Session 2793

The Pilot Design Studio-Classroom

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Abstract

The teaching of fluid mechanics at Cooper Union has been revised to make it an interactive design mode. Key fluid mechanics principles are demonstrated using design project assignments, demonstrations/experiments, videos, and lectures. A series of eleven modules has been developed. Each module consists of an outline of the theory of a topic that will be covered in lectures, an illustrated design problem, historical and cultural notes, a design homework example, a series of demonstrations, and references. Each module is self-contained and takes approximately one to three weeks to cover. One of the ways these modules are unique is that the material is presented by the use of design problems, design homework examples, and design projects. A set of short videotapes (approximately three minutes each) keyed to the professor's lectures allows for basic concepts to be presented by moving from the lecture mode to a video mode.

I. Introduction

The concept of the studio-classroom was originated at Rensselaer Polytechnic Institute Physics Department about eight years ago. Expanding on the traditional lecture format, the studio-classroom concept was designed to revitalize the learning environment using educational technology[4]. Modern educational technology is revolutionizing the traditional classroom learning-teaching model. For example, the fluid mechanics course at Cooper union and elsewhere has been taught in lecture mode using one main textbook[5,7]. In contrast, the studio-classroom model offers lectures plus in-class demonstrations and experiments[8]. Using benchtops apparatuses[1] , an instructor giving a classroom lesson can now flick a switch to dramatically illustrate pressure drop as flow passes into a Venturi meter[2].

Thus the benefits of lab and classroom are combined. Add to this multimedia --video, computer projections, interactive software-- and the classroom becomes dynamic, efficient, and engaging, providing a bridge between abstraction and application [8,9,10]. A place where the classroom is taken to the next level where the dynamic environment makes the design process central to engineering education, and to better integrate analysis into that process [3].

The studio concept has been used successfully at Rensselaer Polytechnic Institute [13,14] and the multimedia enhanced lecture environment has been part of required courses in science and engineering at other institutions for the last decade[2,5]. Students give the new studio higher approval ratings than traditional lectures[13,14] and professors say the new methods made them think more about their teaching. Time is spent so efficiently in the classroom-studio environment that students need only four hours a week in introductory physics versus the five and a half that were traditionally spent in lectures[13]. Further, the cost of multimedia engineering courseware is justified by effectiveness in instruction, as measured by a rigorous assessment in the ECSEL Coalition [12].

The Learning Labs and Prototyping Studio will also stimulate pedagogical research and allow faculty to experiment with teaching methods. In the short term, the educational experimentation will point the way to curricular innovation in more advanced engineering topics.

II. Methodology

This project adapts and takes to the next level the concept of the studio-classroom. Going further, our implementation is innovative, using the studio-classroom model to emphasize the process of design early in the engineering curriculum. A series of learning modules was developed to provide access to the practical, theoretical and experimental knowledge of fluids, flows, fields and pertinent analogies for engineering students of different disciplines.

The modules consist of a series of eleven self-contained sets of material that include:

Theory
Design Examples
Design homework problems
Design homework projects
Historical notes
Experiments and demonstrations
References

The theory consists of a brief overview of topics that generally make up one chapter in a fluid mechanics text. It is given as a guide to students; not to replace a standard fluid mechanics textbook. The design examples, homework, and projects are important in this revised fluid mechanics course because they show the students how fluid mechanics is used in engineering design. The homework problems and homework projects assigned in the modules stress the application of design. As an example, the homework project assigned in the equation of energy and pipe flow module is a pipe network. The students are asked to design pipes to carry flow from a reservoir through a series of pipes. They are given a range of velocities and are guided by the professor to select pipe diameters that will carry a given discharge.

The Cooper union purchased 29 videos and a CD[6] from AVC Marketing (The University of Iowa) Insight Media, Encyclopedia Britannica Education Co. and ASCE. Since each of the videos run approximately half an hour it was not feasible to show each video in class. Therefore, a small segment of the appropriate videos was copied on a master video. Each segment covers at least one of the module topics and is listed in Table 1. The videos were pre-set to run during the scheduled class hours. As the professor was developing a principle, he turned on the video tape to demonstrate that principle. The video demonstration lasts only a few minutes. The lectures and the videos were coordinated, there was a smooth transition from the lecture mode of presentation to the video mode and back to the lecture mode. Each video demonstration ran an average of 3 to 4 minutes. There were an average of one and a half demonstrations for each of the 11 basic topics outlined in the fluid mechanics modules. Each video segment is keyed to one of the 11 modules. As an example: the principle of pressure drag was demonstrated by comparing the drag force on a bomb shape to a sphere. This video lasted for approaximately two and a half minutes.

Experimental demonstrations will be effective on key points in the course and then are reinforced through assignment questions directly related to basic principles presented in the lecture. Thus the students see the most important ideas at least four times (lecture, video, homework, demonstration). As an example of the presentation of important principles using different media, the principle of pressure and velocity heads were presented first in the classroom, by lecturing on pipe flow from a reservoir into a series piping system. A video demonstrating the increase in the velocity head at the expense of pressure head through a Venturi meter (Equation of energy, turbulence, and pipe flow, Table 1) was shown in class. A reservoir flowing into a series piping system was assigned to the students as a homework problem. The dimensions of the reservoir and pipes given in the assignment were the same dimensions as a bench scale model previously constructed. The class finally observed a demonstration of flow in the reservoir series pipe model showing the drop in the pressure head, as observed by the rapid decrease in head in the vertical manometers placed in the center of each pipe section. By changing the diameter of the pipe exiting into air, laminar and turbulent flow was also demonstrated by the use of dye streaks. By the use of this bench scale model a number of fluid mechanics principles (pressure headdrop, turbulent flow, and static head) were clearly demonstrated in a short period of time (less than 10 minutes).

In developing the modules, effort was placed on exciting the interest of the students. This was done, in part, in a historical context usually absent from engineering education. Pipe flow as well as pipe and valve design, for instance, have a long history from pre-Roman times to our own (this was highlighted in one of the historical notes in a module). This theme was continued in the water resources engineering course the students take in the second term of their junior year (fluid mechanics is taken in the first term of the junior year). A nova videotape on plumbing is shown documenting the ancient Roman contributions to hydraulic engineering.

Table 1. Videoclips used in Fluid Mechanics ESC 140

(#) TITLE OF VIDEO –FLUID MECHANICS PRINCIPLES DEMONSTRATED	RUNNING TIME MIN:SEC	MODULE TOPIC
(22) Characteristics of Laminar and Turbulent Flow - Concept of viscosity due to shear flow.	 2:14	Basic Principles
(11) Flow Visualization - Path Lines - Stream Lines - Time Lines	 :35 :17 :58	Kinematics
(10) Eulerian and Lagrangian Description in Fluid Mechanics - Pipe flow showing Eulerian and Lagrangian flow	 2:09	Kinematics
(1) Pressure Fields and Fluid Acceleration - Flow through a contracting conduit	 1:26	Conservation of mass
(1) Pressure Fields and Fluid Acceleration - Use of Euler's equation, showing rotating disc with manometers	 1:09	Conservation of momentum
(1) Pressure Fields and Fluid Acceleration - Flow withdrawn along a pipe - Stagnation and pitot tubes - Venturi section showing a pressure drop	 1:09 1:02 1:03	Equation of Energy, turbulence, and pipe flow
(2) Turbulence - Disorder, Mixing, Vorticity - Momentum transfer - Mixing across streamlines	 1:58 :38 :40	Equation of Energy, turbulence, and pipe flow
(24) Effects of Fluid Compressibility -Water waves with flow superimposed showing Froude and Mach numbers	 1:27	Dimensional Analysis and Similitude
(22) Characteristics of Laminar and Turbulent flow -Couette flow -Poiseulle flow	 :53 :56	Navier Stokes Equations
(31) Vorticity -Vortex meter near boundary layer showing vorticity and a rotating tank showing zero rotation	 3:00	Potential Flow
(23) Form, Drag, Lift, and Propulsion -Flow around a rotating cylinder and other shapes	 3:36	Potential Flow
(5) Fundamentals of Boundary Layer - Turbulent and laminar boundary layer along a flat plate	 2:48	Boundary layer theory
(7III) Fluid Mechanics of Drag - Boundary layer velocity profile of a channel	 1:59	Boundary layer theory
(7I) Fluid Mechanics of Drag -Flow of air past a sphere and bomb -Sphere and bomb falling in a liquid	 :48 1:58	Boundary layer theory
(23) Form, Drag, Lift, and Propulsion -Flow around curved surfaces -Flow around a disc, sphere -Flow around a cylinder and a roof	 :17 2:23 :46	Boundary layer theory
(24) Effects of Fluid Compressibility - Shock waves on solid bodies	 2:56	One-dimensional compressive flow

III. Evaluation

In order to assess the new learning methodologies used in the Fluid Mechanics (ESC 140) course, we developed a questionnaire with nine questions, as shown below in Table 2. As in any pilot educational project, we wanted to know whether (and to what extent) we would achieve the educational objectives expected with the new methods. This is an important endeavor because it allows the instructor to not lose touch with her/his students' learning process, and it allows students to participate in their own learning process by providing feedback to instructors. In this sense, assessment works as a communications tool between faculty and students [15].

The assessment was prepared by both authors in close consultation with one another. Early on during the conceptual development of the project, and before the course had been fully planned, an assessment plan was developed. The plan (see Table 3 below) contains objectives and outcomes for the course, as well as relevant assessment methods. The ABET 2000 criteria addressed in the plan and the Civil Engineering Departmental objectives covered are included as well. Plans such as the one presented here are useful as "road maps" for instructors in so far as they formally describe many routine tasks and implicit ideas that are commonly used in courses, but not often made explicit.

In fact, this approach to assessing courses is common at Cooper, where about 40% of all courses taught at the Engineering School develop according to plans in which the educational objectives, the outcomes, and the assessment methods are specified at the outset. This planning makes it possible to measure progress in meaningful ways and, as our evidence shows, enhances the involvement of both faculty and students in the educational process with very positive results[16].

Once the course had been planned in detail, the task of the assessor was to get familiar with the assessment interests of the instructor. In some instances an assessment instrument can be developed directly from an assessment table like the one discussed above (by asking questions on the outcomes listed, for example). But in the case presented here we also needed to establish a specific set of questions on topics that directly addressed the new methodologies applied in ESC 140, and consistent with the goals of the course.

Accordingly, the questionnaire contains questions on each teaching methodology; it asks the students to rate the relative effectiveness of these methodologies; it also asks them to rate their own individual competence for a number of topics covered in the course, as well as their general satisfaction with their knowledge of fluid mechanics after taking the course. Finally, the questionnaire also asks students to suggest ways to improve the course. The form contains both rating scales and open-ended questions, so that we could quantify the results and also obtain "anecdotal" feedback and individual narratives from the students.

The questionnaire was therefore an instrument critical for the *summative* assessment we performed. We gathered information from the students at the end of the course, and about their past experiences in that course. The results of our summative assessment will be used in a *formative* way in future editions of the course and for the planning of the educational experiences which will be developed in the New Learning Labs scheduled to open at Cooper next year. We will use the feedback from the students to improve the methodologies, the teaching and the learning experiences.

Table 2. ASSESSMENT INSTRUMENT ESC 140 FALL 2000

This course has introduced a number of teaching and learning methods for fluid mechanics. We would like to know your reactions to them. Your feedback is important and will help to improve the course in the future. Please reply to this email. Your instructor will get compiled, not individual results. Confidentiality is assured.

1. How effective were the following methods to understand the material covered in class?
Use this scale: *not effective* (1), *effective to a limited extent* (2) *effective to a moderate extent* (3), *effective to a great extent* (4), *effective to a very great extent* (5), *not applicable* (N/A)

LECTURE	1	2	3	4	5	N/A
MODULE	1	2	3	4	5	N/A
VIDEOCLIPS	1	2	3	4	5	N/A
DEMONSTRATIONS	1	2	3	4	5	N/A
TEXTBOOK	1	2	3	4	5	N/A

2. Now please assess the effectiveness of the methods above for each of the topics covered:

TOPIC	**LECTURE**	**MODULE**	**VIDEOCLIPS**	**DEMOS**	**TEXTBOOK**
Fluid phenomena and continuum;stress	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Fluid statics	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Kinematics of flow	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Basic laws; mass;momentum;energy;thermodynamics laws	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Dimensional analysis and similitude	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Incompressible viscous flow through pipes	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Potential flow	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Boundary-layer theory	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Navier-Stokes	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
One-dimensional compressible flow	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A
Tests	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A	1 2 3 4 5 N/A

3. How effective were the following parts of the module to understand the material covered in class? from *not effective* (1), *effective to a limited extent* (2) *effective to a moderate extent* (3), *effective to a great extent* (4), *effective to a very great extent* (5), *not applicable* (N/A)

THEORY	1	2	3	4	5	N/A
ILLUSTRATION	1	2	3	4	5	N/A
DESIGN HOMEWORK	1	2	3	4	5	N/A
DESIGN PROJECT	1	2	3	4	5	N/A
HISTORY	1	2	3	4	5	N/A

4. Do you feel competent in the following areas covered in the course? Please rate according to the following scale: *not at all (1), to a limited extent (2) to a moderate extent (3) to a great extent (4), to a very great extent (5)*

Fluid phenomena and continuum;stress	1 2 3 4 5 N/A
Fluid statics	1 2 3 4 5 N/A
Kinematics of flow	1 2 3 4 5 N/A
Basic laws; mass;momentum;energy;thermodynamics laws	1 2 3 4 5 N/A
Dimensional analysis and similitude	1 2 3 4 5 N/A
Incompressible viscous flow through pipes	1 2 3 4 5 N/A
Potential flow	1 2 3 4 5 N/A
Boundary-layer theory	1 2 3 4 5 N/A
Navier-Stokes	1 2 3 4 5 N/A
One-dimensional compressible flow	1 2 3 4 5 N/A
Tests	1 2 3 4 5 N/A

5. Lets focus now on the videoclips. Please explain how they helped you to understand the material and to learn fluid mechanics. Be as detailed and specific as you can.

6. Which of the videoclips was (were) more useful? Which was (were) least useful? Why?

7. Are you generally satisfied with your knowledge of fluid mechanics after taking this course? Please explain.

8. In addition to learning fluid mechanics, have you developed any other skill or ability during this course?

9. What would you do to improve this course? Please feel free to make any suggestions

Table 3. ASSESSMENT PLAN

COURSE NAME AND CODE: ESC 140 Fluid Mechanics and Flow Systems
INSTRUCTOR: Cataldo, Brazinsky, Sidebotham
DEPARTMENT: Civil, Chemical, Mechanical Engineering

COURSE OBJECTIVES	STRATEGIES AND ACTIONS	OUTCOMES	ABET 2000	ASSESSMENT METHODS AND METRICS
Learn fluid mechanics	Identify fundamental skills in Fluid Mechanics in lectures and questions/answer sessions	Knowledge of Fluid Mechanics: Hydrostatic, Kinematics, Conservation Laws, Similitude, Bernouilli's Eq., Pipe flow, Turbulence, Potential Flow, Drag.	a, c, e, g, k	1. Test, homework 2. Feedback from oral questions 3. Feedback by putting homework on board 4. Student answers
Expose the students to teamwork, hands-on activities and experimentation	Demonstrations, labwork through homework and written assignments	Theory and application of Fluid Mechanics through hands-on experiments (pipe flow, potential flow, etc.)	a, b, c, d, e, g, k	1. Grade homework and reports 2. Discuss lab results with students
Expose the student to web-based learning and the Internet	Computer-based homework and projects	Knowledge of Key Fluid Mechanics principle by use of CD, instruction tapes, and videos.	a, c, e, I	1. Grade homework assignments and projects 2. Interact with students through the web

IV. Results

The questionnaire was distributed to students via email. We obtained a 50% response rate (9 completed forms) this way. The questiionnaire was distributed again in class among students who did not respond via email. We obtained 7 more responses this way, for a total of 16 responses. The results can be summarized as follows:

As we can see in Table 5, students appreciate an exposure to a variety of teaching methods. In particular, they are enthusiastic about the lecture mode and the demonstrations. 75% of the students say that the lecture was effective "to a great extent" or "to a very great extent" in order to understand the class material, and 68.75% of the students say the same about the demonstrations. The rate of enthusiasm is much lower for the module (37.5%), the videoclips (37.5%), and the textbook (25%).

If we take into account not only enthusiastic responses, but the positive ones as well (moderate, great, very great), then we see that all the teaching methods are highly rated. Almost the whole class felt that the methods were effective to a moderate, great or very great extent to understand the class material, in the following order: demonstrations (93.75%), videoclips and lecture (87.5%), module (75%), and textbook (62.5%).

Table 4. Effectiveness of teaching methods to understand class material (responses show % of respondents for each response category)

	NOT EFFECTIVE	EFFECTIVE TO A LIMITED EXTENT	EFFECTIVE TO A MODERATE EXTENT	EFFECTIVE TO A GREAT EXTENT	EFFECTIVE TO A VERY GREAT EXTENT	N/A	N
LECTURE	0	12.5	12.5	50	25	0	16
MODULE	0	25	37.5	37.5	0	0	16
VIDEOCLIPS	6.25	6.25	50	12.5	25	0	16
DEMONSTRATIONS	0	6.25	25	50	18.75	0	16
TEXTBOOK	12.5	25	37.5	18.75	6.25	0	16

Table 5. Effectiveness of teaching methods: negative, positive and enthusiastic responses (responses show % of respondents for each response category)

	NEGATIVE(1)	POSITIVE(2)	ENTHUSIASTIC(3)
LECTURE	12.5	87.5	75
MODULE	25	75	37.5
VIDEOCLIPS	12.5	87.5	37.5
DEMONSTRATIONS	6.25	93.75	68.75
TEXTBOOK	37.5	62.5	25

(1) Addition of responses "not effective" and "effective to a limited extent"
(2) Addition of responses "effective to a moderate extent," "effective to a great extent," and effective to a very great extent."
(3) Addition of responses "effective to a great extent," and "effective to a very great extent."

On the negative side, 37.5% of the students did not think that the textbook was effective, 25% said the same about the module, 12.5% about the lecture and the videoclips, and only 6.25% (that is, one student) about the demonstrations.

Table 6 gives the relative effectiveness of the teaching methods used for each of the topics covered in the course. Unlike the previous tables showing percent of responses, Table 6 shows number of respondents for each category of response. These results were grouped in two: responses "great" and "very great" on the one hand, and responses "not," "limited" and "moderate," on the other hand. The quotient between the first and the second gives us a figure that we have called "rate of enthusiasm." A ranking procedure was used to determine how effective each method of presentation was for the individual fluid mechanics topics. These rankings are shown on the right side of the table. We proceeded to establish two ranking systems, one for each of the presentation methods (ranking of method), and another one for the topics (ranking of topic).

Note, the lower the score the higher the ranking or the more enthusiastic the students response. The students believe that the lectures are the most effective method of presentation. This method was generally ranked higher than the others. If you group the textbook and the module together, they were ranked lowest by the students. Fluid statics and incompressible flow through pipes topics had the highest ranking. One dimensional compressible flow had the lowest ranking.
The relative lack of enthusiasm shown by students regarding compressible flow may be due to the time spent on this topic and the number of videos and demonstrations presented. In contrast, a total of over four weeks was devoted to statics and pipe flow and less than three hours were spent lecturing on compressible flow. There were also a number of videos and bench scale demonstrations for the static and pipe topics. There was only one two-and-a-half-minute video on compressible flow.

Table 6. Effectiveness of teaching methods for each topic covered

(TheTable shows number of respondents for each response category)

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N	RATE OF ENTHUSIASM (1)		RANKING OF METHOD (2)	RANKING OF TOPIC (3)
FLUID PHENOMENA AND CONTINUUM STRESS											
lecture:	0	0	4	4	3	0	11	07/04	1.75	4	
module:	0	2	4	5	0	0	11	05/04	1.25	7	
videoclips:	0	3	3	3	1	1	11	04/06	0.66	12	
demos:	1	1	2	3	3	1	11	06/04	1.5	5	
textbook:	1	4	3	2	1	0	11	03/08	0.375	17	
									TOTAL	*45*	***3***
FLUID STATICS											
lecture:	0	1	2	6	3	0	12	09/03	3	2	
module:	0	2	5	4	1	0	12	05/07	1.4	6	
videoclips:	1	2	3	4	1	1	12	05/05	1	9	
demos:	0	1	4	4	2	1	12	06/05	1.2	8	
textbook:	1	3	3	4	1	0	12	05/06	0.83	10	
									TOTAL	*35*	***1***
KINEMATICS OF FLOW											
lecture:	0	1	3	5	3	0	12	08/04	2	3	
module:	1	2	5	4	0	0	12	04/08	0.5	14	
videoclips:	1	4	4	2	1	0	12	03/09	0.33	18	
demos:	0	1	4	3	3	1	12	06/05	1.2	8	
textbook:	1	4	3	3	1	0	12	04/09	0.44	15	
									TOTAL	*58*	***7***
BASIC LAWS; MASS; MOMENTUM; ENERGY; THERMODYNAMICS LAWS											
lecture:	0	1	1	6	4	0	12	10/02	5	1	
module:	0	4	4	3	1	0	12	04/08	0.5	14	
videoclips:	0	2	6	3	1	0	12	04/08	0.5	14	
demos:	2	2	2	1	3	2	12	04/06	0.66	12	
textbook:	1	4	2	3	2	0	12	05/07	1.4	6	

									TOTAL	47	4

DIMENSIONAL ANALYSIS AND SIMILITUDE

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N				
lecture:	0	1	5	2	4	0	12	06/06	1	9	
module:	1	1	6	3	1	0	12	04/08	0.5	14	
videoclips:	3	0	5	1	1	2	12	02/08	0.25	20	
demos:	3	1	2	0	2	4	12	02/06	0.33	18	
textbook:	1	5	1	3	2	0	12	05/07	1.4	6	
									TOTAL	*67*	***10***

INCOMPRESSIBLE VISCOUS FLOW THROUGH PIPES

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N				
lecture:	0	0	3	4	5	0	12	09/03	3	2	
module:	0	0	2	6	4	0	12	10/02	5	1	
videoclips:	1	1	6	2	1	1	12	03/08	0.375	17	
demos:	2	1	3	1	3	2	12	04/06	0.66	12	
textbook:	2	2	2	4	2	0	12	06/06	1	9	
									TOTAL	*41*	***2***

POTENTIAL FLOW

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N				
lecture:	0	1	1	5	5	0	12	10/02	5	1	
module:	0	2	6	3	1	0	12	04/08	0.5	14	
videoclips:	1	1	5	3	0	2	12	03/07	0.42	16	
demos:	1	1	4	3	1	2	12	04/06	0.66	12	
textbook:	2	2	2	6	0	0	12	06/06	1	9	
									TOTAL	*52*	***5***

BOUNDARY-LAYER THEORY

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N				
lecture:	0	1	6	2	3	0	12	05/07	1.4	6	
module:	0	2	6	3	1	0	12	04/08	0.5	14	
videoclips:	1	1	5	2	1	2	12	03/07	0.42	16	
demos:	2	0	3	1	2	4	12	03/05	0.6	13	
textbook:	1	3	3	4	1	0	12	05/07	1.4	6	
									TOTAL	*55*	***6***

NAVIER-STOKES

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N

lecture:	0	2	3	2	5	0	12	07/05	1.4	6	
module:	0	4	6	1	1	0	12	02/10	0.2	21	
videoclips:	2	1	3	1	3	2	12	04/06	0.66	12	
demos:	3	0	1	0	3	5	12	03/04	0.75	11	
textbook:	2	1	3	5	1	0	12	06/06	1	9	
									TOTAL	*59*	***8***

ONE-DIMENSIONAL COMPRESSIBLE FLOW

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N				
lecture:	2	2	2	3	3	0	12	06/06	1	9	
module:	1	2	8	1	0	0	12	01/11	0.09	22	
videoclips:	2	0	4	2	1	3	12	03/06	0.5	14	
demos:	2	0	2	2	2	4	12	04/04	1	9	
textbook:	2	2	5	3	0	0	12	03/09	0.33	18	
									TOTAL	*72*	***11***

TESTS

	NOT	LIMITED	MODERATE	GREAT	VERY GREAT	N/A	N				
lecture:	0	0	4	5	3	0	12	08/04	2	3	
module:	0	4	6	1	1	0	12	02/10	0.2	21	
videoclips:	0	2	5	3	0	2	12	03/07	0.42	16	
demos:	1	2	4	0	2	3	12	02/07	0.28	19	
textbook:	1	2	2	7	0	0	12	07/05	1.4	6	
									TOTAL	*65*	***9***

(1) Rate of Enthusiasm. Number of responses great + very great divided by number of responses not + limited + moderate
(2) Ranking of Method. Relative position of each method according to rate of enthusiasm.
(3) Ranking of Topic. Relative position of each topic according to the combined ranking of methods in that topic.

Tables 7 and 8 focus on the effectiveness of the module. As we saw in Table 5, students responded to the module in a *positive* way (75% of "moderate," "great," or "very great" responses), although they were not very *enthusiastic* about it (37.5% of "great" or "very great" responses). These results are consistent with the ones in Table 7 (which gives the distribution of responses for each of the module parts), and Table 8 (in which responses have been grouped in three: negative, positive, and enthusiastic). Again here, most students think positively of each module part. The illustration part, and both the design homework and the design project get 81.25% of positive responses (moderate, great and very great effectiveness combined). In addition, 68.75% of the students think positively of the theory part.

Table 7. Effectiveness of module parts to understand class material (responses show % of respondents for each response category)

	NOT EFFECTIVE	EFFECTIVE TO A LIMITED EXTENT	EFFECTIVE TO A MODERATE EXTENT	EFFECTIVE TO A GREAT extent	EFFECTIVE TO AVERY GREAT EXTENT	N/A	N
THEORY	0	31.25	43.75	25	0	0	16
ILLUSTRATION	0	18.75	37.5	31.25	12.5	0	16
DESIGN HOMEWORK	0	18.75	37.5	31.25	12.5	0	16
DESIGN PROJECT	0	18.75	37.5	18.75	25	0	16
HISTORY	12.5	50	18.75	0	6.25	12.5	16

Table 8. Effectiveness of module parts: negative, positive and enthusiastic responses (responses show % of respondents for each response category)

	NEGATIVE(1)	POSITIVE(2)	ENTHUSIASTIC(3)
THEORY	31.25	68.75	25
ILLUSTRATIONS	18.75	81.25	43.75
DESIGN HOMEWORK	18.75	81.25	43.75
DESIGN PROJECT	18.75	81.25	43.25
HISTORY	62.5	25	6.25

(1) Addition of responses "not effective" and "effective to a limited extent"
(2) Addition of responses "effective to a moderate extent," "effective to a great extent," and effective to a very great extent."
(3) Addition of responses "effective to a great extent," and "effective to a very great extent."

The exception is the history part, which is rated positively by only 25% of the students. In addition only one student (6.25% of the total) was enthusiastic about the history part, and two students (12.5%) checked the "not applicable" column as their response. In contrast, 43.75% of the students are enthusiastic (great or very great effectiveness) about the illustration, the design homework and the design project, and 25% are enthusiastic about the theory part.

So far we have discussed the teaching methods used in the Fluid Mechanics ESC 140 course. We asked the students about the methods' effectiveness and we have seen that students generally think these methods to be effective for learning the material, in different degrees. An indirect way to measure the teaching methods' effectiveness is to ask the students about their self-perception of competence. The assumption is, of course, that if the teaching methods used in a particular course are indeed effective, then students will feel competent in the topics covered in the course.

Tables 9 and 10 show the students' self-perception of competence in each of the areas covered in class. Students feel competent in almost all the fluid mechanics topics (average of 88.75%) and about half (49.42%) rated themselves very competent. The only exception to this trend was the Navier Stokes equation topic where 43.75% of the students rated themselves below competence. This may be due to the period of time spent on this topic (less than two hours) and lack of videos and demonstrations.

Almost all students believe they are competent in the following topics: Kinematics, Basic Laws, Similitude, Pipes, and Boundary Layer. In all of these cases there was an extensive use of videos, demonstrations and module homework assignments and projects. The most frequent expressions made by the students were: "It is easier to understand the theories when they are made visual," "The demonstrations show experiments in action and allow me to see the actual results of the theory," "It was great to see fluid mechanics instead of imagining it." There were a number of negative comments about the text book and the module. The students felt the module should have better supplemented the text books deficiencies.

Table 9. Student self-perception of competence (responses show % of respondents for each response category)

	NOT COMPETENT	COMPETENT TO A LIMITED EXTENT	COMPETENT TO A MODERATE EXTENT	COMPETENT TO A GREAT EXTENT	COMPETENT TO A VERY GREAT EXTENT	N/A	N
Fluid phenomena and continuum stress	0	18.75	37.5	37.5	6.25	0	16
Fluid statics	0	6.25	31.25	37.5	25	0	16
Kinematics of flow	0	0	31.25	62.5	6.25	0	16
Basic laws; mass;momentum;energy;thermodynamics laws	0	6.25	31.25	50	12.5	0	16
Dimensional analysis and similitude	0	0	43.75	43.75	12.5	0	16
Incompressible viscous flow through pipes	0	6.25	37.5	50	6.25	0	16
Potential flow	6.25	12.5	43.75	25	12.5	0	16
Boundary-layer theory	0	6.25	56.25	31.25	6.25	0	16
Navier-Stokes	6.25	37.5	37.5	6.25	12.5	0	16
One-dimensional compressible flow	0	0	43.75	37.5	0	18.75	16
Tests	0	0	31.25	56.25	6.25	6.25	16
AVERAGES	1.13	8.5	38.63	39.77	9.65	2.27	

Table 10. Student self-perception of competence: below competence, competence, and expertise (responses show % of respondents for each response category)

	BELOW COMPETENT(1)	COMPETENT(2)	VERY COMPETENT(3)
Fluid phenomena and continuum stress	18.75	81.25	43.25
Fluid statics	6.25	93.75	62.5
Kinematics of flow	0	100	68.75
Basic laws; mass;momentum; energy;thermodynamics laws	6.25	93.75	62.5
Dimensional analysis and similitude	0	100	56.25
Incompressible viscous flow through pipes	6.25	93.75	56.25
Potential flow	18.75	82.25	37.5
Boundary-layer theory	6.25	93.75	37.5
Navier-Stokes	43.75	56.25	18.75
One-dimensional compressible flow	0	87.75	37.5
Tests	0	93.75	62.5
AVERAGES	9.6	88.75	49.42

(1) Addition of responses "not competent" and "competent to a limited extent."
(2) Addition of responses "competent to a moderate extent," "competent to a great extent," and "competent to a very great extent."
(3) Addition of responses "competent to a great extent," and "competent to a very great extent."

V. Conclusion

A studio-classroom in fluid mechanics was taught in the Fall 2000 semester to junior level Civil Engineering students at The Cooper union. The object of this studio classroom was to present fluid mechanics by a number of different methods (lecture, demonstrations, videos, and design homework and projects). A module was developed for the course as a guide to the students. These methods of presentation were keyed to the module. The students filled out a questionnaire to determine the effectiveness of this studio-classroom. The students had a favorable response to the variety of teaching methods presented.

Almost the whole class felt that the videoclips and demonstrations were effective (over 90%) with approximately an equal amount (87.5%) scoring the lectures positive. The ranking by the students were the highest (lowest numerical score) for fluid statics and incompressible flow through pipes and the lowest for compressible flow. The higher rankings were probably due to the time spent on statics and pipe flow (over four weeks) and larger number of videos and demonstrations compared to the time spent on incompressible flow (less than 3 hours) and only one short video.

An indirect way to measure the teaching methods' effectiveness is to ask the students about competence. The students felt confident in almost all the fluid mechanics topics (average of approximately 90%). The topics scoring the highest were the ones where extensive use of videos, demonstrations and design homework problems were used. The reverse was true for the topics with the lowest score. The least amount of classroom instruction was also given to the lowest scoring topic.

A number of questions were asked to determine the effectiveness of the module. The students gave the module a positive response (75%). With the illustrations and design homework and design projects scoring higher than the theory and much higher than the historical notes.

From the responses in the questionnaire we believe the studio-classroom was a success. The students' written responses also verify that they are engaged by the videos and demonstrations. From a professor's viewpoint, the new methods made us think more about teaching. Time is spent more efficiently in the studio classroom environment. The use of the module demonstrations, and videos, makes the lectures more structured and allows the teacher to focus on presentation, use of time, and more interaction with the students. It was clear that the students had difficulty with aspects of the module. Therefore, appropriate student recommendations have been incorporated in a revised module.

The Cooper Union is committed to the studio-classroom concept and will therefore equip two closely related Learning Laboratories, one for Fluid Mechanics and one for Engineering Mechanics, in the Fall semester 2001. Moveable bench scale equipment will be purchased and used in these laboratories (studio-classroom) for demonstrations and homework assignments that investigate solid and fluid mechanics phenomena. The ultimate goal is to have a studio-classroom where lectures are punctuated with demonstrations, hands-on experiments, and videotaped instruction and illustrations.

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