire Rose-Hulman student body is provided for reference.

Table 2: Retention after First Year - IFYCSEM and Comparison Groups

First Year COHORT:	1990 (Grad '94)	1991 (Grad '95)	1992 (Grad '96)	1993	1994	1995
IFYCSEM	89.7%	92.8%	98.2%	81.4%	93.2%	92.9%
Compare	71.8%	84.1%	73.2%	64.4%	89.8%	91.8%

Table 2 shows the percentage of students who have either graduated (the first three cohorts) or who are still enrolled at Rose-Hulman. The percentages for the 1994 and 1995 cohorts are both high because these are either students who returned for the junior (1994) or sophomore (1995) years.

Table 3: Fall Quarter - Sophomore Grade Point Average - Quarter GPA

First Year COHORT:	1990	1991	1992	1993	1994	1995
IFYCSEM	3.349	3.166	3.227	2.966	3.029	2.969
Compare	2.798	2.7	2.571	2.576	2.675	2.640
Total RHIT Cohort	2.765	2.736	2.628	2.736	2.688	2.807

Table 4: Fall Quarter Junior Grade Point Average - Quarter GPA

First Year COHORT:	1990	1991	1992	1993	1994
IFYCSEM	3.423	3.022	3.254	2.988	3.275
Compare	2.867	2.805	2.83	2.873	3.036
Total RHIT Cohort	2.868	2.834	2.929	2.903	3.020

Table 5: Fall Quarter Senior Grade Point Average - Quarter GPA

First Year COHORT:	1990	1991	1992	1993
IFYCSEM	3.415	3.256	3.275	3.082
Compare	2.951	2.97	2.928	2.963
Total RHIT Cohort	3.028	3.088	3.088	3.079

Faculty Assessment of Student Attributes

Faculty who had students from either the IFYCSEM or matched comparison groups in their class were asked to complete a survey giving their perception of ten students from their class on certain attributes. The students were chosen if they were in either group. Other students from the same entering class were chosen at random to make a total of ten students. This was considered a blind study in that faculty were not aware of who was in the matched comparison group and who was chosen at random—in most cases faculty were probably also unaware of which students were in IFYCSEM.

Faculty were asked to rate the students on a ten-point scale in six different areas:

- develops ideas to their appropriate conclusions
- relates new experiences and concepts to prior knowledge and experiences
- communicates ideas effectively and easily
- demonstrates an attitude which is appropriate for learning
- ability to integrate the use of the computer for problem solving
- type of scientist or engineer you project student will become

Table 6 below is from the 1991 cohort and is generally representative of the responses given by faculty.

Table 6: Faculty Assessment of Student Attributes (1991 Cohort)

1991 Cohort	IFYCSEM	Matched Comparison	Random
Develops Idea	7.4	6.6	6.7
Relates Experiences	7.7	6.9	6.9
Communicates ideas	7.4	6.5	6.6
Attitude for learning	8.0	7.3	7.6
Integrates Computer	8.0	7.5	6.6
Type of Sci./Eng.	7.5	6.8	6.8

All of the differences between IFYCSEM students and the other two groups were statistically significant at the 0.01 level.

Evaluation of the Assessment Results

Evaluation of new curricular initiatives is a difficult problem because carefully controlled experiments can not be implemented. Students, faculty and staff at Rose-Hulman do not agree on a single set of conclusions. Therefore, the following points are intended to represent a spectrum of conclusions.

1. Assessment results show that students who completed IFYCSEM were retained at a much higher rate and did

significantly better, in terms of GPA, in subsequent years. GPA differences are largest in the sophomore year and decline in the junior and senior years. All these differences with respect to the carefully constructed matched comparison group are statistically significant.
2. There appears to be universal agreement that students who have participated in IFYCSEM have not, on the average, been hindered in their subsequent academic careers. This conclusion is important because faculty, in general, are pleased with the traditional curriculum and are concerned that significant changes may hurt students. While some argue that conclusions drawn from the matched comparison group may be flawed (see next points), no one argues that students who have completed IFYCSEM have been hindered academically.
3. The question of whether IFYCSEM offers a superior learning environment to the traditional curriculum remains an open question. The central issue is whether conclusions drawn from the assessment results with two groups, students who completed IFYCSEM and the matched comparison group, can be extrapolated to the entire entering student body. Some faculty assert that the data demonstrates that IFYCSEM is superior. They believe that increased sense of community among faculty and students, increased integration among topics from different disciplines, increased emphasis on problem solving and increased emphasis on learning and working in teams better prepares students for the sophomore year and beyond.
4. However, other faculty insist that other factors may account for the increases in retention and GPA. For example, they mention that students volunteer for the program in spite of the fact that information sent to prospective students indicates IFYCSEM requires more work than the traditional curriculum. Therefore, IFYCSEM students could be more highly motivated and willing to take risks. These factors, they assert, may account for much of the increases in retention and GPA. They believe that the fact that students volunteer to participate in IFYCSEM is not corrected by the criteria used to select the matched comparison groups. In addition, faculty volunteer to participate in IFYCSEM and could be more highly motivated.
5. Students who complete IFYCSEM earn forty-one credit hours. Therefore, IFYCSEM covers the equivalent of forty-one credit hours of material in a thirty-six credit-hour format.
6. Despite a well-designed assessment plan and extensive data collection, the question of whether IFYCSEM is an improvement on the traditional curriculum remains unanswered in the minds of many students, faculty and staff.

Formative Assessment[2] and Continuous Improvement

IFYCSEM is using several methods to obtain feedback from students and faculty with which to improve the program.

1. Faculty solicit strengths and suggested improvements (plus/delta) from the entire IFYCSEM cohort.
2. Students elect an IFYCSEM Council which meets bi-weekly with IFYCSEM faculty.
3. Faculty administer end-of-quarter evaluations which include the standard Institute evaluation plus questions targeted at the IFYCSEM. These questions ask students to compare their experience in IFYCSEM to their perception of their peers' experience in terms of amount of work involved, opportunity to participate in co-curricular activities, confidence in mathematical and scientific fundamentals, problem solving capabilities, and abilities to work in a team.
4. Faculty collect comments from informal meetings with faculty and students.

Using this feedback faculty have made numerous changes to the program. For example, faculty have spread topics throughout the year more evenly, reduced the number of design projects from six to three, placed more emphasis on and stretched out the introduction to the computer algebra system, created an IFYCSEM Council, increased emphasis on cooperative learning and team building, introduced a competency matrix approach to assessment of student performance, improved the format for help sessions, introduced sophomore mentors for IFYCSEM students, worked to coordinate assignment due dates, attempted to coordinate group assignments (further work is still required here), and changed the way faculty assign students to base teams. The continuous improvement approach has improved the retention within the program as shown in Table 7.

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[2] Formative assessment is collection of data for continuous improvement of a program.

Table 7: Retention within IFYCSEM

Year	Number of students after drop day	Number of students completing IFYCSEM	Retention within IFYCSEM	Number of faculty	Design Projects
1990-91	43*	39	90.7%	5	6
1991-92	117*	69	60.0%	7	5
1992-93	77*	56	72.7%	8	3
1993-94	77*	59	71.9%	8	3
1994-95	95	59	62.1%	8	3
1995-96	115	85	73.9%	9	3
1996-97	99	87	87.9%	8	3

*IFYCSEM drop/add day was after three weeks into the quarter

Impact Beyond Rose-Hulman

Since 1988, work on IFYCSEM [1, 2] has helped stimulate nation-wide interest in integrated curricula [3-22]. IFYCSEM provided a model for prototype first-year science, engineering, and mathematics curricula that are being offered by each partner in the Foundation Coalition [23], an engineering education coalition funded by the National Science Foundation. Prototypes, offered at Arizona State University [3, 5, 18, 19, 20], Maricopa Community College District, Texas A&M University[4, 9, 10], Texas A&M University at Kingsville [22], Texas Woman's University, and the University of Alabama [6, 7, 8, 13, 21], demonstrated the efficacy of the model in diverse environments. Rose-Hulman has hosted two conferences on integrated curricula. Seventy-five faculty from thirty-four schools attended the first at Estes Park, Colorado in June 1994. Twenty-five faculty from fifteen schools attended the second at Wagner College, Staten Island, New York, in 1995. Encouraged by the second conference, three schools - Auburn University[11], Diablo Valley Community College, and the University of Puget Sound - formed a partnership to explore integrated mathematics and physics curriculum. They held a conference in August 1996 in San Francisco, California. Faculty from Adirondick Community College, Dartmouth University, and Union College who attended one or both of the initial conferences are now offering integrated curricula. Finally, integrated curricula are also being offered at Drexel University [15], North Carolina State University [12] and University of Florida.

Developing an Institute-Wide First-Year Program

In September 1995, the President appointed a first-year team whose mission is stated below.

> The First Year Team's mission is to assist the Institute in defining its first year program. It will seek out and disseminate all appropriate information germane to the task, engage all constituents in a process of reflection, discovery, discernment and planning, and foster consensus and ownership in the development of a first year program.

The First-Year Team first prepared a process flowchart to describe the process through which the first-year experience will be prepared and indicate points at which feedback from the entire Institute is particularly expected. The process flowchart was approved by the Institute in Spring 1996. Next, the First-Year Team prepared a platform which summarized the beliefs which the Institute holds about the first-year experience and goals for the first-year experience. The platform was approved by the Institute in January 1997. Now, the First-Year Team is preparing a high-level design for the first-year experience. It is anticipated that work on the high-level design will continue through Summer 1997 and be presented to the Institute in Fall 1997. The Institute's experience with IFYCSEM will provide the starting point for the high-level design. Work on the high-level design is expected to be complete before the 1997 Frontiers in Education Conference and details will be presented at the conference.

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