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Integrating Skills, Transforming Culture: Reforming all Engineering Curricula in SEAS

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Introduction

The School of Engineering and Applied Science (SEAS) \cite{1} at Miami University of Ohio is undergoing significant growth by adding new majors and increasing enrollment. To support this growth SEAS has developed a unified strategy for reforming all engineering (existing and proposed) curricula at SEAS by integrating academic skills throughout the four years and enhancing the learning culture by utilizing teams comprised of students, faculty, and industrial representatives. This reform will enhance the quality of academic experience for SEAS students and boost the current engineering pedagogy \cite{2}, while building upon the current strengths of Miami’s liberal undergraduate education.-The goals of this strategy are to provide for the following divisional reform: 1) develop and implement a fully integrated first-year curriculum for all majors in engineering and computing; 2) design and develop skills threads for each major (existing and new) to build upon the first-year experience by incorporating hands-on, team-based, inquiry-centered learning in an environment utilizing modern computing tools and methods; and 3) create an interdisciplinary community to build an enhanced intellectual climate by providing avenues for collaboration amongst all majors in engineering and computing in SEAS at Miami. This will contribute to the university’s goal of enhancing intellectual climate for effective learning and will provide a benchmark for educating engineers of the twenty-first century.

An integrated curriculum will be created within SEAS at Miami University by incorporating threads of learning throughout the four years and by enhancing the academic

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climate of inquiry-based problem solving. This reform will improve the engineering curricula at a time when the number of engineering majors at Miami is increasing and will also significantly advance the pedagogy of educating engineers within a broad liberal arts education. This engineering education reform will promote a stronger environment for teaching and learning by providing a bridge between science and engineering; SEAS students will obtain an in-depth theoretical understanding of engineering fundamentals, apply them to real-world problems, and communicate them with a broad liberal arts perspective. This reform will further the integration of research-based learning and hence improve our graduates’ abilities to analyze, interpret, and synthesize solutions for real life problems of the society.

**Background**

In 1999, Miami University established an ambitious set of goals designed to help Miami University become a premier undergraduate university by its two hundredth anniversary in the year 2009. Two of those goals in Miami’s “First-in 2009” [3] plan are to develop a curriculum for the twenty-first century and to strengthen academic standards and enrich campus intellectual and cultural life. The first-year undergraduate experience was identified as one tangible area where many assets currently exist which can be readily built upon and strengthened to advance the overall intellectual climate of the campus. Historically, Miami has established a strong first-year experience with many successful and innovative first-year initiatives: a long-lasting summer reading program, a focus on liberal education, an expanding honors program, some existing first-year seminars, themed living and learning communities, residentially-based courses and advising, and many leadership development and involvement opportunities in student organizations. Because expectations about learning and college life are often set in students’ first undergraduate semester, it is imperative that faculty, staff and administrators collaborate to enhance first-year students’ academic experience and send them clear and consistent messages about the importance of intellectual challenge and academic life.

In 2002, a new committee was charged to “Explore ways to enhance the holistic First-Year Experience, connecting existing programs and strengthening the interaction between Student Affairs and Academic Affairs. Through campus dialogue, identify some priorities for short-term enhancements and some longer-term suggestions for potential new and expanded programs.”

In response to this charge, the committee chose to create a model or framework for enhancing the intellectual experiences for first-year Miami students that focuses on key themes or goals which span and link students’ in-class and out-of-class experiences. The framework draws from relevant theories of students’ intellectual development as well as professional research that define best practices for the first-year experiences throughout the nation and on this campus [4]. The mission of this university committee is to raise the intellectual standards and enrich campus intellectual and cultural life for first-year Miami students. To do this, students must be challenged to deepen learning in their courses, in their professions, and in all facets of their lives. The resulting student goals to meet this mission are:

- Invest considerable time in your own and your peers’ academic learning.
- Identify your educational goals, and make purposeful choices about your major, courses and extracurricular experiences to advance those goals.
Seek new challenges and take informed risks.
Understand that knowledge is gained through making connections with faculty and other students and among different disciplines, courses, and experiences.

The resulting faculty goals to meet this mission are:
Set high expectations for learning in your courses.
Reflect critically on your own teaching and students’ learning.
Enhance the role that the Miami Plan principles play in your courses, even in the large-enrollment ones. (*The Miami plan is a broad set of distributed course requirements which encourages students to think critically, engage with other learners, understand contexts, and reflect and act.*)
Develop a supportive relationship with students; challenge them to learn inside and outside the classroom.
Encourage yourself and students to take risks and try out new ideas and challenges.
Partner with others on campus to deepen students’ learning.

**Motivation and Objectives**

According to various studies [5, 6, 7, 8] including the Boyer Commission [9] and NSF Engineering Coalitions [10, 11, 12, 13], the engineers of the future must be well trained by making:
1. research-based learning a standard
2. an inquiry-based first-year
3. creative use of information technology
4. a multi-disciplinary capstone for integrating, broadening and deepening the total experience of the major

These statements form the basis of our reform within SEAS at Miami University [1]. Miami University and SEAS are committed to training engineers for the future, and they encourage faculty to incorporate scholarship into curricula to provide students with an intellectually stimulating, interactive and innovative learning environment. SEAS strives to serve society by providing high-quality undergraduate education in the fields of computing and engineering that is integrated with Miami University’s traditional strength in liberal education. The School is recognized for anticipating emerging needs and for partnering with industry to create solutions that benefit society. It has historically been a model for the synergism between professional and liberal education, for the synergism among scholarship, teaching, and service, and for good citizenship within the university and society. SEAS works continually to assess and improve teaching, learning, and critical thinking; to encourage scholarship and creativity; to contribute to the accumulated knowledge of the centuries; and to promote the continuing intellectual growth of our community.

With the growth in SEAS, a common first-year year is being planned to maximize student exposure to a wide breadth of engineering fields; to provide students with the flexibility to choose the engineering discipline that peaks their interests and to prepare a foundation for the threads of skills (such as ethics, problem solving, communication) in the four-year curricula [2].

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The recent growth in SEAS has created a need and opportunity for a reform of undergraduate engineering education at Miami. This broad reform is focused on the following two activities: firstly, create a new first-year curriculum to replace the current department based curricula and to provide a unique, integrated first-year experience; secondly, an integration of a skill set throughout the four year curricula in all engineering majors. The goals of this project are:

**Goal I.** Plan, design, create and assess an integrated first year curriculum

**Goal II.** Design and develop threads for each major (existing and new) to build upon the first year experience

**Goal III.** Create an interdisciplinary community with an enhanced intellectual climate by providing avenues for critical thinking

The specific issues addressed to achieve the specified goals of this reform are listed in Table 1.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.) Plan, design, create and assess an integrated first year curriculum</td>
<td>Develop a core interdisciplinary first year engineering curriculum for all engineering majors.</td>
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<td>Develop a first-year experience that fosters active learning and requires the development of engineering problem solving skills.</td>
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<td>Develop projects to engage students in interdisciplinary team-based hands-on design problems.</td>
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<td>Develop first year activities that bridge the gap between engineering applications and the underlying mathematics and science.</td>
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<tr>
<td>II.) Design and develop threads for each major (existing and new) to build upon the first year experience</td>
<td>Identify the set of essential skills which will be explicitly connected throughout the curricula.</td>
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<td>Develop plans to integrate this set of essential skills throughout the curricula.</td>
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<td>Develop a framework to foster research based learning in SEAS.</td>
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<td>Explore the possibility of interdisciplinary capstone sequence that requires the application of essential skills on team-based practical problems.</td>
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<tr>
<td>III.) Create an interdisciplinary community with an enhanced intellectual climate by providing avenues for critical thinking</td>
<td>Design activities that promote a learner centered education community.</td>
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<td>Establish and/or strengthen collaborations with local industries to enhance the engineering education in all four years through seminars, field trips, and on-site projects.</td>
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<td>Plan a comprehensive engineering seminar program spanning all four years and all majors.</td>
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Explore collaborations with K-12 programs providing opportunities for undergraduate students to learn by teaching.

Identify opportunities for infusion of modern computing methods and technologies into the whole experience.

This reform will provide an atmosphere of cooperative learning and excitement in science and engineering within SEAS as well as within the local communities. SEAS is now faced with the challenge of planning this common first year for all first-year students enrolled in SEAS. This common first year engineering experience will incorporate common threads of communications, leadership, team-based problem solving, design, and ethics. The threads introduced in the first year will be the foundation for the integration of threads throughout the four-year curricula for each of the programs offered in SEAS. The set of skills that will be enhanced by incorporation of this integrated experience will be determined by a team of faculty, students and advisory council members. They will include team building, leadership, communication, application of mathematics and science to real-world problems, computer skills, critical thinking, and research-based problem solving skills. Some of the objectives of this reform are also listed in Table 2.

Table 2: Objectives of Reform in SEAS

<table>
<thead>
<tr>
<th>Goals</th>
<th>Objectives</th>
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</thead>
<tbody>
<tr>
<td>Goal I</td>
<td>To enable students to acquire essential skills</td>
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<td></td>
<td>To enable students to think critically</td>
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<td></td>
<td>To engage students in research based problem solving</td>
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<tr>
<td>Goal II</td>
<td>To enable students to build upon the essential skills</td>
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<td></td>
<td>To enable students to conduct independent inquiry based problem solving</td>
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<tr>
<td>Goal III</td>
<td>To enable students to solve interdisciplinary problems</td>
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<tr>
<td></td>
<td>To enable students to utilize modern computing methods for problem solving</td>
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<tr>
<td></td>
<td>To create a community of active learners within SEAS</td>
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</tbody>
</table>

Plan of Action

Integrated first-year curriculum: These courses will be common for all majors and will focus on process more than discipline specific content. The intention of these courses will be to enhance the freshmen’s understanding of engineering and computing and the differences that are offered by each specific major within SEAS. The course environment will be welcoming to the new student and will offer a forum for students to develop a sense of community within SEAS and Miami. Soft skills such as teamwork, communication, and ethics will be emphasized in EAS 101 which is to be a 1 credit hour course. This course will introduce all students to the computing and engineering professions and their role in society. Students will explore the common bonds and unique features of different disciplines offered by SEAS. The students will also be engaged in an active forum for dissemination and discussion of ideas, topics, and issues related to engineering and engineering education at the school, Miami University, and the community. The subsequent course, EAS 102, is to be a 3 credit hour course that provides hard skills related to specific
engineering disciplines. These hard skills include applied mathematics, science, engineering and computing. These hard skills are in addition to concepts, techniques, and skills learned in other required courses in mathematics and science. The students will learn creative concepts of problem solving using inquiry-based research. The use of computing and engineering tools and methods for evaluating and synthesizing data for the solution of engineering problems will also be emphasized. Oral and written communication using various technological innovations (e.g., Tablet PC’s) will be initiated in the first-year and will be integrated through out the curricula. These courses have a potential to be the trademark courses for SEAS, making engineering at Miami unique. This first-year experience will lead to student’s intellectual, creative and ethical engagement of ideas; and will strengthen the relationship between faculty research and learning of students.

An example of innovative approaches to be incorporated in these courses is in knowledge sharing and teamwork to solve problems of multidisciplinary nature using various tools of information technology. This will involve using Tablet PC’s in all stages of the problem solving exercise. The various stages of an engineering problem solving include brainstorming, research-based design solutions, trade-off analysis as well as documentation and presentation of results. This use of innovative technology will promote active approaches to learning and encourage students to use writing, and other forms of communications and creative expressions to construct knowledge. Another innovative approach to be implemented is to involve upper class students to assist first year students in learning and research to promote an active environment.

Integrated Threads: This reform will build upon the first-year experience by integrating a key set of skills through out the curricula. Communication skills, logical problem solving, design methods and ethics, trade-off analysis, and computing methods are possible skills that will be integrated. Each of these skills will form a “thread”. These threads will be incorporated in the curricula by appropriately selecting the courses for each major for a unifying experience. This experience will culminate by a multidisciplinary capstone senior design project to further embellish the overall experience and training of our students.

In this plan, integration of threads in the curricula to enhance active learning is achieved by the construction of a four-year model that builds upon a foundation for selected skills developed in the first year (Figure 1). Each of those skills is then built upon in each successive year, maintaining community across disciplines, and encouraging engagement between upper and lower division students. The generic model allows a curriculum to be built upon curricular objectives. Learning based activities that meet these objectives are initiated in the first year and built upon in each engineering major during successive years of the students’ education. In the final year, the capstone course provides an interdisciplinary experience to demonstrate the breadth of engineering skills that students have acquired to meet curricular objectives.

Community Building: The links between the first year experience and the thread-based curricula can be built upon by creating common experiences involving students from all four years and all engineering disciplines. This interdisciplinary community will foster the intellectual climate by providing additional avenues for critical thinking. One aspect of this reform will be to explore
the possibility of a seminar series for all students in SEAS, which will further highlight the relationship between the theoretical foundations and real world engineering experience.

The engineering environment will be further enhanced by practicum experiences throughout the student’s education. Practicum experiences may include plant tours, industry based course projects, and work experiences. Furthermore, the seminars and practicum experiences will facilitate community building across upper and lower division students. The timeline for this planning project is given in Table 3. To achieve the objectives as proposed previously it is essential to obtain feedback from all the customers of SEAS. These customers include students, employers and the community. Therefore, a detailed plan for obtaining feedback, evaluation and benchmarking is also an essential part of this reform.

Table 3: Timeline for the Planning Phase

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Time Line</th>
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<tbody>
<tr>
<td>Develop curricula for integrated first-year experience including new EAS 101 and EAS 102</td>
<td>Spring 04</td>
</tr>
<tr>
<td>Visit of the consultant</td>
<td>Spring 04</td>
</tr>
<tr>
<td>Identify threads to be integrated in selected courses</td>
<td>Spring 04</td>
</tr>
</tbody>
</table>

Figure 1: Illustration of Integrating Threads (EAS: Engineering and Applied Science, MME: Manufacturing and Mechanical Engineering, PSE: Paper Science and Engineering, ECE: Electrical and Computer Engineering)
Identify benchmarking peer institutions/programs | Spring 04
Approval of the pilot EAS 101 and EAS 102 courses | Spring 04
Identification of computing tools for integration | Spring 04
Development of survey for feedback | Spring 04
Field trips and visits to selected institutions | Summer 04
Re-visit of the consultant | Summer/Fall 04
Pilot offering of EAS 101 and EAS 102 | Fall 04
Develop plans for integrating specific threads in each major | Fall 04
Evaluation and feedback from various sources | Fall 04
Developing multi-disciplinary research-based capstone senior design experience | Fall 04
Develop a seminar series for the SEAS | Fall 04

An Example Working Model
The reformed integrated first-year curriculum will provide a foundation for the overall four-year reform. The foundation provided in the first year will be built upon in each successive year by incorporating specific threads of knowledge through out the four-year experience for each major in SEAS. Some of these concepts are in place in the Department of Manufacturing and Mechanical Engineering curriculum (manufacturing engineering major). This department was one of the eight departments selected across the nation by ABET in 1998 to test ABET 2000 guidelines. This curriculum involves integration of specific threads (skill sets). Sample curricula for mechanical, manufacturing and engineering management integrating threads through out the four years are given in Figure 2. This specific sequence of courses integrates modeling, design, and communication skills through out the curricula and enhances the intellectual climate. It is important to note that this is an example of integration of threads. Several threads run throughout the curricula. These threads involve distinct but overlapping set of courses. For example, design and modeling are integrated by involving students in problems and methods of design and model development with increasing complexity in each successive year. Similar details based on this paradigm for all majors will be developed during the planning phase of this project. Each course in this specific sequence is designed to implement the highlighted threads. The course objectives are developed such that design, modeling and communication skills are an integral part of each course in this sequence. This model ensures that students will not only get an opportunity to practice these skills in each year, but that these skills will be built upon in each successive year.

Feedback, Evaluation and Bench Marking
In order to ensure continual improvement, this reform will be assessed on an ongoing basis. There are several assessment methods available at Miami University to evaluate this reform. Evaluation will be implemented using internal and external reviewers including industry executives, undergraduate students, faculty, university staff, and consultants. Review of the curriculum reform plans will be conducted by three sources: the School of Engineering and Applied Science (SEAS) External Advisory Council (EAC), Miami’s First Year Experience Committee, and an external consultant from a peer institution. The SEAS EAC meets biannually and consists of industry executives who will review the project from an industry perspective, ensuring that curricular change meets industry needs. Miami’s First Year Experience Committee

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which was formed to facilitate the “Choice Matters” program will be asked for feedback and suggestions. This committee will also analyze the program in terms of its integration into other aspects of the student’s first year experience at Miami. The external consultant with credentials in engineering education-based assessment from a peer institution will be hired to review the project plan and provide feedback for improvement.

![Diagram](image)

**Figure 2: A Working Model of Threads**

The Center for the Enhancement of Learning and Teaching (CELT) [14] at Miami University promotes the enhancement of teaching and student learning. CELT will provide a trained evaluator to conduct a small group instructional diagnosis, which will determine the students’ impression of the course, the instructor and the materials. During the planning stage of this curricular reform, course surveys will be developed with the assistance of CELT to effectively evaluate the outcomes against the course implementation.

The final source of assessment will be the students and faculty involved in the pilot courses. Standard assessment tools such as student and faculty course evaluations will be analyzed. In addition the program related survey and small group discussions will be utilized to acquire additional student feedback. The assessment practices that will be employed are scheduled as follows during the planning phase.

**Spring 2004**

- Development of a project related assessment survey for first year courses in conjunction with CELT.
• Review of preliminary plans for curricular changes by the SEAS External Advisory Council as well as Miami’s First Year Experience Committee.
• Peer review of preliminary plans of curricular changes by external consultant from a peer institution.

**Summer 2004**
• Visits to selected benchmarking institutions

**Fall 2004**
• Review of final plans for curricular change by the SEAS External Advisory Council.
• Review of final plans for curricular changes by Miami’s First Year Experience Committee.
• Student feedback of pilot course through Small Group Instructional Diagnosis administered by CELT.
• Student and faculty evaluations of pilot course offering.
• Peer review of pilot course and revised program plans by external consultant from a peer institution.

Possible candidate institutions for benchmarking might include institutions which participated in the NSF Engineering Education Coalitions such as Ohio State University, Rose-Hulman Institute of Technology, Duke University, and Dartmouth College.

**Conclusions**

A strategy for reforming the curricula in the School of Engineering and Applied Science at Miami University is presented in this paper. This strategy is designed to enhance the educational environment within SEAS as our enrollment increases and to provide an integrated first-year curriculum for all majors. In addition this strategy will also incorporate cognitive skill threads throughout the curricula to build upon the integrated first-year experience. Moreover, this strategy is an effort to create an intellectual interdisciplinary community within SEAS to provide an enhanced collaborative learning environment. Feedback, assessment and continuous improvement of all components of this strategy will be conducted. The results of assessment will be presented in the future.

**Acknowledgements**

Authors would like to acknowledge Dr. Osama Ettouney (Chair, Department of Manufacturing and Mechanical Engineering) for his valuable comments in developing this strategy.

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   http://www.eas.muohio.edu


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10. The Foundation Coalition Website: http://www.foundationcoalition.org/.


Biographical Information

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