Constructing a Civil Engineering Program from the Ground Up

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Abstract

This paper discusses the development and continuing refinement of the curriculum for the new Civil Engineering Program at the University of Minnesota Duluth. Included is a discussion of the program objectives, curriculum development, and integration of assessment into the curriculum.

Introduction

The University of Minnesota Duluth (UMD) is a comprehensive regional university located in Duluth, MN. There is an active student population of 11,664 as of fall 2009 enrolment. There are currently 74 different majors available with one of the newest being Civil Engineering. The program started in the fall of 2008 with the first graduating class in 2012. The program was formed because of a need for a civil engineering program in northern Minnesota and was heavily driven by local industry. UMD was well suited to take on this task as they had relatively recently started a new mechanical engineering program and had (and continue to have) a growing number of engineering students. The program had strong support from many local industries including engineering firms located in Duluth, as well as the mining companies that operate within northern Minnesota. This paper discusses the development of the new civil engineering program to date, including the program objectives, curriculum development, and the integration of assessment into the curriculum.

Program Objectives

The program has two main focuses that distinguish it from many of today's civil engineering curriculums. Both of these focuses are included in the mission statement of the department: "to prepare graduates for professional practice and graduate study through a program firmly based in strong technical skills, fundamentals, hands-on learning, sustainability, and professionalism."

In recent years, the pressure on engineering programs to reduce the number of credits and to include more liberal education courses at most universities in conjunction with financial pressures had led to the scaling back of laboratory and hands on courses and components [1]. Within the development of the curriculum at UMD it was decided early on that there was a need for a program that emphasized practical, hands on learning while still including the technical skills and fundamental knowledge that is required to be a successful engineer. In addition to there being a need for this type of program, it was thought that having an intensive hands-on program would result in graduates who are better prepared to enter the workforce. The justification being that even if you are employed as a design engineer, the more practical knowledge you have about what you are designing or where the data you are using comes from, the better the end product will be.

To have a hands-on program it is critical that lab space be readily accessible and equipped for student use. UMD and the Swenson College of Science and Engineering showed considerable foresight when planning the building as they included significant state-of-the-art laboratory space in the new James I. Swenson Civil Engineering Building. The floor plan of the lab level is shown in Figure 1, with a photo of the completed general projects lab shown Figure 2.

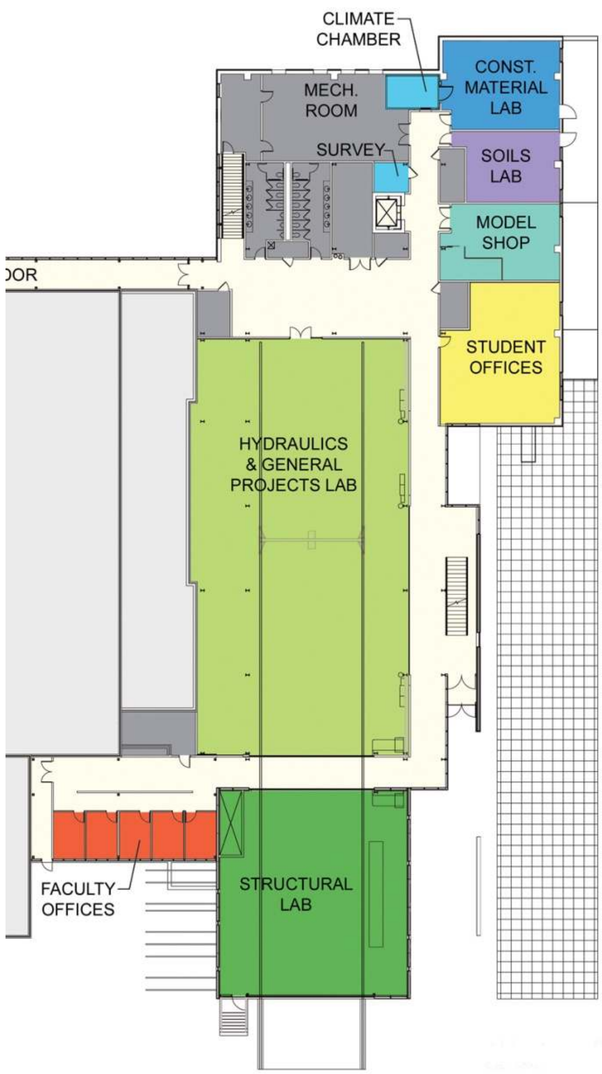

Figure 1: 1st Story Floor Plan of Swenson Civil Engineering Building

Figure 2: General Purpose/Hydrology Lab

The second focus area of the curriculum is sustainability. Sustainability has grown in importance over the past decade, and it will only continue to grow as environmental, political, and economical factors increase the need to engineer green structures and systems. Therefore, to ensure that the graduates of UMD are adequately prepared for the workforce it is essential that they have a thorough understanding of what sustainability is, and how to apply it to their profession. As discussed in the next section, this goal is achieved through both classes focused on sustainability and integration of the topic throughout the curriculum. In addition, just as the building provided space for the hands on focus, the building provides examples of sustainable design. The Swenson Civil Engineering Building in which classes are taught is a LEED Gold rated building.

Curriculum Development

Once the program objectives were established a curriculum to meet those objectives needed to be developed. When the initial design of the curriculum was established, many outside criteria needed to be met. These included: the liberal education criteria for the university, ABET requirements, requirements from the American Society of Civil Engineers (ASCE), knowledge required for the Fundamentals of Engineering Exam, credit limits established by the university, and the needs of employers. Once these requirements were met, the more difficult part of curriculum development begins: developing the structure of the courses, course subject material and prerequisites, and the availability of technical electives – all with input from faculty and industry. The end result of the curriculum is shown in the program description sheet in Table 1.

First Year			
Fall Semester		**Spring Semester**	
Intro to Civil Engineering	1 cr	Liberal education course	3 cr
General Chemistry I	5 cr	Intro to Programming: Visual Basic	3 cr
College Writing	3 cr	Calculus II	5 cr
Calculus I	5 cr	General Physics I	4 cr
Total:	14 cr	Liberal education course	3 cr
		Total:	18 cr
Second Year			
Engineering Mechanics	5 cr	Principles of Economics	3 cr
Differential Equations w/Linear Algebra	4 cr	General Physics II	4 cr
Engineering Statistics	3 cr	Fluid Mechanics	3 cr
Global Issues	3 cr	Calculus III	4 cr
Total:	15 cr	Engineering Geology	3 cr
		Total:	17 cr
Third Year			
Soil Mechanics	4 cr	Environmental Eng	3 cr
Structural Analysis	3 cr	Public Speaking	3 cr
Transportation Engineering	4 cr	Hydrology & Hydraulics	4 cr
Infrastructure Materials	4 cr	CAD & Engineering Drawing	3 cr
Project Management	3 cr	Liberal education course	3 cr
Total:	18 cr	Total:	16 cr
May Session			
Surveying	2 cr		
Total:	2 cr		
Fourth Year			
Senior Design I	3 cr	Senior Design II	3 cr
Advanced Writing	3 cr	CE Technical elective	3 cr
CE Technical elective	3 cr	CE Technical elective	3 cr
CE Technical elective	3 cr	Technical elective	3 cr
CE Technical elective	3 cr	Technical elective	3 cr
Total:	15 cr	Total:	15 cr
Technical Electives			
Structures Focus Group Advanced Structural Analysis & Design (3.0 cr) Design of Concrete Structures (3.0 cr) Design of Steel Structures (3.0 cr)		Transportation Engineering Focus Group Traffic Systems Operations and Safety (3.0 cr) Highway Planning and Design (3.0 cr)	
Geotechnical Engineering Focus Group Geotechnical Design (3.0 cr) Rock Mechanics (3.0 cr) Underground & Surf. Excavations in Rock (3.0 cr)		Water Resources Focus Group Design of Hydraulic Structures (3.0 cr) Water Resources (3.0 cr)	

Table 1: Typical Program of Study

Within the curriculum it is apparent how the course objectives outlined in the previous section are met; there is a hands-on focused course in each focus area. Courses with a dedicated laboratory component within the civil engineering curriculum include: Soil Mechanics, Transportation Engineering, Infrastructure Materials, Hydrology and Hydraulics, and Surveying. These courses will include laboratories in the field, lab and on computers. In addition to these courses with dedicated lab sections, many upper level courses will include lab based activities, included many of the design classes.

This emphasis on labs does come at a credit cost as each class with a lab has an additional credit. Much of the emphasis of the curriculum development was on determining what knowledge was essential to a civil engineering graduate and determining the best way to package that information into a course. The results are that some of the tradition courses have been removed or altered. One change was to combine what is traditionally 2-3 credit courses (Engineering Statics and Mechanics of Materials) into 1-5 credit course. This served 2 purposes: it eliminated 1 credit of material that was covered in Physics and it allowed students to begin taking many of their Civil Engineering courses 1 semester sooner as these courses are prerequisites for many of the introductory level courses.

Other courses that were removed as requirements include Dynamics and Thermodynamics. The material in these courses was not completely removed as much of it is introduced in Engineering Mechanics, Fluid Mechanics, and Construction Materials. However, it was decided that the material in these courses did not need the extensive treatment that was able to be given in a dedicated course. Care is taken to ensure the basics required for the FE exam are still covered. The result is a curriculum that allows additional credits of lab while still providing sufficient electives.

The objective of sustainability is not as directly apparent within the curriculum though it is just as integral of a component. Sustainability is integrated into all of the courses, most notably Introduction to Civil Engineering, Project Management, and Senior Design. In each of these classes the sustainability (typically related to the LEED rating system) is included as an important aspect of the final project for the class. In addition, there is an upper level elective class dedicated to the topic of sustainability that is available for the students to take.

Assessment

Assessment is an important tool for any curriculum and even more so when that curriculum has not had the opportunity to be evaluated over multiple years [2]. Therefore assessment has been imbedded throughout the development of the curriculum. It has also been emphasized in the recruitment and hiring of faculty members. There are 17 outcomes (a-q) that are assessed to determine the effectiveness of the new curriculum. The first 11 (a-k) are the standard ABET outcomes assessed by most engineering schools. The next 5 (j-p) are based on guidelines provided by the American Society of Civil Engineers. The final outcome was added to further emphasize and provide a means to measure the focus of the curriculum on sustainability. The outcomes are summarized in Table 2.

a) an ability to apply knowledge of mathematics, science and engineering;
b) an ability to design and conduct experiments, as well as to analyze and interpret data;
c) an ability to design a system, component, or process to meet desired needs;
d) an ability to function in multidisciplinary teams;
e) an ability to identify, formulate and solve engineering problems;
f) an understanding of professional and ethical responsibility;
g) an ability to communicate effectively;
h) the broad education necessary to understand the impact of engineering solutions in a global and societal context;
i) a recognition of the need for and an ability to engage in life-long learning;
j) a knowledge of contemporary issues;
k) an ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
l) an ability to apply mathematics through differential equations; probability and statistics; calculus-based physics; general chemistry; and geology
m) an ability to apply knowledge in the following four recognized major civil engineering areas: structural engineering, geotechnical engineering, transportation engineering, water resources engineering with a depth of focus in one or more of the four areas;
n) an ability to conduct laboratory experiments and to critically analyze and interpret data in the following four (4) recognized major civil engineering areas: structural engineering, geotechnical engineering, transportation engineering, water resources engineering
o) an ability to perform civil engineering design by means of design experiences integrated throughout the professional component of the curriculum culminating in a senior design experience;
p) an ability to explain basic concepts in management, business, public policy, and leadership; and explain the importance of professional licensure;
q) an ability to apply knowledge of sustainability to civil engineering practice.

Table 2: Program Outcomes

Included in the development of each course was a discussion of what outcomes would be covered and assessed. In this way all of the faculty members have been involved in the discussion and have a better understanding of the assessment process. By involving assessment at this stage it also allows for the actual assessment itself to become an integral part of the course instead of just an afterthought. When practical for the outcome being assessed the assessment is based on a dedicated in-class assignment that is consistent from instructor to instructor and from year to year. This allows for a more consistent evaluation of the outcome. Another way consistency is ensured is that each assessment is evaluated by two different people, minimizing grading biases.

The results of assessment are stored for each student in each class. This allows the gathering of data that using typical assessment schemes would be difficult to obtain. For example, it is possible to examine how the order in which classes are taken affect the performance of the students, or how the performance in a certain class predicts the latter performance. This allows for the effect of changes in the curriculum to be evaluated more quickly and more accurately, increasing the benefits of assessment.

Having consistent, integrated assessment can also benefit the instructor. It allows for an unbiased, quantitative evaluation that is very useful for evaluating different teaching styles, techniques or organization. For example, you could evaluate the effectiveness of adding a comprehensive class project to the course by determining if it improves the knowledge of the students in areas that are considered critical to the course.

Conclusion

The development of the new Civil Engineering program at the University of Minnesota Duluth is a unique opportunity to evaluate the current methodology and curriculum of engineering education. UMD has decided to emphasize practical knowledge as well as sustainability while designing their curriculum. The program has approximately 65 students in each class (currently freshman, sophomores, and juniors), which is significantly higher than the 25 that was initially estimated, indicated that there is potential interest in such a program from students. A very active industrial advisory board continues to state that the industry is interested in graduates from the program. An integrated assessment system is in place to identify any weaknesses in the program that need further examination. All of initial steps to create a successful Civil Engineering program have been completed, and the authors are confident that this new program will continue to succeed.

References

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2. Nichols, James O., and Nichols, Karen W., A Road Map for Improvement of Student Learning and Support Services Through Assessment, Agathorn Press, Fleminton NJ, 2005.