Paper 2005-2156

A Pilot Study for a "Course-less" Curriculum

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Abstract

In 2002, we received an NSF planning grant (NSF EEC 0230681) that builds upon our Sooner City project, which was funded through the Action Agenda program (NSF EEC 9872505). Briefly, Sooner City is a comprehensive, integrated, infrastructure design project that is threaded throughout the OU civil engineering curriculum, beginning in the freshman year. For practical purposes, the original Sooner City project was implemented in the context of the traditional "course-dictated" curriculum. While this strategy promotes faculty buy-in and minimizes institutional cost, we believe that desired outcomes may be more fully realized if the curriculum were more flexible, viz, provide basic engineering science skills and tools to the students on an as-needed basis to complete the project. Thus, the objective of the planning grant is to pilot a project-driven, "course-less" curriculum. In this setting, "course-less" does not refer to "no courses." Rather, there would be "less" of them because traditional courses that teach basic concepts would be replaced with self-paced IT modules. The pilot study consists of four phases: 1) develop electronic modules to deliver content from fluid mechanics on a just-in-time basis; 2) beta-test the modules with students who have not had fluid mechanics; 3) develop Sooner City design projects that integrate these modules in a just-in-time fashion; 4) assess the efficacy of the methods. Herein, we report on progress to date. Outcomes from the project will provide the needed insight to direct future steps toward a more robust "course-less" educational experience.

1. Overview of the Sooner City Project.

1.1 Background.

The Sooner City project seeks to reform the traditional civil engineering curriculum by threading a comprehensive, integrated, infrastructure design project across the curriculum, beginning in the freshman year. Basically, freshmen are given a plat of undeveloped or partially developed land that, by the time they graduate, is turned into a blueprint for Sooner City's infrastructure [21]. Among other things, the project promotes five outcomes not fully addressed by traditional curricula, but which are emphasized by the NSF Engineering Education Coalitions and ABET 2000: team building, communication, leadership, design, and higher level learning skills.

1.2 Project Philosophy.
Students are taught to view engineering design as a constrained optimization problem, viz, given a design task, raw data, and constraints (technical, political, economic, or social), they develop the "best" solution from among multiple alternatives. Each engineering course is devoted to a different component of the overall design, but they are structured so that the solution often requires cross-course integration, both vertical (e.g., freshman/junior) and horizontal (e.g., two concurrent senior courses). Distinct classes act as sub-consultants with design data and calculations shared between them via common meetings, the web, or formal engineering reports.

1.3 Key Features.
Sooner City provides an ideal venue for other reform initiatives, such as team learning, peer mentoring, wireless laptops in the classroom, and just-in-time learning. Students learn technical material using the latest hardware and software, while at the same time learning how to communicate, how to function effectively on a team, how to balance the political/social/ethical aspects of engineering projects, how to teach themselves, how to engage in higher level thinking skills, how to self-assess, and how to be effective leaders on projects.

2. Sooner City in the Context of ASCE’s National Referendum for Engineering Education Reform.

At many institutions, undergraduate engineering education has become outdated. During the past five decades, the following paradigm, for the most part, has become the norm: lectures on technical concepts, little or no discussion, individual homework on idealized problems, and problem-solving exams. While this traditional formula has produced generations of competent engineers, it is ill-suited to produce graduates who can contribute in a dynamic, team-oriented environment, who have advanced critical thinking skills, who are proficient with computers, and who can communicate effectively with management and the public. This same traditional system is also discouraging many talented engineering students; the attrition rate in engineering exceeds 40% at many leading institutions. [2, 4-8, 10, 15, 17-19, 22-28, 32-35]

ASCE, the predominant professional organization for civil engineering, also recognizes the need to reform engineering education in order for graduates to meet the challenges of the 21st century: globalization, information technology, a diverse society, new technologies, enhanced public awareness, and a deteriorating infrastructure. After more than a decade of study, a task force has prepared a report that lays out the “Body of Knowledge” that civil engineers should possess in order to meet these challenges; it has been adopted as ASCE's Policy Statement 465. [1]

3. Motivation for Planning Grant Activities.

As stated earlier, the original Sooner City model fits into an integrated systems project into an *existing* “course-dictated” curriculum. The objective of this planning grant is to pilot the concept of a “course-less” curriculum, so that teaching and learning activities are not bound by the constraints of a 50-minute, MWF class format (a system that has been optimized for the traditional lecture/note taking paradigm). In order to realize our vision of a curriculum driven by student projects, three essential components must come together: 1) a protocol for delivering technical information on an as-needed basis; 2) well-defined, comprehensive, multidisciplinary projects; and 3) a flexible, yet rigorous assessment tool.

Before describing some specifics of our project, it is useful to reflect on past approaches to teaching core knowledge in the engineering curriculum. Literature suggests that it typically follows one of three models: 1) traditional; 2) integrated; 3) in-between [9,15,20,33]. In the traditional approach, core subjects are taught by faculty in their respective disciplines with little regard for the ultimate application. This approach, as cited earlier, is one of the reasons for low retention rates [6,15,17,19,31]. An integrated core approach is one where students learn multiple subjects in the context of "real-world" applications [29]. We are guided here by the Rose-Hulman and Drexel (i.e., both small private colleges) approaches, where students enroll in a 12-credit supercourse that spans core subjects. Institutions that adopt an in-between model maintain individual courses, yet try to incorporate meaningful applications to motivate student learning.. Many attempts fall into this category, including some of our own, and, given the institutional climate at many schools, it is a good first step. But we would like to do more.

Our *long-term* goal in the College of Engineering (CoE) at OU is just-in-time, project-based, "course-less" learning across the curriculum. Figure 1 illustrates the overall program philosophy as it relates to just-in-time learning. At the left of the figure, the arrow spanning the four years represents the continuum project (Sooner City in this example). Suppose that students are working on a surface water supply reservoir for the city; this is indicated in the middle part of the

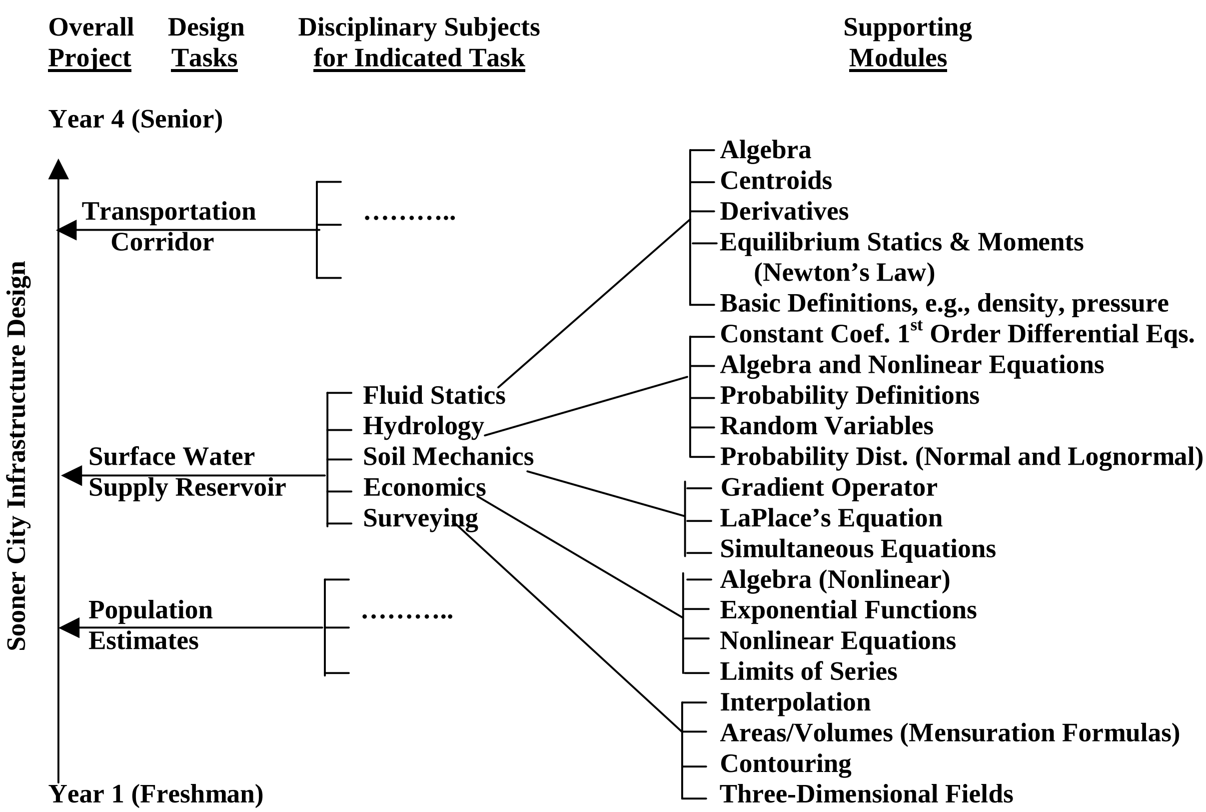

Figure 1. Example of just-in-time learning in a project-driven curriculum.

figure, along with the disciplinary subjects involved. Finally, at the right of the figure, we show the core modules needed to complete the reservoir design. This knowledge is gained on an as-needed basis. In essence, the intellectual content of traditional courses has been identified, and each individual topic is delivered in a self-contained module. Modules can be self-paced, multimedia packages, short seminars, directed study, formal peer-mentoring activities, or a combination thereof. It is precisely this granularization of existing courses that will allow just-in-time learning to succeed in the context of curriculum-long design projects.

With this backdrop, we present the four planning grant activities that will pilot test this philosophy: 1) develop electronic modules to deliver content from fluid mechanics on a just-in-time basis; 2) beta-test the modules with students who have not had fluid mechanics; 3) develop Sooner City design projects that integrate these modules in a just-in-time fashion; 4) assess the efficacy of the methods. The following sections will discuss each activity and report on its current status, as of press time for the proceedings.

4. The Water Resources Design Tasks

Just-in-time learning will be piloted within a junior-level water resources engineering course. For this course, we have developed the following design tasks centered around Sooner City's water and sewer infrastructure; the tasks follow a logical sequence, from demand to source to disposal. Only design objectives are described below, in the interest of brevity. Full design materials can be located at the Sooner City website: www. SoonerCity.ou.edu. Note that for this particular class, the students are working on an extension to Sooner City to accommodate a 50% increase in the population over the next 30 years. Also note that in this course, students focus on water quantity; water and wastewater treatment issues are addressed in a subsequent course.

Task 1: Water demands. Given current and projected population figures, students are asked to estimate the current and future water demands for Sooner City, considering such uses as public, industrial, domestic, commercial, and fire flow.

Task 2: Surface water supply. Once the water needs have been determined in Task 1, the students are then instructed to find a source of water for Sooner City, i.e., placing a dam on the nearby Sooner River and withdrawing water from the reservoir. Students use hydrologic data and a mass balance analysis to determine the sustainable yield from the reservoir.

Task 3: Ground water supply. A second possible source of water for Sooner City is to withdraw water from the ground. Students are given hydrogeologic information about the underlying aquifer, including pump test results, and determine the safe yield from the aquifer.

Task 4: Water distribution system. Students are to design the distribution system to convey the water from the source to the homes, considering all possible demands on the system, ranging from average day to maximum day plus fire. Pipes must satisfy all pressure criteria, as well as being economically viable. Also included are a pump station design to lift the water from the source to the user and the sizing and placement of elevated storage tanks.

Task 5: Sanitary sewer system. Once the water is delivered to the users, it must be disposed of via a sanitary sewer system. Students design a gravity sewer system to convey the waste from industrial and domestic users to the treatment plant near Sooner River.

Task 6: Storm sewer. Students use basic urban hydrology concepts, such as the rational method and unit hydrographs, to estimate the runoff from storm events and route it to the outfall via a gravity sewer system.

To the extent possible, students use commercial software to facilitate design tasks. Currently, we use Haestad Method's software suite: WaterCAD, SewerCAD, StromCAD, and FlowMaster [16]. Similar design tasks have been used for several years, so historical perfomance in the course can serve as a control for the pilot study.

5. The Fluid Mechanics Modules

For each of the design tasks discussed in Section 4, we identified the fluid mechanics principles needed to complete the task, as shown in Table 1 below. These basic principles guided development of the fluid mechanics IT modules. To the extent possible, the modules are independent of one another; where some previous knowledge is needed, the student is linked to the appropriate section(s).

Table 1. Fluid mechanics principles needed for projects in water resources engineering.

Task	Description	Fluids Principles
1	Water demand	• basic units (Q, V, gallons, liters, etc.) • hydrographs • steady vs. unsteady flow
2	Surface water source[1]	• mass balance (water budget) • components of the hydrologic cycle (precipitation, evaporation, runoff) • forces in static fluids (for concurrent dam design in soil mechanics)
3	Ground water source	• mass balance (continuity equation) • piezometric head/surface • hydraulic grade line/hydraulic gradients • laminar vs. turbulent flow • steady vs. unsteady flow • Darcy's law
4	Water distribution system and pump station	• flow in pressure conduits • friction loss in pressure conduits (Manning, Darcy-Weisbach, Hazen-Williams) • Reynolds number • minor losses • energy equation (loop equations) • energy and hydraulic grade lines • continuity equation (node equations) • hydrographs • pressure variation in a static fluid • forces on bends • flow measurement (venturi meters, pitot tubes) • gage vs. absolute pressure • vapor pressure • power in a fluid • pump efficiency

[1] This design task is integrated with a concurrent soil mechanics class; the soils class designs the earth dam itself, while the water resources class determines the needed water volume.

		• system vs. pump curves • cavitation • water hammer
5	Sanitary sewer	• free surface flow • momentum analysis • drag coefficients • dimensional analysis • Froude number • subcritical vs. supercritical • energy equation • specific energy • Manning equation • settling velocity
6	Storm sewer	• (same open channel stuff as task 5) • rational method • kinematic wave • time of concentration • unit hydrograph convolution • reservoir routing • flow through orifices and over weirs

Each self-paced module follows the same format, namely, the topic, such as pressure variation in a static fluid, is introduced via a case study. Next, the theory behind the principle is presented, and where appropriate, the explanation is augmented with movie clips or animations or narrations. Once the theory is complete, the solution to the case study is given. A simulator for each topic allows the student to conduct numerical experiments in order to further explore the behavior of fluids; fluid properties and conditions of the problem are adjusted with slider buttons, and the results are presented in graphical form.

As an example of the multimedia modules, we show a few frames from the topic on hydrostatic pressure forces on a plane, which is needed by the water resources students to help design the earth dam. Figure 2 shows the problem being introduced as a case study about forces on a gravity dam. Figure 3 is taken from the theory section that discusses the center of pressure of the resulting force, while Figure 4 shows the solution to the case study. Finally, Figure 5 is a snapshot of the simulation module, which allows the student to see how the magnitude of the force and center of pressure vary as the fluid depth varies.

The modules are grouped as an eBook, which is part of the eCourse software being developed by Dr. Kurt Gramoll at the University of Oklahoma; these have been reported in previous ASEE venues [26,30] and can be found on-line at www.eml.ou.edu. Important features of the multimedia package include the following: animations, simulations, sound, graphics, database of questions, web discussion board, Flash-based animated lectures of concepts, instructor administrative management system, online collaboration tools, and an online system to track the user progress and present problems at the end of each module. Students must master the topic, as indicated by assessment testing, before proceeding to the design task. The modules can be used as a resource for a single course dedicated to fluid mechanics, or they can be used on a just-in-time basis, as is the case for this project.

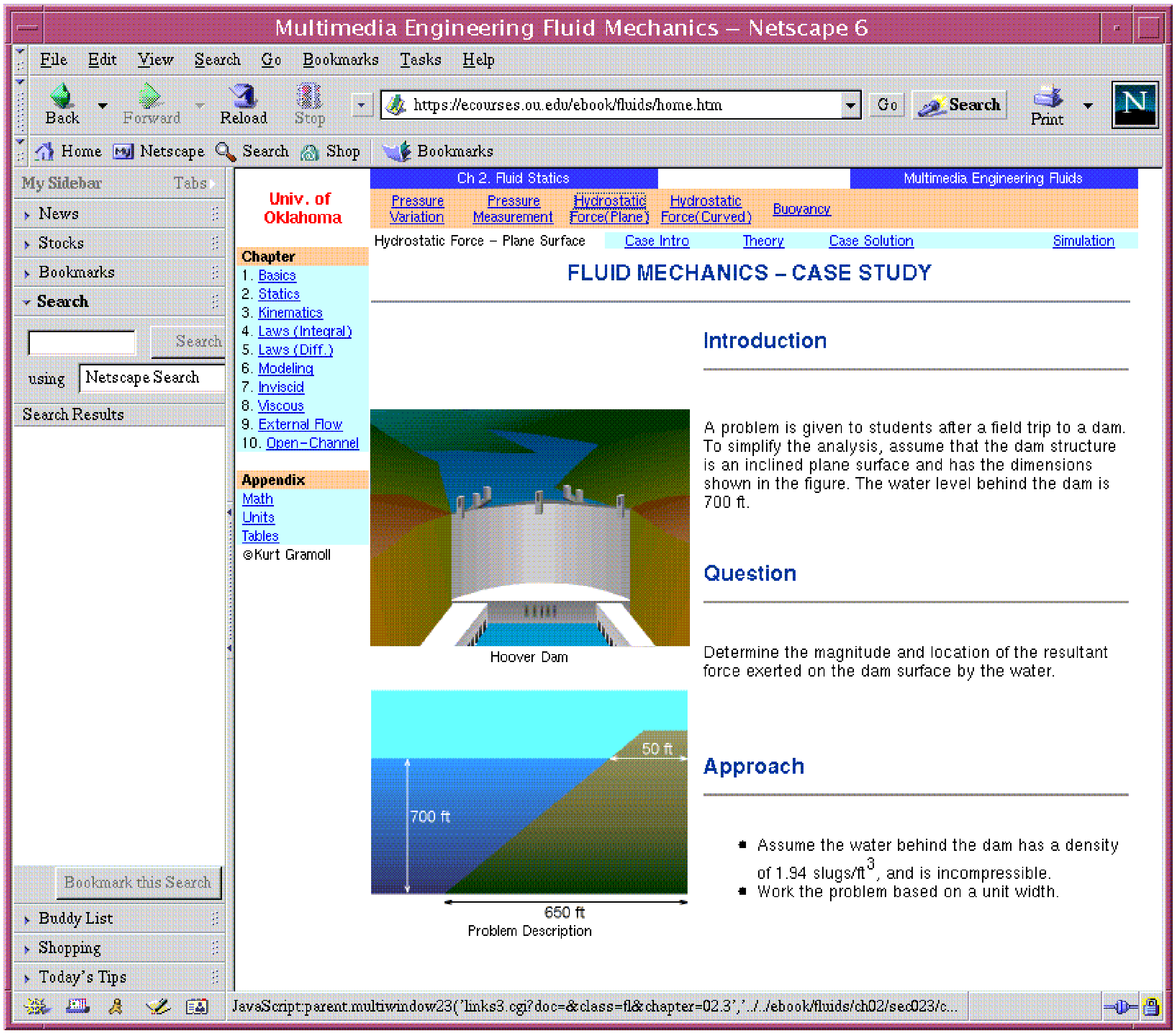

Figure 2. Case study about forces on dams to introduce the topic about hydrostatic forces on plane surfaces.

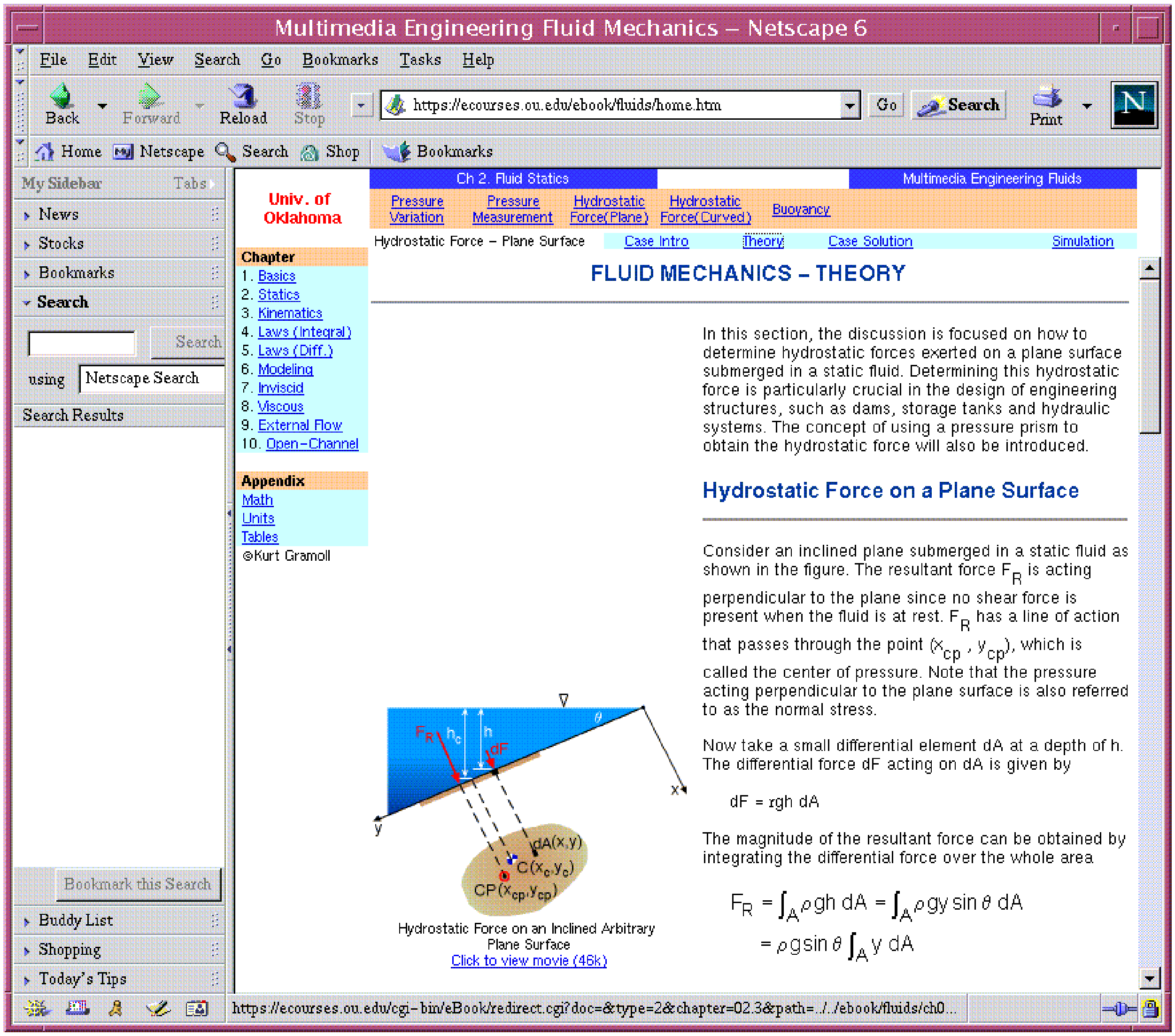

Figure 3. Theory behind hydrostatic forces on plane surfaces.

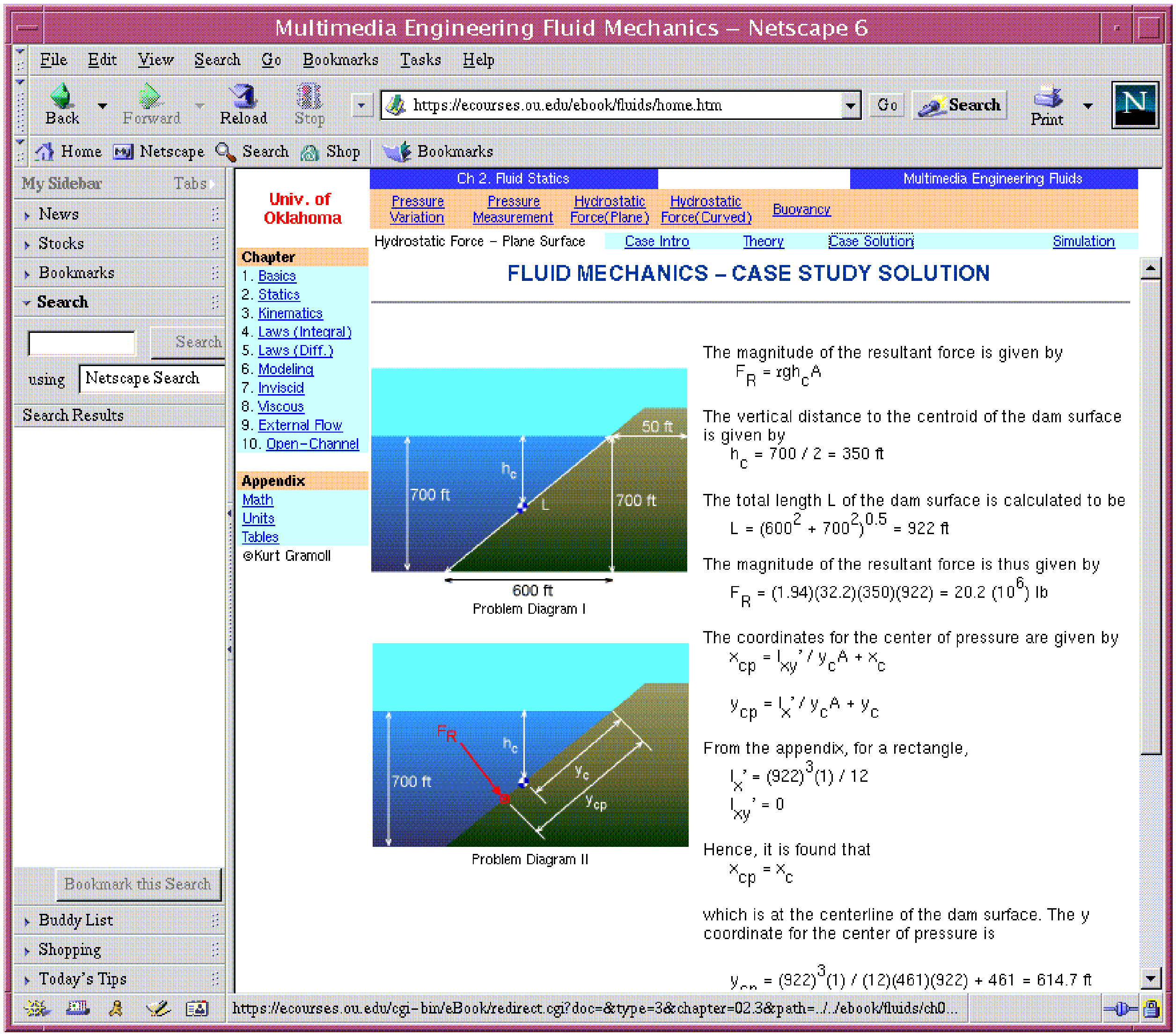

Figure 4. Solution to the case study about hydrostatic forces on plane surfaces.

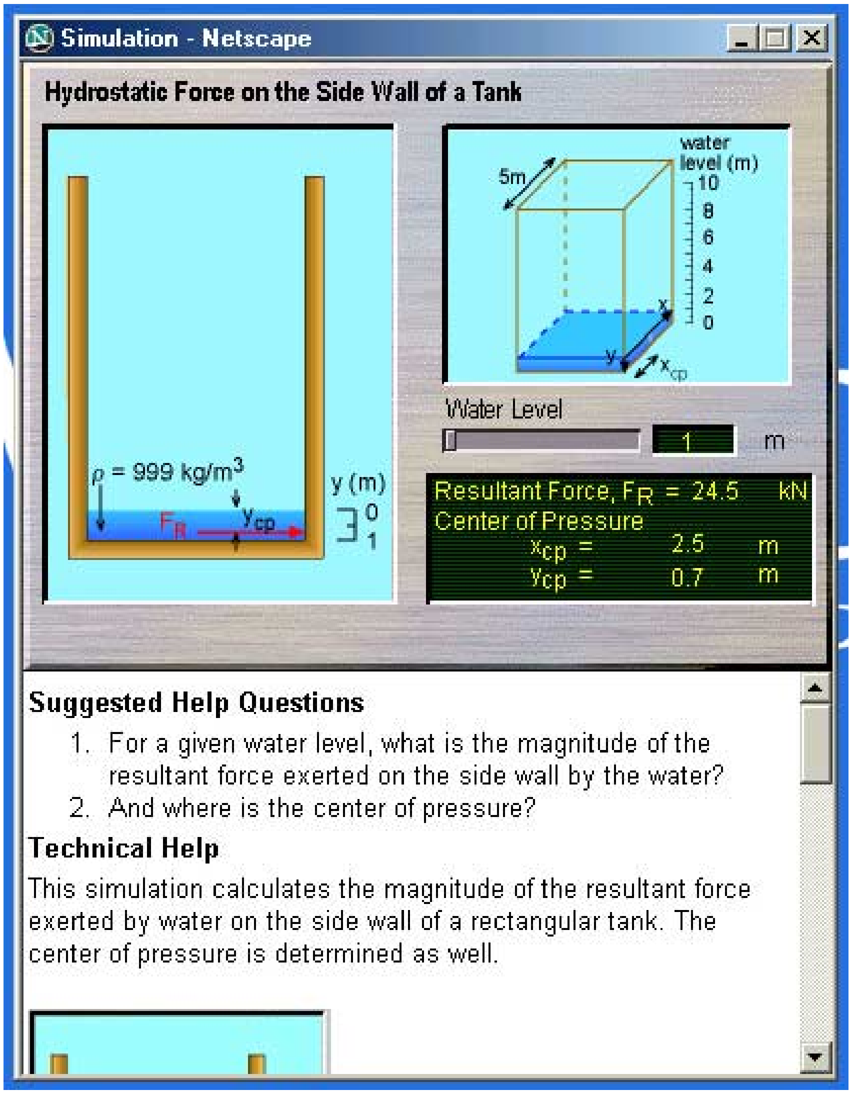

Figure 5. Simulator to show how hydrostatic force (magnitude and center of pressure) varies with water depth.

6. Beta Test of the Modules

In Spring 2005, students will beta test the fluid mechanics modules. They will *not* learn fluids on a just-in-time basis. Rather, they will learn fluids from self study via the multimedia modules. We will have an instructor meet with the students on a regular basis in order to answer questions, but no formal lectures are planned. Their progress will be contrasted to a control group of students who are taking fluid mechanics from a regular, three-hour course. Performance will be assessed by regular exams and pre- and post- testing using the fluids concepts inventory (see Table 2 in Section 7). The beta testers will also be required to keep a log of their activities, paying particular attention to aspects of fluid mechanics or the modules that they find confusing. Their feedback will guide refinement of the modules in Summer 2005, before the pilot test in Fall 2005 (see below). Results from the Spring 2005 beta test will be presented at the Annual Convention.

7. Pilot Study of Just-in-Time Learning

The full pilot study, wherein the fluid modules are used on a just-in-time basis within the water resources course, is scheduled to begin Fall 2005. Students who opt for the pilot study will earn six credits, three for water resources engineering and three for fluid mechanics, upon successful completion of the just-in-time project. The control group of students will be those who are taking the water resources class, but who have already completed a regular fluid mechanics course. Assessment will consist of formative and summative evaluations.

7.1 Formative Evaluation.

The two key formative questions are: (a) Is the project working as anticipated? and (b) Are any significant changes needed? The information to answer these questions will be gathered from the key constituents: undergraduate students, faculty, and the department chair. A combination of questionnaires and selected student and faculty interviews will be developed to identify which parts of the project are working well and which need to be modified.

7.2 Summative Evaluation.

The overall goal of this project is to improve undergraduate engineering education by means of a just-in-time, project-driven model. Summative evaluation information relative to this goal will be collected by comparing performance data between students in the pilot course and students taking fluid mechanics in the traditional mode (the "control" group). A summary of the project's goals, target objectives, and evaluation activities is shown in Table 2.

One key idea for the first goal in Table 2, improving the quality of student learning, is to utilize the Taxonomy of Higher Level Learning, which is illustrated in Figure 6 [12-14]. This taxonomy is able to provide the language and conceptual framework necessary for describing the kind of learning goals referred to earlier, specifically:

- *Foundational Knowledge:* Acquiring the basic content of engineering, e.g., the terminology, formulas, relationships, principles, etc.;
- *Application:* Learning how to *use* the content to solve problems, make decisions, design complex projects, etc.;
- *Integration:* Relating different aspects of engineering to each other and connecting engineering practice with other realms of knowledge and human activity;
- *Human Meaning:* Developing an understanding of the personal and social implications of engineering knowledge;
- *Valuing:* Coming to value the professional aspects of engineering: integrity, hard work, the excitement of challenging problems, continuous learning, etc.;
- *Learning How to Learn:* Monitoring one's professional knowledge to determine what else one needs to learn and knowing how to acquire additional knowledge, skills, certification, etc.

This taxonomy can assist professors in the formulation of significant learning goals for their curricula and individual courses; it can also assist students in the creation of learning portfolios to document the level and extent of their engineering education.

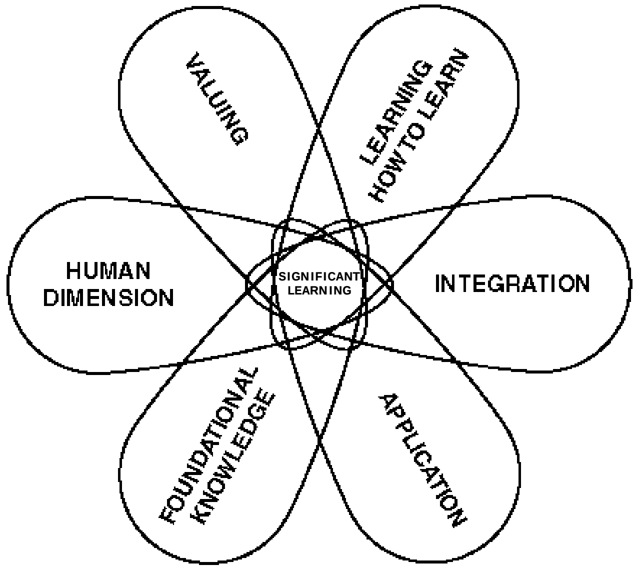

Figure 6. Interactive nature of higher level learning.

The second goal in Table 2 for this project is to enhance the quality of teaching. Evaluation will require tracking the nature of the teaching activities in both the pilot section and the control section (i.e., a second cohort of students who are simultaneously enrolled in a traditional section of fluid mechanics).

Table 2. Goals, objectives, and associated summative evaluation activities.

Goals	*Target Objectives*	*Evaluation Activities*
1. Improve the Quality of Student Learning • Students cognitive learning will increase (foundational knowledge) • Students will achieve more higher level learning: o Application o Integration o Human meaning o Valuing o Learning how to learn • Students attitude toward engineering will improve	• Basic cognitive skills will improve 25% relative to the skills of the control group (students enrolled in a traditional fluids course) • 25% more students from the pilot study will demonstrate <u>substantial achievement</u> of all 5 kinds of higher level learning relative to the control group. • 25% of the students will have a better attitude toward engineering (relative to the control group)	• Cognitive skills – o Fluids concepts inventory [11] o Passage rate of fluid mechanics on the FE exam • Higher level learning: o Interviews o Questionnaires o Diagnostic testing using open-ended design questions o Quality of class projects • Pittsburg Engineering Attitude Survey [3]
2. Improve the Quality of Teaching • Through a project-	• The proportion of "face time" devoted to active, higher-level	• Continually monitor class activities in the pilot and control sections.

Goals	*Target Objectives*	*Evaluation Activities*
driven, just-in-time, course-less curriculum, teachers will better integrate active, higher-level learning activities	learning activities will increase by 50% relative to the control group (students enrolled in a traditional fluids course).	

8. Summary

Because the pilot project is on-going and will not be completed until December 2005, we do not have results to present at this time. However, we anticipate that project-based education will lead to more competent engineers who take leadership roles in the changing world of engineering; that just-in-time learning, now feasible with information technology, allows students and faculty to learn material in a more natural sequence; and that just-in-time learning will enhance understanding and improve retention of basic engineering concepts.

9. Acknowledgments

Financial support for this work was provided in part by the National Science Foundation under contract EEC-0230681 and by the OU College of Engineering. Any opinions, findings, and conclusions expressed herein are those of the authors and do not necessarily represent those of the funding sources. We thank the reviewers for their comments.

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