First-Year Integrated Curricula Across Engineering Education Coalitions

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Abstract *- The National Science Foundation has supported creation of eight engineering education coalitions: Ecsel, Synthesis, Gateway, SUCCEED, Foundation, Greenfield, Academy, and Scceme. One common area of work among these coalitions has been restructuring first-year engineering curricula. Within some of the Coalitions, schools have designed and implemented integrated first-year curricula. The purpose of this paper is to survey the different pilots that have been developed, abstract some design alternatives which can be explored by schools interested in developing an integrated first-year curriculum, indicated some logistical challenges, and present brief descriptions of various curricula along with highlights of the assessment results which have been obtained.*

Introduction

American industry faces stiff competition in today's world markets. As competition increases, manufacturers search for ways to produce more at a lower cost with higher quality. Few would disagree that the long-term key to improving productivity is education. At the same time as such needs are rising dramatically, however, engineering education faces substantial challenges from, among other things, rising costs, reduced operating budgets, aging laboratory resources, declining standards of academic preparation of incoming students and increased competition for those students from other disciplines.

There are also difficulties associated with using the traditional classroom system for learning when high fractions of the learner population are non-traditional students. This is more frequently the case than not, especially in urban universities. [1] Such difficulties include traveling distance between work place and university, interruption of work schedules, and the challenges of integrating the latest information and technology into the instruction. Many studies have documented that traditional classroom teaching is not the best approach to teach college students [2,3,4,5].

A widespread conclusion has been that a new and innovative teaching pedagogy is needed. As a result, government, industry and educational institutions have started searching for innovative ways to improve learning. Moreover, American industry has initiated cooperation with universities to build modular educational programs that allow employees to expand their knowledge and increase the company's competitive edge. Also, educational institutions have started their own initiatives to enhance student learning [6,7,8,9,10,11,12]. The National Science Foundation has funded a number of coalitions around the country to focus on change in pedagogy and to develop new, high-quality curriculum for traditional and non-traditional students in engineering. The eight coalitions are Greenfield, Gateway, ECSEL, Foundation, The Academy, SCCEME, SUCCEED, and Synthesis [13].

This papers presents a synthesis of efforts across the NSF-sponsored engineering education coalitions to design, implement and evaluate integrated, first-year curricula. A unique element of this paper is its attempt to present the broad spectrum of integrated curriculum development activities across all of the NSF-sponsored engineering education coalitions and abstract design elements that could be considered by any institution exploring an integrated first-year curriculum. Instead of focusing on a single integrated curriculum, this paper attempts to collect the large number of issues which have been raised in connection with integrated curriculum, synthesize these issues into non-overlapping design options, and describe the state-of-the-art regarding these design options for institutions interested in future integrated curriculum implementations. The paper will explore four broad categories of questions about integrated curricula: motivation, different pedagogical models, logistical issues and assessment and evaluation processes and results.

Motivation: Why Integration?

Faculty are interested in two important questions about integrated curricula: 1) Why? and 2) Why not? The following two subsections will address the two questions.

Why?

Faculty interested in implementing an integrated curriculum must answer the question: Why? What are the reasons why an integrated curriculum may offer an improved learning experience for at least some, if not all, of the entering engineering students? Frequently offered reasons are provided below.

- Learning theory suggests that learning occurs as students add elements to their ideological scaffolding. Students construct, discover, transform, and extend their own knowledge. Learning is something the learner does, not something that is done to a learner. Students do not passively accept knowledge from the teacher or curriculum. They use new information to activate their existing cognitive structures or construct new ones. The teacher's role in this activity is to create conditions within which students can construct meaning from new material, study by processing it through existing cognitive structures, and then retain it in long-term memory where it remains open to further processing and possible reconstruction. [14]
- Arranging the topics in these courses so students learn related topics simultaneously promotes a broad-based level of understanding rather than a more narrow discipline specific understanding. [15]
- If a necessary framework is not present, then students will have enormous difficulty assimilating new information that a professor is presenting. If a professor can link current material to other concepts which a student is currently working on, then the probability that students can assimilate the material is increased, since the number of joints in a student's conceptual framework to which the new material may be linked are increased.
- Better match with the practice of engineering. Engineering problems are not presented in discipline-oriented categories. Instead, engineers working to solve real-word engineering problems must synthesize knowledge across several different disciplines.

  Many of these changes are driven by today's global multidisciplinary industrial environments, where in addition to technical knowledge in their fields, engineers are required to understand and apply several disciplines in the solution of complex problems. In addition, they need to be flexible and adaptable to new technology and changing situations, combine ideas to synthesize creative solutions, work effectively in teams, have excellent written and oral communications skills, and be highly productive. [16,17]
- Integrated curricula help students to visualize and understand links among different disciplines. These links can help practicing engineering synthesize multi-disciplinary solutions
- Better retention of material
- Integrated curricula can help smooth the transition and improve the interface between subjects. For example, laboratory experiments in physics, chemistry and engineering can be designed to reinforce common concepts. [18] It may also be possible to develop a common report format to decrease the number of different formats a student is required to understand. As another example, it may be possible to use one set of course/program evaluation forms.
- Integrated curricula establish increased relevance between the material being studied and student perception of their career needs. As a result, students are more highly motivated to master material being presented.
- Integrated curricula help decrease compartmentalization.
- Integrated curricula may offer more opportunities to connect with different student learning preferences.
- If an interdisciplinary faculty team designs an entire integrated curriculum, they can avoid haphazard repetition of material and concentrate redundancy in conceptual area in which students have demonstrated difficulty in mastering the material. Presentation economies may one-time presentations on common topics such as symbols and units. It may be possible to reduce presentation time by eliminating redundant presentations on topics that do not require repetition. For example, team development and team skills can be taught once and reinforced in other courses. Further, careful design will allow faculty to reinforce difficult topics by knowing what other faculty have presented. Students can then see different faculty presenting similar topics and each faculty member's presentation may appeal to different learning preferences.
- Integrated curricula often emphasize the development of student abilities to work in teams. If faculty expect students to learn to work in teams, they need to provide a role model so students can learn from watching faculty work in a team. Further, student teams can benefit from the different strengths of each member in different

disciplines. Finally, an integrated approach helps students be successful in all topic areas.
- Faculty who participate on the interdisciplinary faculty team which offers an integrated curriculum are better informed.

Why not?

Faculty offer several of reasons for not implementing integrated curricula. These are presented below.

- "We can't do that. Although some schools have implemented integrated curricula, the needs of our students and our institutional culture prevent offering integrated at this institution." One reason this paper has been prepared is to illustrate the wide variety of integrated curricula that have been offered at many diverse campuses.
- "My class is 5 hours and I need all of the time allocated." Faculty don't believe there is sufficient time to allow presentations and activities to be coordinated.
- "I can't work with Physics, Chemistry, Mathematics, Engineering, etc." "I have to cover the material my way."
- Faculty often express reluctance to work in teams with other faculty, especially across departmental boundaries. Faculty are accustomed to working alone and many resist initiatives change their preferred mode of operation.
- " I believe students have to pass everything at the same time for this to be successful." "Students come with different backgrounds. Our current mode works well for ultimate flexibility." One the major obstacles to implementing integrated curricula are tradeoffs between the breadth of integration and the flexibility of curricula to accommodate different student needs. When a large set of courses are integrated into a single curriculum, the number of students that can participate in the curriculum may be too small. On a set of axes where the horizontal axis is the flexibility to accommodate student needs and the vertical axis is the breadth of integration, an institution may construct a curve showing its tradeoff. Then, an institution may choose an optimal point on curve. One of the motivations for this paper is to illustrate the diversity of possible approaches.
- "Let students do the integration we will give them the topics." Some faculty believe it is the responsibility of students to make connections among the topics they are studying. They do not believe it is appropriate for faculty to help students identify and process these connections.

Pedagogical Models: One Size Does Not Fit All

Although the benefits of curriculum integration can be realized at every institution, one approach to first-year integrated curricula will not work for all institutions. Differences in mission, student population and institutional culture demand different models. This section will explore different models that have been implemented at different schools across all the coalitions.

Engineering coalitions have tried numerous integrated curriculum models. Rather than describe all of the variations that have been tried, a multi-dimensional framework is presented into which existing and many future experiments may be fit. The framework has five dimensions: course structure, time-sharing, topical span, topical coordination, and learning environment.

Course Structure

The first dimension is course structure. Along this dimension are three distinct options and variations within each option.

- <u>Separate courses</u>: The first option is that the course structure is the same as the traditional set of courses taken by any first-year engineering students. In this option, courses such as calculus, physics and chemistry retain their independent departmental structure and integration is achieved through topical alignment and other methods.
- <u>Course pairs/triads</u>: The second option is course pairs or triads. In this possibility two or three of the courses taken by first-year engineering students are coupled together so that a student who takes one is jointly registered in both or all three. Within this variation, students may receive separate credit for each of the courses that have been coupled together or students may receive credit in a block for the pair or the entire triad. The course pair/triad option may be appropriate for institutions that serve a large percentage of part-time students such as community colleges or large urban universities.
- <u>Large course block</u>: The third option is a large block of courses, for example, calculus, physics, engineering, writing/communication and chemistry. Students take the entire course block simultaneously. They may receive separate grades for courses in the block or they may receive a single grade for the entire course block.

Time-Sharing

Time-sharing describes how the time for the set of courses being integrated is allocated among the different faculty or disciplines that are participating. Two major variations exist: real-time sharing, fixed time allocation.

- <u>Real-time sharing</u>: In real-time sharing, faculty agree to adjust time shared among courses on a regular basis during the term (quarter or semester). Under real-time sharing mathematics may be receive more time during one week to work on specific concepts which are difficult or develop mastery with certain skills, such as a computer algebra system.
- <u>Fixed-time allocation</u>: In fixed-time allocation, faculty agree to allocate a fixed amount of time each week to each of the courses. Time allocation usually follows traditional

course allocation methods. For example, mathematics courses may receive four hours each week and chemistry courses three hours each week throughout the entire term.

Real-time sharing offers flexibility in scheduling topics so that links can be arranged on a daily basis or so that students can focus on difficult concepts for a longer block of time during one week. However, real-time sharing requires a higher degree of coordination among the interdisciplinary faculty team. Fixed-time allocation requires less adaptation for faculty who agree to participate.

Topical Span

Topic span describes the range of courses that are being integrated. Again, numerous combinations have been tried both across the coalitions and beyond the coalitions. Two major variations can be mentioned. In the first variation, only courses from mathematics, science and engineering are integrated. In the second variation, courses from mathematics, science and/or engineering are integrated with courses in non-technical areas such as writing, communication, team dynamics, and others. Within both variations, numerous combinations have been tried.

- mathematics and science, such as physics or chemistry
- science and engineering
- mathematics and engineering
- material science and chemistry
- engineering and communication

Topical Coordination

Topical coordination describes the mechanisms to help students build links, connections, and/or relationships between topics. Mechanisms include helping students learn different nomenclature, topical alignment, and integrated examinations.

- *Nomenclature coordination*: One approach establishes a common nomenclature and set of symbols to be used throughout the integrated structure. An alternative approach recognizes that different disciplines use different terminology, symbols, and units and points out where different terms, symbols and units are being used and how they are related.
- *Topical alignment*: An approach to topical alignment organizes the topics in the integrated structure to help create links and ensure common foundation information and prerequisite material. There are many possible variations of course structure and topical span arrangements.
- *Integrated examinations*: Integrated exams can range from using a single exam with integrated problems to test the student over all subjects to discipline specific exams where the student is expected to knowledge from other integrated topics.
- *Integrated design projects*: Projects can help students synthesize concepts from several different disciplines and demonstrate the relevance of these concepts to the practice of engineering and science.

Learning Environment

There are many different factors that describe the new learning environments within the integrated curricula that have been tried across the coalition.

- Cooperative learning
- Teams: team projects, team training, team building,
- Passive versus active learning
- Experiential learning: Faculty use hands-on experiments, dissection problems, and industrial experience to add context to the learning process. Co-op environments, case studies and Integrated Product and Process Design (IPPD) illustrate this approach.
- Discovery-based learning, inquiry-based learning, project-based learning, problem-based learning: These methods focus learning more complex problems for which students seek out the procedures, foundation information and solution tools required to achieve the problem goal.
- Student cohorts: Although student cohorts appear to be a part of the learning environment for every integrated curriculum tried across the coalitions, student cohorts are not automatic for scale-up across an entire entering class. A design decision of whether or not to have student cohorts across an entire entering class must be made. Cohorts may consist of the group of students registered in a large credit class or a large credit block of classes or students who are block registered as a group.
- Self-paced learning:
- Technology-enabled learning: Many experiments have been tried where students have routine access to computers both within and outside the classroom.
- Student feedback: Almost every integrated curriculum experiment has implemented one or more mechanisms to obtain student feedback have been tried. Mechanisms include student councils, group meetings, e-mail feedback, surveys and advising sessions. In general, student feedback increases the sense of students belonging to a learning community built around an integrated curriculum.

Implementation/Logistics Issues

Interested faculty have raised numerous questions about implementation of integrated curriculum. This section attempts to raise as many issues as possible and indicated some of ways in which the challenges have been overcome.

- Course scheduling: Difficulties range from working across departmental lines to problems in linking courses for cohort registration.
- Classroom scheduling: Classroom space is always a problem. Additional issues include technology needs for

an integrated course, laboratory space needs and scale-up problems of the increased number of sections needing active learning classrooms.

- Grade assignment, reporting and recording: Non-traditional credit assignments, e.g., twelve-credit courses, four-credit courses taken one credit per term pose difficulties for the registrar.
- Accounting: One of the biggest obstacles to integration are the accounting boundaries between academic units, for example, college and department credit for faculty loads, that exist at many campuses.
- Different entry points: Integrated courses can cause problems with transfer students, advanced placement credits, different levels of students' preparedness and how to handle different levels of success. Methods to handle these types of issues need to be addressed within integrated structures include a pre-calculus option, extensive mathematics diagnostics coupled with pre-calculus instructional modules, and one credit courses
- Students who perform poorly require innovative solutions that allow them to continue to progress in an integrated curriculum.
- Faculty development: Integrated curriculums usually require the faculty to operate in a different teaching environment. Many of the programs use an active learning environment that reduces lecture and increases faculty mentoring. Engineering faculty generally have not formally studied pedagogy and integrated curriculums require faculty development efforts in order for the programs to succeed. Questions that must be addressed include: How do faculty learn to participate on interdisciplinary teams? How do faculty learn about areas outside their areas of expertise? How do faculty learn to incorporate computer technology into their teaching and into student learning? How do faculty learn how to form and facilitate student teams?

Assessment Processes and Results

This section addresses two very broad questions: First, do integrated curricula that have been tried in the engineering education coalitions offer a superior learning environment? How do you obtain answers to this question? Second, what assessment results are have been obtained in the various integrated curricula that have been offered throughout the engineering education coalitions? Each question will be address in its own subsection.

Does It Work? How Do You Know?

Faculty have attempted to measure success of integrated curriculum pilots in many ways. The most common are though retention studies, grade point average (GPA) performance, and student self evaluation. Retention can mean many things and four types of retention measures have been frequently employed.

1) Retention within the curriculum: What percentage of students who were initially enrolled in the integrated curriculum complete the program.
2) Retention within engineering: What percentage of students who were initially enrolled in the integrated curriculum is either still enrolled in the college of engineering or have graduated with a degree in engineering?
3) Retention within the institution: What percentage of students who were initially enrolled in the integrated curriculum is either still enrolled in the institution or have graduated?
4) On-track performance: What percentage of students who were initially enrolled in the integrated curriculum is estimated to complete their degree within four years?

All four measures are important, especially to different stakeholders within the institution, but each measures a different aspect of the program's effectiveness. Issues connected with GPA performance are more complicated.

1) Is the GPA of students in the integrated curriculum important?
5) Is the GPA after the first-year of the students who complete an integrated curriculum important?
6) To which group is the GPA performance of students who complete an integrated curriculum compared?
7) How is the comparison group selected? What criteria are used? Is it possible to obtain a reasonable comparison group?
8) Are faculty external to the integrated curriculum involved in the design of the analysis of GPA performance?

Finally, student self evaluation is important, but the results may be difficult to interpret. The wide range of measures of success, the variety of methods that the measures of success have been implemented at different schools, and the wide variety of schools who have piloted integrated curricula make interpretation of the results very complex.

Other assessment measures that have been used are shown in the following list.

1) End of term class assessment by students
2) End of term teacher assessment by students
3) Self and team members assessment of student teamwork skills
4) Weekly anonymous journals - open or selected topics
5) Student interviews - students leaving programs - students staying in programs
6) Longitudinal tracking of retention, overall GPA, specific GPA for course sequence, progress toward graduation, co-op / internship participation
7) Surveys of industry for input (alumni and managers)
8) Rating by students of opportunities to work on ABET competencies
9) Faculty interviews

10) Longitudinal tracking of retention
11) Specific GPA for course sequence
12) Co-op / internship participation
13) University of Pittsburgh survey of student attitude toward engineering [25]

The critical issue is what is the desired objective of the integrated curriculum. In many cases, the objective is improved content understanding. This is much more difficult to measure and has been measured to a much more limited extent.

Coalition Survey

Several integrated curriculum experiments will be reported here. A summary of the different programs is included in Table 1.

Table 1. Summary of Integrated First-Year Curriculum Experiments

Program	Ref.	Course Structure	Time Sharing	Topical Span	Topical Coordination	Learning Environment
IFYCSEM (Rose-Hulman)	[50-60]	large course block, one 12-credit grade	real-time	mathematics, physics, computer science, engineering, chemistry	topical alignment, integrated exams	coop learning, teams, team projects, required notebook computers for every student
University of Florida	[19]	separate courses	fixed time	calculus, physics, chemistry, engineering	pre-arranged topical alignment	moderately structured cooperative learning, teams, student cohorts, computers in classroom
FYIEC (Texas A&M University - Kingsville)	[17, 61, 62]	large course block with separate grades	fixed time with minimal real-time sharing	mathematics, physics, chemistry, engineering, and English	topical alignment, thematic concepts, integrated exams, integrated design projects.	co-op learning, teams, team projects, computers in classroom, student cohorts
The Ohio State University		course triad	fixed time	engineering, mathematics through differential equations, physics, statics, technical report writing	nomenclature coordination, some topical alignment, computer tools introduced once	coop learning, CAI materials
Texas A&M University	[20-23, 63-65]	large course block, separate grades	fixed time	calculus, physics, engineering, chemistry,	topical alignment, integrated exams	co-op learning, teams, team exams
IMPEC (North Carolina State University)	[24-28]	large course block, separate grades	¾ fixed time and ¼ time shared	mathematics, science, and engineering, with written and oral communication	integrated lectures, homework assignments, projects, and examinations	structured co-op learning, experiential learning, teams
Arizona State University	[66-74]	large course block, separate grades	real time	mathematics, physics, and engineering, English	integrated lectures, homework assignments, projects, and examinations	structured co-op learning, experiential learning, teams
University of Alabama	[15, 18, 29-44]	large course block, separate grades	real time	mathematics, physics, chemistry, and engineering	integrated lectures, homework assignments, projects, and examinations	structured co-op learning, experiential learning, teams

Maricopa Community College District		course pairs	fixed time			
Drexel University	[75-81]	large course block, separate grades	fixed time	mathematics, physics, chemistry, biology, engineering, and humanities	homework assignments, faculty team meetings	experiential learning, teams

Note: Every pilot project includes mechanisms for student feedback so this aspect is omitted from the learning environment.

In the following sections, each curriculum will be described briefly along the dimensions outlined in the section on different pedagogical models. Special variations of the pedagogical model can be noted along with exceptional solutions to the logistical issues outlined in section three. Finally, selected assessment results will be shared for each experiment. Readers interested in more complete descriptions of the assessment results are referred to the references.

Rose-Hulman Institute of Technology

Since 1990, Rose-Hulman Institute of Technology has offered an integrated, first-year curriculum with the characteristics listed in Table 1.

Innovations: IFYCSEM has pioneered at least five significant innovations.

1) IFYCSEM has developed a yearlong curriculum that successfully integrates concepts across calculus, mechanics, engineering statics, electricity and magnetism, general chemistry, computer science, engineering graphics, and engineering design. The curriculum has been developed and revised by an interdisciplinary faculty team.
2) IFYCSEM has developed a positive and flexible learning environment that 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 that meets bi-weekly with faculty, and plus/delta feedback.
3) IFYCSEM has developed a collaborative 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).
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.

Assessment: The IFYCSEM summative evaluation model uses both quantitative and qualitative methods. Prior to the beginning of the first year, all RHIT students are asked to participate in an assessment program. Collected baseline data include scores on critical thinking skills, intellectual development, Force Concept Inventory [45], Mechanics Baseline Test [46], and personality type preferences. This information provides a rich baseline on students' skills and learning preferences and provides a mechanism for examining program outcomes. Evaluation includes post-testing on baseline measures, retention at Rose-Hulman, grades in upper-level courses, faculty assessment of student characteristics in upper-level courses, and student focus groups.

All of the students who have participated in IFYCSEM volunteered. To compare how IFYCSEM student performance compares with that of students who take the traditional curriculum, a comparison group of students was chosen using cluster analysis. Students from the traditional curriculum were matched with IFYCSEM students on characteristics such as predicted grade point average, SAT scores, pre-test scores on baseline assessment measures and parent's education. These two groups have been tracked through their upper level courses and their performances compared. Comparison data include grades, persistence at Rose-Hulman, faculty assessment of student characteristics, and post-testing at the sophomore and senior levels.

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. All these differences with respect to the carefully constructed matched comparison group are statistically significant. 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. On the Physics misconceptions test sophomore students from IFYCSEM significantly improved their scores, that is, have fewer misconceptions than students who have completed the traditional curriculum. These differences are less dramatic in their senior year.

Retention and grade point average data for both students who completed IFYCSEM and carefully matched comparison groups are shown in Tables 2, 3, 4 and 5.

Table 2. Retention after Completing IFYCSEM - Rose-Hulman

Entering Cohort	1990	1991	1992	1993	1994	1995	1996
IFYCSEM	89.7%	92.8%	98.2%	81.4%	93.2%	92.9%	94.3%
Comparison	71.8%	84.1%	73.2%	64.4%	89.8%	91.8%	98.9%

Table 3. Sophomore Fall Quarter Grade Point Average - Rose-Hulman

Entering Cohort	1990	1991	1992	1993	1994	1995	1996
IFYCSEM	3.349	3.166	3.227	2.966	3.029	2.969	2.847
Comparison	2.798	2.700	2.571	2.576	2.675	2.640	2.650
All Students	2.765	2.736	2.628	2.736	2.688	2.807	2.740

Table 4. Junior Fall Quarter Grade Point Average - Rose-Hulman

Entering Cohort	1990	1991	1992	1993	1994	1995
IFYCSEM	3.423	3.022	3.254	2.988	3.275	3.099
Comparison	2.867	2.805	2.830	2.873	3.036	2.925
All Students	2.868	2.834	2.929	2.903	3.020	2.964

Table 5. Senior Fall Quarter Grade Point Average - Rose-Hulman

Entering Cohort	1990	1991	1992	1993	1994
IFYCSEM	3.415	3.256	3.275	3.082	3.173
Comparison	2.951	2.970	2.928	2.963	2.973
All Students	3.028	3.088	3.088	3.079	2.996

Data on the faculty evaluation of sophomore students can be found in [59].

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) 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.
2) 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.
3) 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.
4) 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.

University of Florida

In 1994, the SUCCEED Coalition supported an experiment on an integrated freshman-sophomore integrated curriculum. The project ran for two years with a cohort of 92 students. The main objectives were:

1) Provide a more structured academic and social learning environment.
2) Provide applications and introduce the engineering thought process in the early years.
3) Search for models that are sustainable, cost effective and transportable.
4) Match teaching and learning styles (e.g. cognitive and active learning).
5) Develop an advanced learning laboratory to provide optimal physical facilities.

Faculty made the following course modifications as part of the experiment.

1) They converted calculus from a 3 lecture, 1 recitation to 3 lectures, 1 2-hour problem lab and 1 1-hour recitation.
2) They converted physics from a 3 lecture and companion laboratory class to 2 lectures, 1 2-hour problem lab and the companion lab class.
3) They maintained chemistry in a lecture format, but they converted the laboratory portion of the class to a data acquisition based, group laboratory format.

The following results are intended to illustrate the impact of the changes on student learning. First, the incoming SAT scores of both the program student and the comparison group are shown in Table 2.

Table 2. Incoming Student Profiles **-** *University of Florida*

	Program Students	Comparison Group
SAT Quantitative	627	656
SAT II Math	580	637
SAT II Chemistry	507	535

Retention results are based on students who stayed in engineering at the end of the two-year experiment as compared to a control group that entered at the same time. Students who participated in the program were retained at a higher rate than students in the comparison group were. These results are summarized in Table 3.

Table 3. Retention Results **-** *University of Florida*

	Program Students	Comparison Group
Started Program	92	571
Completed (enrolled for Junior year)	55	286
Percent	60%	50%

Overall GPA for the first two years of mathematics is shown in Table 4.

Table 4. Performance in the First Two Years of Mathematics - University of Florida

	Program Students	Comparison Group
Number of students	55	275
GPA for all math courses	3.03	2.88

In all cases, these were shown to not be statistically significant possible due to the small number of project students. The trends are encouraging and data is being analyzed further.

Texas A&M University-Kingsville

As a partner in the Foundation Coalition, Texas A&M University-Kingsville (TAMUK) has offered its First-Year Integrated Engineering Curriculum (FYIEC) since fall 1995.

As indicated in Table 5, in a two year span, retention and GPA of FYIEC students is better, particularly in 1996, when compared to matched compared groups of traditional first year engineering students. In addition to that, in both years, FYIEC students outperformed traditional students in the number of math, science, and engineering hours earned in their first year. These results, shown in Table 6, indicate they are progressing faster towards graduation.

Table 5. Retention and GPA of FYIEC and Matched Comparison Groups

Year	FYIEC	Traditional
1995	58 % (26)	56 % (25)
	2.5 GPA	2.37 GPA
1996	63 % (24)	46 % (26)
	2.75 GPA	2.29 GPA

Number in parenthesis denotes total number of students in each group.

Table 6. Progress Towards Degree of FYIEC and Matched Comparison Groups

	Earned Hours After First Year			
	1995		1996	
	FYIEC	Traditional	FYIEC	Traditional
Math	5	3.2	6	3.3
Science	9.2	4.2	11.2	4.7
Engineering	5.2	1.7	3.4	3.3

The Ohio State University

Since 1993, Ohio State has offered and integrated first-year curriculum with the characteristics shown in Table 1. During these five years 381 students have participated in the curriculum. Participants have volunteered from Honors students for four pilots and current Honors program. Faculty made the following course modifications as part of the experiment.

1) Physics faculty use cooperative learning and active learning. Special labs are set up for the first Physics

course using Hot Wheels cars and the students must design the experiments to determine forces, displacements, velocities and acceleration. Two nationally normed tests (Mechanics Baseline Test and Force Concepts Inventory) are used as part of the course assessment. The 1997-98 Ohio State students outperformed all other groups on one test and all but one on the other test. The Physics, Math, and Statics are coordinated so topics are covered just in time

2) Physics and engineering faculty have developed and used CAI materials.
3) Faculty have developed a hands-on laboratory created for students in the curriculum. They use laboratory experiments as a basis for experiential learning.
4) Engineering faculty use teams for laboratory experiments and design projects.
5) Engineering faculty teaching statics use CAI materials to augment lectures.
6) Students send anonymous, weekly journals to a group of faculty and staff. These journals are discussed in weekly faculty meetings.
7) Students assess themselves and each other for team learning and laboratory exercises.
8) Faculty have aligned the program objectives with ABET 2000. They are working on course objective alignment.
9) Faculty have placed computers in the engineering classroom and made computers available in laboratory for freshmen engineering students. Faculty introduce computer tools once, then they use them more than once in other courses.
10) In the Spring Quarter, the students work in four-person teams where each team designs and builds and autonomous robot for an end-of-the-quarter competition. Students use Physics, Mathematics and Engineering (graphics, computer programming) topics and hands-on laboratory experiments during the projects. Physics, Mathematics and Engineering faculty and graduate teaching associates choose teams.

To evaluate the impact on student learning, Ohio State has tracked retention, GPA, GPA in follow-on mathematics and physics courses, and participation in Co-op Internship. In brief, retention is 10% higher than matched comparison groups if students complete one quarter, >20% higher if they complete the year. Overall GPA is higher by junior year. Participation in co-op / internships is higher.

Texas A&M University

Faculty at Texas A&M have redesigned the first-year curriculum to nurture development of the following attributes in their graduates:

- good grasp of engineering science fundamentals
- profound understanding of the importance of teamwork
- curiosity and desire to learn - for life
- good communication skills

The engineering component of the curriculum has the following central goals:

1) Provide the student with the necessary skills to perform effective problem solving;
2) Help the student develop a logical thought process;
3) Introduce the students to some of the basic engineering tools;
4) Enable the students to have better spatial analysis skills;
5) Help the students develop appropriate sketching skills;
6) Teach the students how to read and/or interpret technical presentations; and
7) Develop the ability to think both critically and creatively - independently and cooperatively.

Course Structure: Since the fall of 1994, seven hundred and seventy five students have registered in the Foundation Coalition pilot first year engineering program. Of these, 633 have been in the calculus track described herein (the remaining 141 have participated in a pre-calculus track which is very close to the calculus program - offset by one semester). The freshman year of the Foundation Coalition program at Texas A&M University consists of a large course block including: a semester of chemistry (4 hours of chemistry including lab), a two semester English writing class (3 hours of English, technical writing follows in the sophomore year), a two semester engineering course (5 hours of engineering including engineering graphics, and an introduction to engineering problem solving and computing), two semesters of calculus (8 hours of mathematics although not all materials comes from the first two semesters of a traditional calculus class), and two semesters of physics (7 hours of physics including mechanics, and electricity and magnetism). The courses are delivered to students as a 12-hour block in the fall semester and a 15-hour block in the spring semester. Separate courses grades are given within the blocks. These are taught in an integrated *just in time* fashion using technology and delivered in an active-collaborative environment to students working in teams of four.

Time Sharing: Each course is taught in a standard university time block (Fixed-time allocation); however, each course occasionally gives up a class period for common topics such as team training, team development, or a speaker from industry. In addition, there is an understanding that small amounts of time can be traded or gifted to colleagues in other courses to improve the flow of the course block.

Topical Span: All courses in the block are integrated together. Some are more tightly coupled than others (e.g., math and physics) are; but all are involved in a just in time participation of one or more of the threads that weave the courses together.

Topical Coordination: Nomenclature coordination, topical alignment, integrated exams, and integrated projects all are used to help students build links among the various courses.

Learning Environment: The primary thrust areas used in the development of this program are integration, teaming, and active/cooperative learning and appropriate use of technology. Cohorts of students are in the same team across all courses with routine access to computers both within and outside the classroom. In addition, small groups of students serve as an interaction group for each faculty member and provide a feedback mechanism for the students, thus building a stronger sense of community.

Assessment: Overall the Texas A&M has been successful in both recruitment into the Coalition and retention in the College of Engineering (number at the start of their third semester as a percentage of those starting the first semester). Students in the Coalition are retained at a rate higher than the rate for those in the traditional freshman program. This is especially true of students from underrepresented groups: Women, Hispanic, and African-American engineering students. Selected recruitment and retention statistics for underrepresented students in the college of engineering and in the Coalition are presented in Tables 7 and 8 (others years are available).

Table 7. Enrollment by Gender and Ethnicity (1995-96 freshmen)

	Women	Hispanic	African-American
All Engineering	19.8%	11.0%	3.2%
Math Ready	19.8%	10.3%	1.7%
Coalition	24%	16%	5%

Table 8. Retention by Gender and Ethnicity (1995-96 freshmen)

	Women	Hispanic	African-American
Traditional	72%	70%	70%
Coalition	88%	84%	90%

Grade point averages for the coalition students and those students completing the same courses in the traditional program are essentially the same. On the other hand, as illustrated below, the distribution of grades is not the same (Table 9 below represents those students who do **not** successfully complete the courses).

Table 9. Percentage of D, F and Q-Drops

	English	Engin.	Math	Physics
Traditional	17.17%	19.84%	33.75%	43.08%
Coalition	6.52%	16.09%	12.57%	17.9%

Students with grades of D, F or Q (quit before end of tenth week of class) represent those students who will be repeating the course, and therefore requiring greater resources. It should be noted that the difference between the percentages in Table 9 is due to Q-drops, and, because of integration, Coalition students are not allowed to Q-drop a course.

A series of standardized tests, including a critical thinking test (SCT), the Force Concepts Inventory (FCI) [45], a Mechanics Baseline Test (MBT) [46], and a Calculus Concepts Test (CC) [47], has been administered to the students in the Freshman Coalition classes and to a similar group of students in the traditional freshman engineering classes each year. Although performances by the two groups are virtually identical when the instruments are administered at the start of the year tests, Table 10 shown that there are substantial differences between the two groups when the instruments are administered again at the end of the year.

Table 10. Performance on Standardized Tests

	Critical Thinking	Force Concept Inventory	Mechanics Baseline Test	Calculus Concept Test
Traditional	41	51.2	37	47
Coalition	57	66	47	57

In addition, the Gregorc Style Delineator [48] has been administered to the students in the TAMU Freshman Coalition classes since the fall 1995 semester. Of the 193 students enrolled in the Fall 1995 semester, 73 were Concrete Sequential (CS), 50 were Concrete Random (CR), 35 were Abstract Sequential (AS), and 35 were Abstract Random (AR). Attempts to use the information collected on the learning styles of the students have, so far, been limited to correlating this information to other data obtained from our students. The most significant results obtained to date [49] are that AR students are less likely to perform well in Coalition classes (this was especially true of Hispanic students who were AR) and that CS students who are more likely to perform well in Coalition classes. This does not necessarily mean that AR students are better off in the traditional classes. There is currently no data on the comparison of learning styles versus performance in the traditional freshman engineering courses at TAMU.

Greenfield Coalition

The Greenfield Coalition challenge is to develop and deliver a new paradigm manufacturing education in both engineering and engineering technology. The central features of that paradigm are intimate blending of academic and experiential learning, using modularized and integrated learning experiences, highly leveraged through use of advanced instructional and information technologies. Instead of students, the Greenfield curricula offer learning to “candidates”. These people are candidates to become manufacturing engineers or engineering technologists. They are a combination of students and key employees in an advanced technology factory.

In one of the important facets of designing an integrated manufacturing engineering/ engineering technology curriculum, Greenfield re-examined traditional studies in scientific and engineering fundamentals with the dual purposes of integrating learning in physics with that in the related engineering sciences and of focusing these fundamentals towards the applications of science in the engineering major subjects. At the same time, the fundamental principle of preserving (at least) or enhancing (preferably) academic rigor was kept in the forefront of this re-examination of traditional fundamentals.

To this end, the Greenfield Curriculum Committee devised a high-level design for integrating the fundamental content of conventional physics courses with the their application in relevant engineering sciences. Through this approach, concepts in physical science would be introduced and immediately followed by their extensions in engineering sciences. Moreover, throughout the Greenfield curricula, a central feature of courseware development is an intimate intermingling of fundamental theory with practical application in the context of the major field of engineering study – in Greenfield's case, manufacturing engineering and technology. This contextual relevance is central to the development of the "integrated engineering science" knowledge areas.

In order to design an integrated manufacturing engineering curriculum, Greenfield re-examined the engineering fundamentals courses so as to ensure linkages to manufacturing practice, while preserving academic rigor. To this end the Greenfield curriculum committee proposed integrating the fundamental content of conventional physics with the their application in relevant engineering areas. In this way concepts would be introduced such that the knowledge of them is both meaningful and addresses the specific needs of both the engineering and engineering technology curriculum. The three "stems" that constitute the coalescing of physics fundamentals with the applied side of manufacturing engineering (and engineering in general) are mechanophysics, electrophysics, and thermophysics.

The electrophysics area includes the complementary concepts of electricity and magnetism from physics and the relevant electrical engineering concepts as used in manufacturing technology and engineering practice. Thus, circuits that are found on the shop floor will be used as primary examples, moving on to more abstract or more removed examples, if needed, as the lessons progress.

The physical, intuitive sense that the candidates already possess from their job experiences will be capitalized upon to first leverage their abilities early on and then demonstrate the principles behind their intuitive experiences as a complementary activity of closure. Secondly, it is important to capitalize on the mechanical tacit knowledge that they immerse themselves in daily to motivate the study of mechanics first and then use that as a base for subsequent development in areas that may be slightly farther away from their current knowledge base. The aim is to follow a basic principle of effective learning that always connects the novel with the known.

In all three stems, integration across the stems is also pursued since the assimilation of the various knowledge constructs into a common schema allows for more effective knowledge organization and ultimately for deeper understanding and a higher level of performance in knowledge applications. This recommended integration takes various forms and includes the following:

- Use of a common glossary and nomenclature to avoid conflicts
- Use of a common interface to minimize redundancy and reduce ambiguity, and
- Use of a common sequencing of activities that should not constrain the possibility of adding new activities where considered appropriate and effective.

The above represents necessary measures to ensure an integrated engineering science fundamentals curriculum for manufacturing technology and engineering; that by no means should be construed as limiting to creativity or innovation. Quite the contrary, they are the minimum set of requirements that may need to be augmented by the joint set of PIs as the project progresses. The PIs both individually and collectively are encouraged to be creative in addressing the specific needs of the candidates as well as in planning for the eventual adoption of this model by schools nationwide. Just as Greenfield results will be useful to them, our curriculum developers will continue to examine and learn from the experiences of other integrated curricula such as those at Rose-Hulman, Morgan State University, and others. Contact with these and other published innovators will make our development efforts more effective as well as non-repetitive. To facilitate this, the coalition office provides contact information or acts in an introductory manner in making these vital linkages.

The "Principles of Electrical Engineering and Physics (Electroscience)" knowledge area is designed to cover the areas of Electrophysics and the Principles of Electrical Engineering and to provide candidates with enough background to take subsequent courses, such as Electrical Machines, Sensor and Instrumentation, and Control systems. Moreover, it should provide knowledge relevant to the manufacturing environment at Focus: HOPE, or any other up-to-date manufacturing environment. In addition, this courseware will achieve the depth required to make it useful to support the educational efforts in this field at participating universities and in the academic community.

The curriculum should serve candidates in three degree programs (AS, BE and BET). This presents unique challenges that have been addressed throughout the project (planning, developing, and delivery). The curriculum provides five credit hours. Three credit hours are common for all degrees (AS, BE and BET), one credit hour for engineering and engineering technology (BE and BET) students, and one credit for engineering (BE) students only. The other challenge is integrating physics with the principles of electrical engineering into one curriculum. Such integration has not received enough attention. To our knowledge, two institutions have tried the integration of physics and engineering courses [13]. Also, the curriculum should have real-world case studies, particularly from Focus: HOPE's Center for Advanced Technology (CAT). Finally, the last and most difficult challenge is to develop the curriculum so that, computer-based instruction (CBI) is the main source of instruction for candidates. There have been few CBI developments in this area, most of which have been intended as supplements or tutorials [14-15]. The objective of this project is to develop a CBI curriculum, which includes real-world case studies, as the main source of instruction for candidates.

IMPEC (North Carolina State University)

An integrated freshman engineering curriculum called **IMPEC** (Integrated Mathematics, Physics, Engineering, and Chemistry Curriculum) has undergone three years of pilot-testing at North Carolina State University under the sponsorship of the SUCCEED Coalition. In each semester of IMPEC, the students take a calculus course, a science course (chemistry in the first semester, physics in the second), and a one-credit engineering course. The engineering course has a heavy dose of non-technical skill training, with the skills including written and oral communications (report writing, presentation graphics), teamwork skills, and time management. The curriculum is taught by a multidisciplinary team of professors using a combination of traditional lecturing and alternative instructional methods including cooperative learning, activity-based class sessions, and extensive use of computer simulations. The goals of the curriculum are to provide:

- motivation and context for the fundamental material taught in the first-year mathematics and science courses,
- a realistic and positive orientation to the engineering profession, and
- training in the problem-solving, study, and communication skills that correlate with success in engineering school and equip individuals to be lifelong learners.

Faculty made the following course modifications as part of the experiment.

1) Faculty integrate lectures, homework assignments, projects, and examinations.
2) Faculty use structured cooperative learning, with several mechanisms in place to provide both positive interdependence and individual accountability.
3) Student teams that stay together for the entire semester work on both weekly homework and semester projects, and also do a lot of in-class work.
4) Chemistry and physics faculty make extensive use of experiential (discovery, problem-based) learning.
5) Faculty have assign two computers for every three students in the classroom. Students use word processing (Microsoft Word), data processing (Microsoft Excel, Maple), and presentation graphics (Microsoft PowerPoint).
6) Students completed midterm and final evaluations, and the teams regularly submitted self-assessments on how they were functioning—what they were doing well and what they needed to improve. In the opinion of the faculty, students think that the team structure is the strongest feature of the curriculum.

Interested faculty have raised numerous questions about implementation of integrated curriculum.

- Course scheduling - IMPEC was assigned dedicated sections of regularly scheduled courses, and block-scheduled the students into them. One of the faculty members did this sort of thing for his department and so knew the system handled the arrangements.
- Classroom scheduling - IMPEC specially equipped classroom that the Electrical and Computer Engineering Department allowed us to use during the morning, and they used it in the afternoon.
- Grade assignment, reporting and recording - IMPEC handles these tasks like regular courses. The integrated exam grades were counted in whichever courses were being integrated.
- College and department credit for faculty loads - This is a serious problem. It was a major overload on faculty time. A SUCCEED grant provided release time to the participating faculty departments and the faculty members themselves got some summer salary, but this will be a real sticking point when external funding goes away. We've about concluded that the full level of integration we achieved in the pilot study will be impossible to scale up at a research university.
- Different entry points - This was another sticky point. We got around it by only letting in students who were eligible to take the courses we were offering, which let out both students with AP credit for any of the courses and students who didn't qualify for them. If you're scaling up, you obviously need mechanisms like those just mentioned.
- Students who perform poorly - The few who failed any of the IMPEC courses had to drop back into the regular curriculum.
- Faculty development - Faculty learned to participate on interdisciplinary teams by doing it and growing from the experience. It would have been much easier if at least one faculty member had prior experience. Faculty learned to form and facilitate student teams by working on interdisciplinary teams that included someone who had the requisite knowledge and that willingness and ability to teach it to others. Another alternative would be short topical workshops.

Retention and grade point average data, on-track performance, performance on common examinations and examination questions, performance on standardized tests, attitudes and confidence levels for both students who completed IMPEC and matched comparison groups. The IMPEC students outperformed the comparison students on virtually every measure, with many of the differences being highly statistically significant. Details are given in [24]

University of Alabama

Description: The University of Alabama began offering an integrated freshman curriculum in the Fall of 1994. The initial pilot involved two semesters of integrated courses in chemistry, engineering, calculus, and physics. The FC mathematics courses differed a great deal from the traditional in that the FC courses used computer-based algebra systems. There was also considerable rearrangement and deletion of material. The FC curriculum replaced the traditional graphics and programming courses with new courses, Foundations of Engineering I/II. These courses introduced students to the fundamentals of engineering design, computer-based problem solving (both productivity tools and programming languages), and teaming. The engineering design projects and in-class problem solving exercises integrated concepts from chemistry, math, and physics and motivated the students with regard to the importance of these fundamentals.

Assessment: Assessment results of the first offering indicate that the FC students had a higher rate of retention within the College of Engineering (see Table 11), higher cumulative GPAs (2.427 vs. 2.186), a greater number of attempts in the second calculus course, (61% vs. 28%) and higher GPAs in the second calculus course (2.116 vs. 1.834) than a comparison group. Table 11 shows retention within the College of Engineering of the cohort of students who participated in the Foundation Coalition First-Year Curriculum in the Fall of 1994 compared to a comparison group of calculus-ready first-year students and the entire class of first-year students. Table 12 shows the same data for the cohort of students who participated in the Foundation Coalition First-Year Curriculum in the Fall of 1995.

Table 11. Retention within Engineering, University of Alabama, Fall 95 Cohort

	Foundation Coalition Cohort: N=36	Calculus Ready Comparison Group: N=86	All F94 COE Freshmen: N=309
Fall 94	100%	100%	100%
Spring 95	100%	92%	86%
Fall 95	86%	77%	69%
Spring 96	81%	66%	58%
Fall 96	78%	59%	49%
Spring 97	72%	57%	44%

Table 12. Retention within Engineering, University of Alabama, Fall 95 Cohort

	Foundation Coalition Cohort: N=61	Calculus Ready Comparison Group: N=69	All F95 COE Freshmen: N=324
F95	100%	100%	100%
S96	98%	96%	85%
F96	92%	74%	67%
S97	85%	70%	56%

In order to make the Foundation Coalition first-year curriculum available to more students at the University of Alabama, a pre-calculus track was added in 1996. Data has been gathered for both tracks since the pilot began and results have been very encouraging. In fact, the assessment results were a strong contributing factor to the recent recommendation by a faculty committee that the FC curriculum replace the traditional beginning in 1999.

The Drexel Engineering Curriculum

E^4 History: In 1989, Drexel University initiated a major curricular change entitled "Enhanced Educational Experience for Engineers" or simply E^4. Supported by the National Science Foundation, the GE Foundation, the Ben Franklin Partnership and several major U.S. corporations, Drexel aimed to fundamentally reform its undergraduate engineering curriculum and provide a widely recognized national model. Drexel faculty designed, developed, and tested a new freshman and sophomore engineering core curriculum emphasizing:

- interdisciplinary scientific foundations integrated with engineering applications,
- laboratory oriented experiential learning,
- extensive utilization of the computer to enhance learning,

- development of communications and effective teamwork skills,
- design as an integral part of the professional practice, and
- the culture of life-long learning.

In 1989, a cohort of 100 students was accepted into the experimental E^4 program. In 1990 and 1991 second and third cohorts followed, as the preceding classes continued with the sophomore year of the E^4 program and later joined the non-E^4 cohorts in their pre-junior year. The students entering the E^4 program were randomly selected from volunteers having generally similar levels of academic preparation and achievement as the non-E^4 cohorts. The success of the program resulted in the expansion of the E^4 program to two cohorts of 100 freshman students in the fall of 1992. The College of Engineering simultaneously began to examine the extension of the curricular revision to all five years with the first two years based on the E^4 experience. In 1993, an analysis was performed on the retention rates, GPA, and completion to degree. These results clearly showed the positive effects of the new curriculum on student performance and success rate. Following the unanimous faculty approval of the completely restructured five-year engineering curriculum based on E^4, three cohorts of 100 students were accepted into the new program. In early 1994, the Faculty Senate approved the new engineering curriculum. Finally, in the fall of 1994, E^4 was formally "institutionalized" as the new Drexel Engineering Curriculum, and all 500 + engineering freshman were admitted to the new program. Subsequently, in fall 1995 the program was evaluated by ABET and received full accreditation.

In early 1992, NSF funded the Gateway Engineering Education Coalition consisting of ten universities under Drexel's leadership for a five-year duration. Two of the key objectives of Gateway was to disseminate the E^4 innovations to the other coalition members by adapting and adopting, and building the new upper division curriculum (i.e., beyond the sophomore year) on this foundation. Drexel's efforts were concentrated in sharing and disseminating E^4 innovations within Gateway, and expanding the curricular reforms to the upper division (i.e., pre-junior through senior years) with Gateway support and assistance. Drexel will complete this process by the beginning of the fall term of the 1998-99 academic year by unveiling a completely new and restructured five-year coop-engineering program.

Description: The core of the Freshman Engineering program is built on two themes: curricular integration and Engineering Design and Laboratory. Typical freshmen take Mathematical Foundations of Engineering (MFE), Physical Foundations of Engineering (PFE), Chemical & Biological Foundations of Engineering (CBFE), Engineering Design & Laboratory (ED&L) and Humanities. In the three yearlong courses, MFE, PFE and CBFE, topics of mathematics, physics, chemistry and biology are presented from an application and engineering perspective. For example, while dealing with static equilibrium, the relevance and application to bridge and structural design are invoked. While introducing the topic of electrochemistry, production of aluminum from bauxite is introduced. While presenting the topic of integral calculus, engineering design is often used as a motivator. The basic tenant of Drexel's approach is that when fundamental concepts are put into engineering and practical applications context, the students find the topic to be more interesting therefore learn and retain better. (It should be noted that Drexel offers a full five-year Co-op program that requires twelve ten-week quarters of academic work and six quarters of Co-op assignments. Freshman and senior years require three quarters of academic work, while the sophomore, pre-junior, and junior years consist of alternating six-month periods (i.e., 2 quarters) between school and industry.)

The humanities are integrated into the freshman curriculum. Humanities faculty coordinate the content of the course with all other course instructors. In addition to the typical freshman humanities course content, students write journals, essays and poetry related to science and engineering. They read about scientific discoveries, the practice of engineering, engineering projects and failures, and address the environmental and social impacts of engineering. Books to be read as part of the course are selected with science or engineering as a theme. During class discussion, a science or engineering faculty member participates in the class with the humanities instructor.

A significant element of Drexel's integration theme is in the implementation. In nearly every freshman engineering course the students are exposed to instruction or recitation by an engineering faculty member. Such exposure enables discussion of engineering-relevant examples in class and provides a unique forum for students to interact with engineering faculty.

In the ED&L, a yearlong engineering design and laboratory course, students are given instruction to develop computer skills, experimental skills, design, and presentation skills. The modules are organized to develop competency in the use of such software as CAD, Maple and others, conduct and report (written and oral) experimental investigations and to complete a design project ending with a formal presentation to the college and writing of a report. Students work in groups of three to five. Students either generate their own project or select from a list of projects/faculty advisors. The design group works on the selected project over a four-month period, straddling almost all three quarters. A large fraction of the students have reported very positive Freshman design experiences which integrates the students' Freshman year both academically and culturally.

Assessment: E^4 established a dramatically different approach to the engineering educational process than the traditional programs that were widespread and dominant for over the last forty years. One of the outcomes of the E^4 program manifested itself in improved retention of engineering students, both within the College of Engineering as well as the University. The key factors that contributed to the improvement of retention may be listed as follows:

- A new and revolutionary academic paradigm was successfully created in which the general environment and all academic activities focus on the students as emerging professional engineers from the very beginning of the educational process.
- Engineering is up-front, with Engineering Design and Labs serving as the key element of experiential learning and integration of basic engineering sciences, engineering and humanities, based on projects that provide the context for engineering problem solving. Integration of theory and practice in engineering and science is perhaps the most critical factors in improving the retention rates by emphasizing the engineering experience early on.
- Faculty's primary role as a mentor and a facilitator to establish a community of learners.
- Close faculty-student interaction through regular meetings of student cohorts with faculty teams. This creates a community feel and esprit de corps and strong identity as a "team of engineers". This is strengthened by the close interaction between the members of the engineering, science, math and humanities faculty team.
- The yearlong emphasis on design during the first-year begins with a "first-week" design competition held in public with general participation. This reinforces the "engineering focus" and the "team project concept" in an exciting fashion.

The E^4 program was evaluated with the voluntary participation of 800 students and 60 faculty members over a six-year period. The first part of the evaluation process was based on a variety of quantitative methods and written instruments developed by the faculty and focused on the following elements: 1) student attitudes, level of preparation, abilities and maturity, 2) effectiveness of different curricula and methodologies, and 3) internal consistency among course objectives, subject matter, methodology and student ability. The second part focused on the understanding and measuring the complexities of change processes, which involved qualitative evaluation to capture the underlying processes of the students' educational experiences. Student journals were examined, as well as in-depth interviews held for both E^4 and traditional engineering students. The results of the evaluation were very positive and showed E^4 students developed excellent to outstanding levels of communication, laboratory and computer skills. The E^4 students also had, in general, higher grade point averages (see Table 13), improved progress rates (see Table 14), and higher retention rates [Figs. 10-14] than their counterparts in the traditional program. Perhaps most importantly, many indicated in their written commentaries that they had begun to sense that the practice of the "engineering profession" would be personally exciting, rewarding, and enjoyable.

Table 13. Drexel E^4 Cumulative Grade Point Average Comparison

	1988 Cohorts		1989 Cohorts		1990 Cohorts		1991 Cohorts	
Term	E4	Control	E4	Control	E4	Control	E4	Control
1	2.91	2.70	2.90	2.39	2.79	2.61	3.06	2.72
2	3.01	2.70	2.80	2.36	2.90	2.50		
3	3.08	2.80	2.95	2.49	3.00	2.52		
4	3.11	2.80	2.97	2.51	2.99	2.62		
5	3.24	2.80	3.02	2.61				
6	3.22	2.95	2.96	2.68				
7	3.24	2.94						
8	3.24	2.93						

Table 14. Drexel E^4 Progress Comparison

	1998 Cohorts		1989 Cohorts	
	E4	Control	E4	Control
On Track	58%	35%	74%	33%
Changed Major	5%	11%	1%	2%
Withdrew	9%	18%	4%	12%
Dropped	0%	7%	0%	1%

A closer look at the quantitative measures compiled for the cohorts from the E^4 and traditional tracks show a clear trend favoring the performance of the former. Table 13 compares cumulative GPA's for the two cohorts labeled E^4 and Control. The GPA for the E^4 cohort is consistently higher (between 0.21 and 0.51) than the Control cohort having similar academic backgrounds, both while they were in their separate tracks (i.e., terms 1-5) and subsequently when the classes merged following the sophomore year. Table 14 shows that for the 1988 and 1989 cohorts, the "on track" progress to degree was significantly higher for the E^4 cohort when compared to the Control cohort.

Data on retention by term (including co-op terms), for the first four freshman classes (1989-1992) show exhibit similar retention trends for the E^4 and Non-E^4 cohorts. Comparison of the final retention rates for the freshman class of 1989 (i.e., graduating class of 1995) exhibit 23.4% higher retention for E^4 students in engineering (68.4% vs. 45%), and 18.1% higher retention for E^4 students in the University (75.5% vs. 57.4%). While the E^4 students have significantly higher retention rates in both categories, it is noteworthy that the relative retention rates within engineering are even higher than within the University. It is clear that within minor statistical variations these general trends were maintained for the later freshman classes (Figs. 1-4).

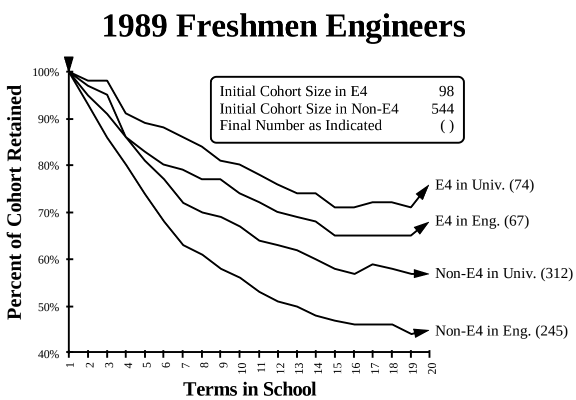

Figure 1. Retention Rate of Students E4 vs. Traditional Students; Freshmen Class of 1989

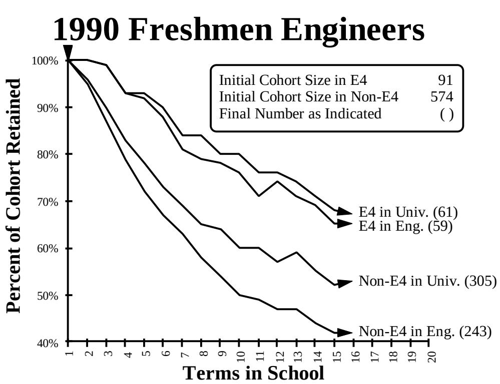

Figure 2. Retention Rate of Students E4 vs. Traditional Students; Freshmen Class of 1990

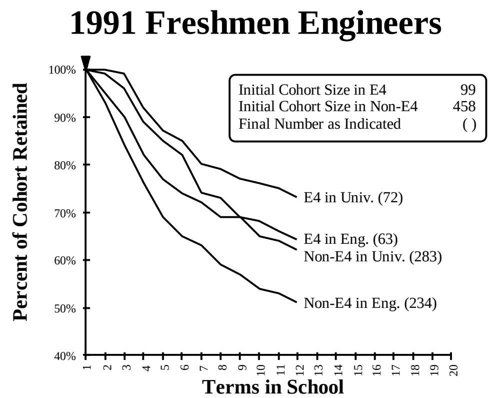

Figure 3. Retention Rate of Students E4 vs. Traditional Students; Freshmen Class of 1991

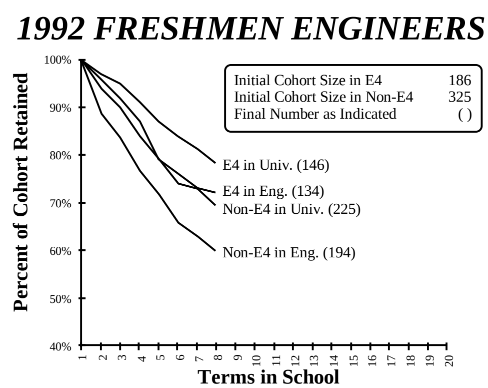

Figure 4. Retention Rate of Students E4 vs. Traditional Students; Freshmen Class of 1992

Conclusions

Diverse integrated first-year curricula have been piloted at a number of different schools across the engineering coalitions. Assessment results indicate a positive impact on student retention and learning. Furthermore, design alternatives have been abstracted from the different pilots. Institutions considering an integrated first-year curriculum should explore the different alternatives to identify a configuration that fits the student population and culture.

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