

The Integrated Civil Engineering Curriculum: The Gap Between the Blackboard and Business

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Abstract:

Civil Engineering curricula have been criticized for not effectively preparing engineering students for the workplace. Industry wants technically competent students who also can work as part of teams, manage projects, communicate well and understand the economic, social and political context of their professional activities. The Accreditation Board for Engineering and Technology, with Engineering Criteria 2000 has joined industry's cry and requires programs to show evidence graduates are prepared for the job market. Iowa State University developed initiatives within the Civil & Construction Engineering (CCE) Department to address these demands in a new integrated learning based curriculum.

The new integrated curriculum includes new courses, revisions to existing courses, and collaborative efforts with the Department of English. Some of the new courses focus primarily on professional practice skills as applied in industry. Other new courses offer a synthesis to tie other non-departmental courses to civil engineering practice. Collaboration efforts with the English Department have resulted in the development of a Technical Communication Guide, faculty workshops on effective teaching of communication within the CCE curriculum, and the review and modification of several courses and assignments.

The new curriculum consists of a series of twelve integrated courses beginning in the freshman year and ending in the senior year. Some of these courses cover topics that were included in previous civil engineering (CE) curricula, such as:

- Civil Engineering Projects
- Engineering Problems with Computational Laboratory
- Graphics for Civil Engineering
- Civil Engineering Capstone Design

However, the new curriculum places a strong emphasis on the following professional practice skills:

- Leadership Skills
- Team Processes in CE Practice
- Interpersonal Skills
- Communication Skills
- Project Management
- Agreements and Contracts
- Continuous Quality Improvement
- Business Management
- Professional Ethics

Implementation of this new curriculum began in the spring of 2001. The planning, design, and implementation of this integrated curriculum will be discussed in the paper.

Introduction:

Educators at Iowa State University (ISU), like many other academic institutions, have been successful in teaching the technical aspects of civil engineering. However, industry is now demanding engineering graduates with more than superb technical capabilities – they want students who have business acumen. Rapid changes in the business world, organizational structures, technology and lifestyles are introducing a significant rethinking of the role of the civil engineer. The role they perform has broadened significantly in scope and engineering education must change in response.

The Accreditation Board for Engineering and Technology (ABET), with Engineering Criteria 2000 (EC 2000), requires programs to show evidence graduates are prepared for the job market in the 21st Century. Engineering programs now must demonstrate that their graduates have an understanding of professional practice issues in addition to proficiency in specific subject areas that are tabulated in the civil engineering program criteria (Koehn 2000).

The American Society of Civil Engineers (ASCE) Program Criteria notes that graduates must demonstrate proficiency in the technical areas. It also requires graduates have an understanding of professional practice issues. These include the ability to effectively communicate, manage projects, pursue life-long learning, and apply critical thinking.

Many agree that an engineer is hired for her or his technical skills, fired for poor people skills, and promoted for leadership and management skills (Russell and Yao 1996). Because of this we have to make decisions today about what to teach future engineers and how to prepare them for an increasingly complex workplace without compromising the hard-won quality of our existing program.

To address this need for the business acumen, or the application of professional practice skills, at ISU an integrated curriculum was developed. The integrated curriculum uses both existing and new courses to teach the business and performance skills that enable engineers to optimize application of their technical skills.

Initial Action:

The need to enhance the professional practice skills of students in engineering has been outlined by the educational and professional community. To address these needs, the CCE Department developed initiatives in the fall of 1997 to evaluate the civil engineering curriculum and determine changes needed to accomplish the following objectives:

- Meet new university, college and department vision and mission statements.
- Meet changing external CE industry needs.
- Meet/Exceed ABET EC 2000 accreditation criteria.
- Develop an integrated learning based curriculum.

As a first step in this process, a task force was appointed and charged with designing a civil engineering curriculum that met all of the objectives.

Planning for the Revised Curriculum:

Since many others in academia have heard similar cries from industry and evaluated ABET requirements, the task force reviewed literature and programs for learning lessons and potential ideas. Additional data were collected through questionnaires designed to determine future needs in the revised curriculum and to benchmark the current skills of ISU CE graduates. Questionnaires were sent to ISU CE alumni and employers of ISU CE graduates. Lastly, in the initial data collection process, the ISU CE Industry Advisory Council conducted a review of the CE curriculum to determine areas for potential enhancement and modification. The suggested enhancement areas from the council included:

- Communicating effectively, especially with non-engineers
- Utilizing and effectively participating in team processes in CE practice
- Understanding the importance of multi-disciplined project teams
- Incorporating technical communication in courses
- Utilizing practitioners to lead classes
- Exploring the viability of offering “just in time” course work

Interim Report, Subcommittee on Curriculum, ISU CE Advisory Council, January 7, 1997

The results of the academia review, questionnaires, and ISU CE Advisory Council recommendations were analyzed with the ABET EC 2000 criteria and ASCE program criteria. From this analysis, the Task Force developed a list of perceived enhancement areas for the CE curriculum:

- Understanding cost estimating, planning, and scheduling
- Utilizing critical thinking
- Communicating effectively to engineers and non-engineers
- Understanding the importance of timely and effective communication
- Working effectively within multi-disciplinary teams
- Understanding the necessity for high professional and ethical standards
- Having basic knowledge of business and management principles
- Interacting with practicing professionals
- Developing leadership skills

To enhance these areas and meet, or exceed, the criteria set forth by ABET, ASCE, and industry, the task force revised the CE undergraduate academia program goals and objectives. These revised goals and objectives were presented and approved by the ISU CE faculty in November 1998. The program goals included the ABET Criteria 3 a-k criteria but also added additional program goals unique to the ISU program.

The task force developed learning models to accomplish the revised academic program objectives. These were patterned after the U.S. Military Academy West Point learning models and went through several revisions as the task force moved through the process of planning the integrated curriculum.

Designing the Integrated Curriculum:

During the design of the integrated curriculum, the task force needed to assure other concurrent issues were addressed:

- The curriculum meets the program goals and objectives developed from ABET, ASCE, CE Industry Advisory Council, academia review, and questionnaires.
- The necessary course material is integrated into the appropriate areas or applications.
- The technical content of the program is not adversely affected.
- The program is moving toward a learning based program.
- Strategies and a mechanism for external course assessment are developed.

The Task Force investigated several methods for integrated curriculum design and adopted a model that incorporates a set of integrating core courses to “link” and integrate the traditional courses in a systematic fashion. Figure 1 presents this concept utilizing the existing 1997-1999 catalog. This concept was finalized and approved by the CE faculty and approved in October 1999.

In order to complete the linking, or integration, and meet all the objectives of the revised curriculum, the task force prepared the new integrated curriculum for the 2001-2003 catalog. The concept for that curriculum is illustrated in Figure 2.

The new, integrated curriculum consists of a series of twelve courses, beginning in the freshman year (semesters 1 and 2) and ending in the senior year (semesters 7 and 8). A brief description of the integrated course topics is presented in Figure 3.

Five of the twelve integrated courses are new courses (203, 204, 303, 304 and 403). The other, existing integrated courses were revised to meet the required objectives. Additional revisions were incorporated, such as integrating technical communication and engineering economics into the CE curriculum. Hence, some of the previously required courses were eliminated from the curriculum.

































Semester	Required Non-Departmental Courses	Required Integrated Courses	Other Required CE Courses
8	 	<input type="text"/>	 
7	 	452/486	 
6	 	<input type="text"/>	 
5	 	<input type="text"/>	 
4	 	295	 
3	 	<input type="text"/>	 
2	 	<input type="text"/>	 
1	 	<input type="text"/>	 

Figure 1. Concept of the Integrated Curriculum for 1997-1999 Catalog

































Semester	Required Non-Departmental Courses	Required CE Integrated Courses	Other Required CE Courses
8	 	403/486	 
7	 	453/485	 
6	 	304	 
5	 	303	 
4	 	204	 
3	 	203	 
2	 	104/170	 
1	 	101/160	 

Figure 2. Concept of the Integrated Curriculum for 2001-2003 Catalog

COURSE	CONTENT
Engr 101	(R cr) Introduces objectives, learning process and provides access to engineering professionals.
CE 104	(1 cr) Introduction to CE projects and practices. Field trip. Beginning of technical writing instruction. Teams and ethics.
CE 160	(3 cr) Engineering problem solving and presentation. Use of spreadsheets for problem solving. Graphing and visual design. Start of engineering economy instruction and application.
CE 170	(2 cr) Graphics with applications in hand and AutoCAD methods. Computer aided modeling for civil engineering.
CE 203	(2 cr) Integration of topics from mathematics, chemistry, physics and engineering mechanics in civil engineering applications. Continued work with technical writing and engineering economy. Participation in ASCE student chapter.
CE 204	(2 cr) Application of mathematics, chemistry, physics, engineering mechanics and engineering economy to advanced civil engineering problems. CE technical reports. Sophomore assessment.
CE 303	(2 cr) Professional issues in civil engineering. Leadership, team building and TQM. Engineering business management. Project management. Engineering economy applications. Engineering ethics, law and regulation.
CE 304	(2 cr) Civil engineering design and construction. Project planning. Managing design. Agreements and contracts. Construction. Project management and communication. Case studies. Junior assessment.
CE 403	(R cr) Outcomes assessment. Review and assessment of the CE curriculum from senior students.
CE 453	(4 cr) Capstone highway design. Group projects.
CE 485	(2 cr) Capstone planning and design including environmental impact and preliminary design. Synthesis of previous coursework in a group project.
CE 486	(3 cr) Capstone design including final design, cost estimating, and planning and scheduling. Synthesis of previous coursework in a group project.

Figure 3. Integrated Courses Listing

Implementing the Integrated Program:

There are a variety of implementation issues associated with the revision of a curriculum ranging from the need to create new courses to the lack of an adequate text. Most of the issues are independent, but all result from the typical problems associated with first time innovation and implementation. Creation of five new courses and a new curriculum is problematic at a time when resources are being cut back. It is important to always focus on the benefits provided by the new program to continually obtain the support necessary to move forward.

The CE faculty approved the new Integrated Curriculum in May 2000. In the fall of 2000, the Task Force advertised for an instructor/coordinator in charge of the integrated curriculum. The criteria stated the position required a dynamic individual that would be able to teach and develop new curriculum materials and the individual must be a professional engineer with a minimum of

eight years in industry to assure the business acumen would be integrated in a practical manner. The professional engineer hired brought 15 years of experience, as well as being a trainer in both business and performance skills.

After the new instructor/coordinator in charge of the integrated curriculum was hired, the task force was disbanded. A new Integrated Curriculum Committee was appointed to oversee, guide, assess and modify the integrated curriculum. One of the first tasks undertaken by this committee was contacting the ISU Department of English (English). Since a main component of the integrated curriculum is technical communication, assistance from English faculty was requested to integrate technical communication into the CE courses. The English faculty were appreciative that CE faculty had interest in enhancing technical communication within the revised curriculum and enthusiastically agreed to assist.

The initial collaboration efforts between the two departments started with workshops for CE faculty. These workshops covered such things as the writing-to-learn (e.g. describing a key civil engineering term from a reading assignment) and learning-to-write (e.g. applying rhetorical elements in a report) concepts; the design and application of technical communication assignments; effective teaching techniques; and assessment strategies for monitoring technical communication skills. Collaboration also led to the development of a CE Technical Communication Guide, a manual designed to provide students guidance on applying technical communication in civil engineering applications. The English faculty (one professor and one Ph.D. student) also participate in weekly meetings with the Integrated Curriculum Committee. In this environment, they have provided assistance in areas such as reviewing assignments in CE courses to achieve the course objective and identifying technical communication outcomes for specific courses and the curriculum.

Integrated Core Courses and the Teaching of Design:

The CE curriculum has a strong emphasis on design throughout the curriculum. At the senior level there are three courses (CE 453 - Highway Design and CE 485 and CE 486 – Civil Engineering Design I and II) that represent the capstone design experience. These courses build on the technical material and professional practice skills from all of the previous courses taken by the CE students. The integrated core courses illustrated in Figure 2 and described in Figure 3 will support the objectives of the senior capstone design classes by enhancing and applying the professional practice skills prior to the classes. Now students will be exposed to the application of effective technical communication, cost estimating, project scheduling, teamwork, leadership and business management prior to capstone design.

The CE students begin preparing for design applications in the capstone courses during their freshman year when they take Engineering 101 (Engineering Orientation), CE 104 (Civil Engineering Projects), CE 160 (Engineering Problems with Computational Laboratory), and CE 170 (Graphics for Civil Engineering). Within this year, they learn more about the civil engineering profession and problem solving techniques. They also become involved with such professional practice skills as technical communication, teamwork, professional ethics, and continuous quality improvement.

During the sophomore year, two new courses are taken by CE students – CE 203 and CE 204, Civil Engineering Synthesis I and II. These courses focus primarily on integrating other non-departmental required courses such as mathematics, chemistry, physics, and engineering mechanics in civil engineering applications. For example, students may be asked to analyze the corrosion of reinforcing bars in bridges to synthesize the application of chemistry in CE practice. Students also utilize teamwork, technical communication skills, continuous quality improvement, and business principles in these courses.

In the junior year, students take two more new courses - CE 303 (Professional Issues in Civil Engineering) and CE 304 (Civil Engineering Project Life Cycle). These courses are more business oriented and cover such topics as project stages, project management, leadership skills, team processes, technical communication skills, professionalism, professional ethics, and business practices and principles. Students apply these concepts in both, hypothetical and current, CE applications.

Finally, in the senior year, the students take the three capstone courses and CE 403, a course designed to obtain assessment information from the seniors prior to graduation. In the capstone courses the students simulate the workings of a small consulting engineering firm. They have a project with a real client assigned in the first week of classes. They must interview the client, determine the client needs, identify the engineering problems to be solved, identify alternative solutions, select the “best” alternative and ,then, design the system. These are intense courses that prepare students for the workplace environment. Students must face very open-ended problems, uncertainty in solutions, ambiguous and incomplete data, and a re-discovery of the written literature. They must also identify appropriate design standards and codes. Integration of previous knowledge is critical to the student success. The conclusion of the courses is development of a persuasive final report that convinces the client the proposed solution is the best one.

The integrated curriculum is designed to enhance the leadership and teamwork skills of the students. These are critical skills in the civil engineering design courses. In addition, the focus on improving technical communication (written, oral, and visual) provides a foundation for the reports and oral presentations in the senior capstone design courses. Ability to manage a design project is stressed in the integrated curriculum and is a key to success in senior design teams. Finally, the introduction of continuous quality improvement provides the background for the evaluation system in senior design that emphasizes high standards and continuous improvement.

Assessing the Program:

The first sequence of the integrated courses was offered in the spring of 2001. Hence, there has not been enough data collected to conduct an assessment study that measures how well the goals and objectives of the revised curriculum have been achieved. However, the data available so far does indicate a positive impact. In the future, the curriculum will be assessed through course evaluations, program evaluations, pre- and post-course surveys, questionnaires, and student learning portfolios. The information obtained will be used to continually improve the program.

Conclusion:

In an attempt to develop an undergraduate program that will remain relevant, attractive and connected to the civil engineering profession during these changing times, ISU faculty integrated professional practice skills with technical integrity in the civil engineering curriculum. The revised curriculum extends the undergraduate engineering education beyond knowledge generation and technical skills to the broad realm of business and personal skills. This will improve the ability of engineering graduates to work on teams, be effective communicators, be socially adept, manage projects, and be prepared for leadership roles.

Changing an existing education program can be a daunting task. However, when inspired to successfully prepare graduates for engineering practice in the 21st century, it is well worth the effort.

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