Project Based Teaching: A Case Study from a Hydraulics Class

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Abstract

Hydraulics is currently taught as one-half of a 3-credit course in the Environmental Engineering Program at the Mercer University School of Engineering. The topics covered include fluid properties, fluid pressure, forces on submerged surfaces, fluid flow in pipes, pipelines, pipe networks, and pump design and selection. The first semester this course was taught the material was presented topic by topic. This created a very choppy course structure and the impression that hydraulics was a collection of individual topics, many of which had little relevance to each other.

A project-based teaching format was adopted to create a more cohesive course structure, help the course move more fluidly from topic to topic, and demonstrate to the students the application of the material they were learning. The project required the students to design a dam to create a reservoir in a theoretical gorge, pipe and pumps to convey water from the reservoir to a downstream community, and a pipe network to distribute the water within the community. This project was distributed to students on the first day of class and was used to drive the sequence of the course lectures. In addition to keeping the students focused on why they were learning a topic, the project based teaching format also produced a just in time teaching format.

This paper will present the project used to teach the hydraulics class, a qualitative analysis of how the use of project-based teaching affected this class, and modifications planned for the next offering of the course. Suggestions for the design of projects will also be presented.

1.0 Introduction

Hydraulics is currently taught as one-half of a 3-credit course in the Environmental Engineering Program at the Mercer University School of Engineering. The topics covered include fluid properties, fluid pressure, forces on submerged surfaces, fluid flow in pipes, pipelines, pipe networks, and pump design and selection. The first semester this course was taught the material was presented topic by topic. This created a very choppy course structure and created the impression that hydraulics was a collection of individual topics, many of which had little relevance to each other. It was obvious that the students did not see how the course topics fit together as a whole.

Literature on project-based teaching (Felder, et al., 2000; Mahendran, 1995) suggested that this approach could be used to create a more cohesive course structure, help the course move more fluidly from topic to topic, and demonstrate to the students the application of the material they were learning. The use of a project to drive instruction also seemed to be a promising a method to approach an active learning format where the instructor is more of a facilitator than a lecturer. The challenge was to develop a project that was realistic, incorporated all of the course topics, and contained the appropriate level of complexity.

The final project required the students to design a dam to create a reservoir in a theoretical gorge, pipe and pumps to convey water from the reservoir to a downstream community, and design a pipe network to distribute the water in the community. This project was distributed to students on the first day of class and was used to drive the sequence of the course lectures. Thus, project based teaching not only kept the students focused on why they were learning a topic but, it also produced a just in time teaching format. Material was presented only as it was needed to work on the project.

This paper presents the project used to teach the hydraulics class, a qualitative analysis of how the use of project-based teaching affected this class, and modifications planned for the next offering of the course. Suggestions for the design of projects will also be presented.

2.0 Project Details

The project used in a project-driven course may or may not be used to cover all of the course material. The project used to cover the hydraulics section of this course did provide coverage of all of the required topics, Table 1.

Table 1. Correlation between project topic and hydraulics material covered.

Project Topic	Hydraulics Material Covered
Reservoir Analysis	Mass balance
Dam Design	Water properties, fluid pressure, pressure on submerged surfaces, and statics
Pipe Design	Water properties, pipe flow theory, pipe design, and pipeline design
Pipe Network Design	Fluid flow theory, flow between connected reservoirs, and pipe network design
Pump Design	Pump theory, single pumps, multiple pumps, selection of single pumps, and design and selection of pumps in parallel and series.

The following section presents the project as it was distributed to the students

2.1 Introductory Statement

Your task as an engineer is to provide a water supply for a planned community. Your project will involve (as a minimum):

- Sizing a reservoir to provide a water supply,
- Designing a pipe and pump system to convey the water to downstream communities, and
- Designing and evaluating the pipe network used to distribute water at two facilities downstream from the reservoir.

The community and reservoir will be constructed in the Mercer Gorge. The Mercer Gorge has the cross-section shown in Figure 1. The reservoir and community will be located in a 10 mile straight section of the Gorge. The gorge has an average down gradient slope of 10 ft per mile (0.001894 ft/ft), see Figures 2 and 3. The Mercer River runs through the gorge with an average annual flow rate of ~800 cfs and an average annual depth of ~4 ft. Weekly river flow rates and anticipated community demands are presented in Figure 4.

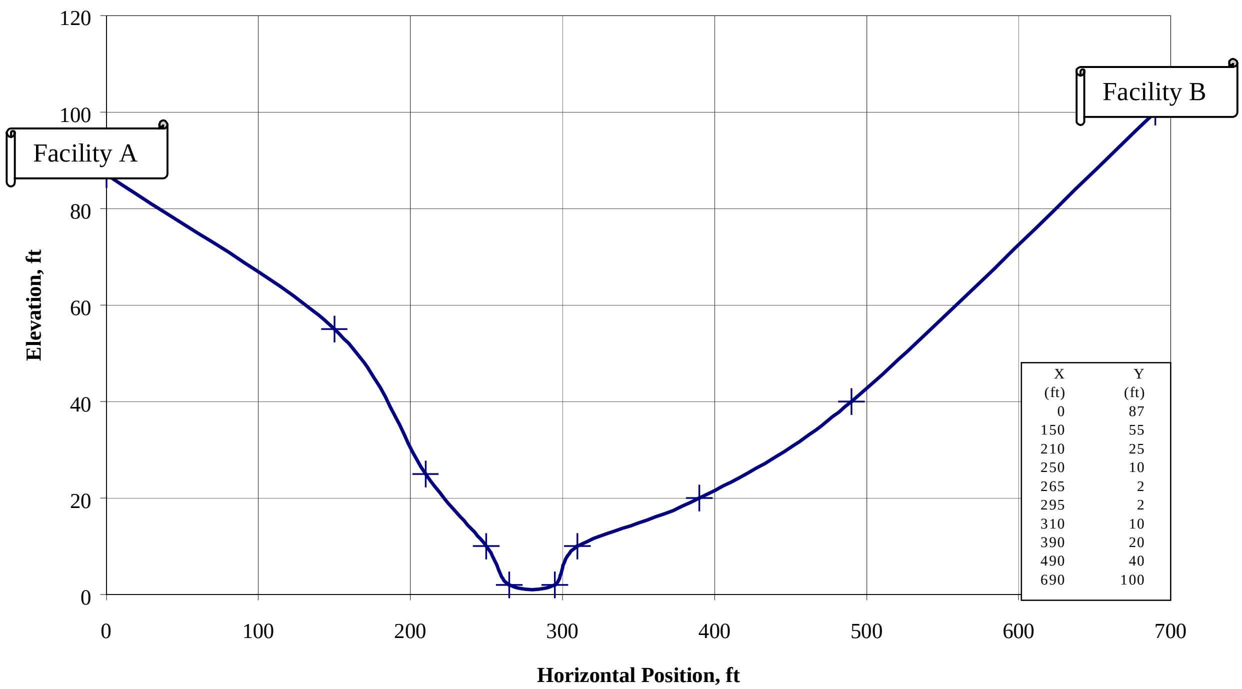

Figure 1. Mercer Gorge cross-section.

<u>2.2 Reservoir Analysis and Dam Design</u>

In the design of the reservoir, a stable gravity dam cross-section must be designed and the weekly variations of the water depth in the reservoir must be determined. The design constraints include:

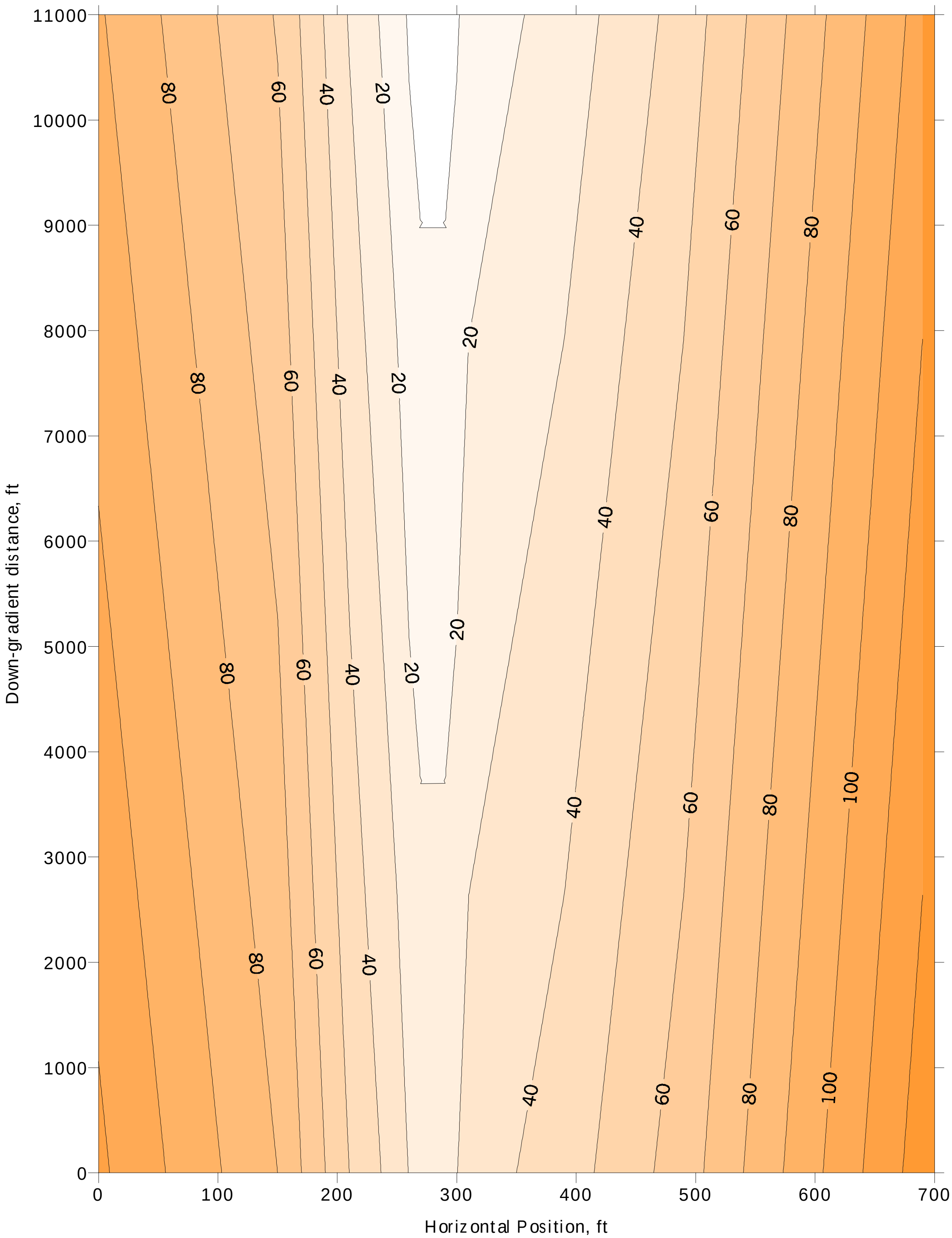

Figure 2. Iso-clines of constant elevation measured in feet for a two-mile linear section of the Mercer Gorge.

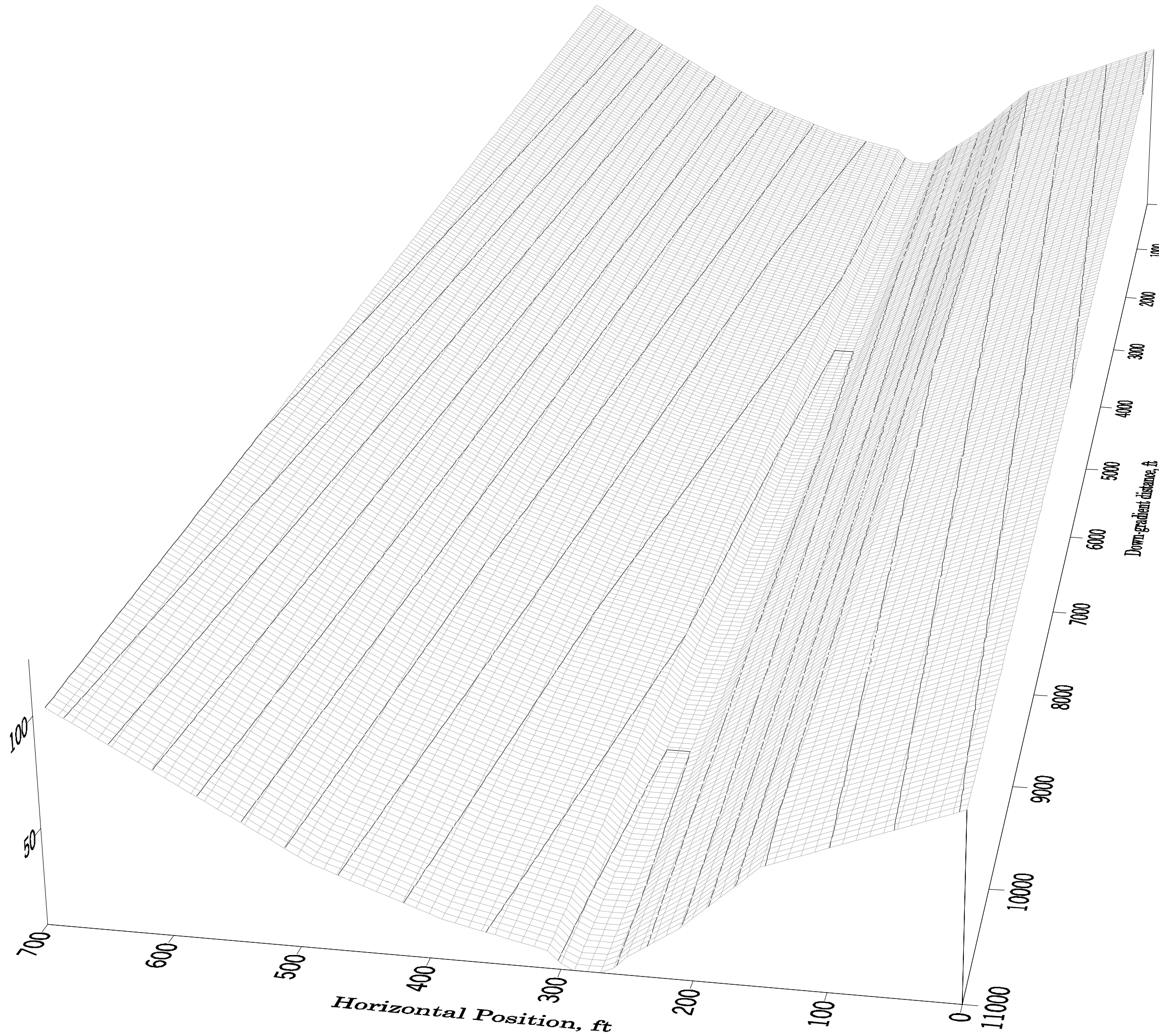

Figure 3. Surface plot of a two-mile linear section of the Mercer Gorge, all units in feet.

- a maximum dam height of 40 ft,
- a maximum reservoir length of eight miles,
- the difference between the maximum and minimum yearly reservoir depths must be no more than three feet, and
- the maximum weekly change in the reservoir depth must be no more than one foot.

The fluctuations in the reservoir water depth will be a function of the reservoir length, dam height, and the release rate to the downstream river section. The stability of the dam cross-section will be dependent on the cross-section chosen, the dam height, and the reservoir water depth.

You have been requested to perform the following tasks:

- determine appropriate reservoir dimensions (length of reservoir and dam height) and a constant release rate to the downstream river section,

- plot the weekly reservoir water depth,
- evaluate three different dam cross-sections for stability, and
- select a dam cross-section for construction (be sure to justify your selection).

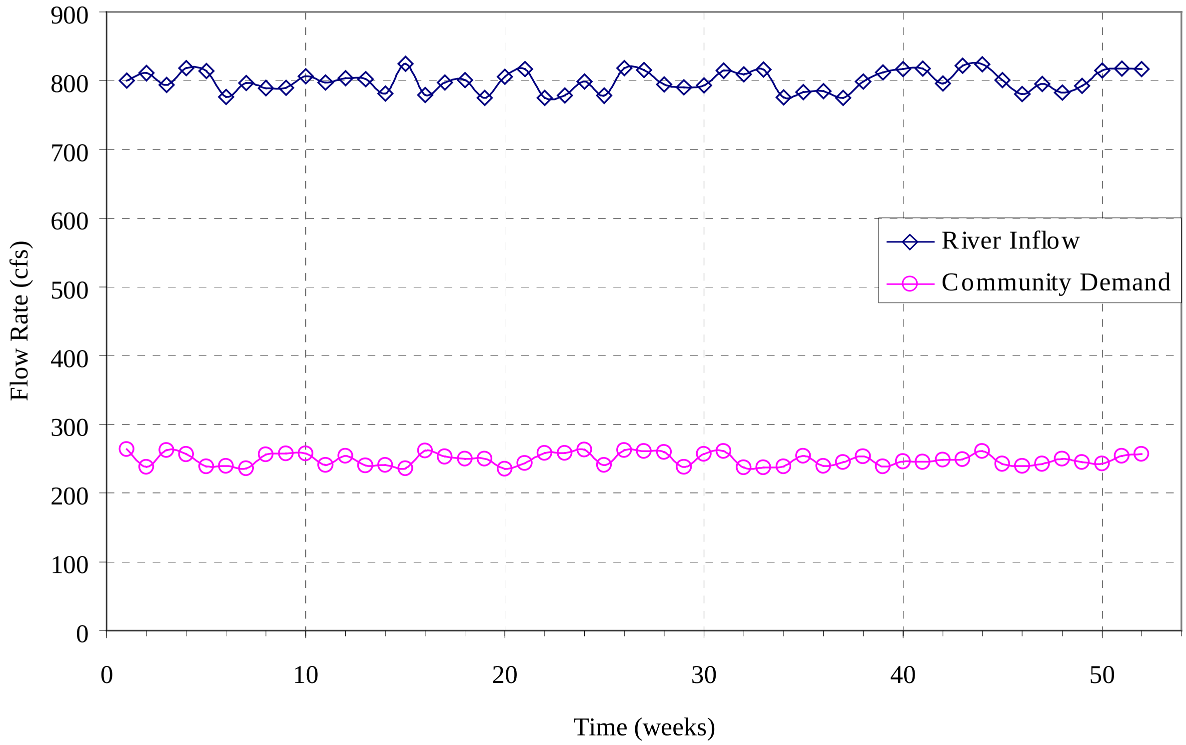

Figure 4. Weekly river flow rates and anticipated community demand.

2.3 Pipe, Pipe Network, and Pump Design

Two vacation facilities consisting of multi-story buildings will be constructed 1/2 mile downstream from the reservoir. These facilities will be located directly across the gorge from each other at the highest elevation on either side of the gorge (see Figures 1 and 5).

The facilities will be laid out as shown in Figure 5. Table 2 contains information on the heights and water demand for each of the buildings.

Table 2. Building height above ground level and water demand.

Building	A	B	C	D	E	F
Height (ft)	31	27	11	20	32	15
Water Demand (cfs)	0.2	0.2	0.1	0.3	0.3	0.4

You have been requested to perform the following tasks:

- Design a main pipe to convey water from the reservoir to each of these facilities
  - Evaluate a direct run from the reservoir to the facility versus running the pipe straight down the gorge and then up to the facility (90° bend).
- Size a pump or pumps to supply water to each of these facilities
  - Evaluate both of the main pipe layouts
  - Determine how far downstream from the reservoir the pump(s) can be before cavitation will be an issue
- Size a pipe to convey the water in excess of the vacation facilities demand downstream by gravity flow (use Darcy-Weisbach, Hazen-Williams, and Mannings equations to justify your specification).
- Size the pipes for the water distribution pipe network at the vacation facilities

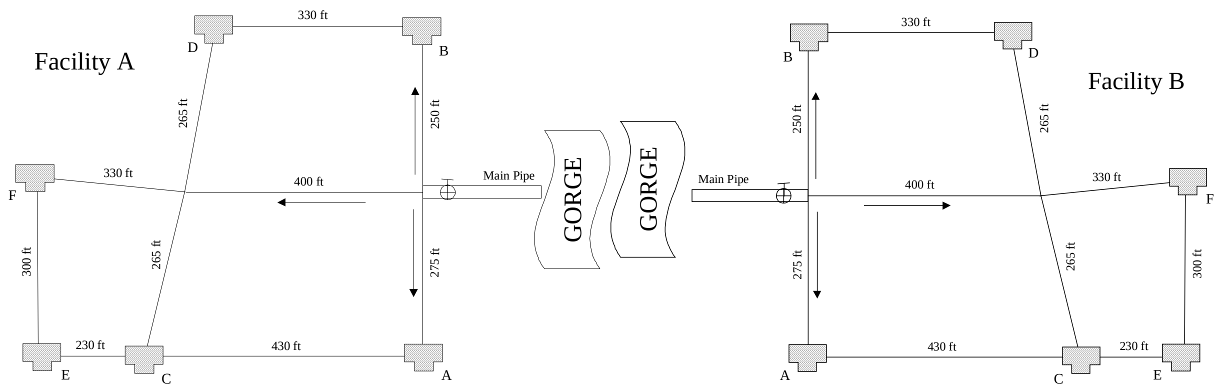

Figure 5. Layout of downstream vacation facilities.

3.0 Qualitative Analysis

This effort clearly demonstrated that a project can be used to cover all of the materials in a course and link them together into one, cohesive unit. From the instructional theory perspective this is obviously desirable. However, from an instructional reality perspective the course was not as successful. The potential of project-based teaching can only be fully realized in an active learning format wherein students take an earnest part in the learning process. For a student to do this, they must be motivated, enthusiastic, excited, and diligent in their studies. Students with these characteristics are becoming rare in an increasingly consumer-minded student body. When teaching a project-driven course, students that 'buy-in' to the project will be successful in the course, appreciate it, and provide a positive course review. Students that do not 'buy-in' to the course can be expected to have the opposite experience. Student 'buy-in' and motivation must be addressed to successfully employ project-based teaching.

A project-driven course is difficult to fully plan the first time around and requires a great degree of flexibility and preparation from the instructor. Students may not necessarily follow the optimum or anticipated sequence of tasks in approaching the project. Thus, planned lectures and activities may have to be dropped at a moments notice and other topics covered.

In order for students to fully benefit from project-based teaching, they must be allowed to flounder without becoming discouraged and need to be directed towards a solution but not shown it. Ultimately, an instructor will be constantly trying to balance project reality with material coverage and learning objectives.

The most common concern expressed by students related to the open-ended nature of the project. They seemed to be very uncomfortable with the fact that multiple physical designs could effectively solve the same problem and were obsessed with finding a single (preferably numeric) answer.

4.0 Planned Modifications

Three modifications are planned for the next offering of this course. The first modification will be the development of on-line modules. These modules will contain information, example problems, and suggested references for basic hydraulic concepts, project topics, and/or project deliverables. Orienting these modules towards the project topics and deliverables should prevent students from floundering too long, straying too far down unproductive solution paths, and enable motivated students to work ahead.

The second modification will be to develop a direct link between homework assignments and the project. The intent of this approach would be to force students to keep pace with their design work and to keep track of their technical progress. This mechanism should help keep less motivated students involved in the course and the project. In using this approach, it will be important to make sure that the project does not become one large compendium of homework assignments.

The third modification will be to provide the students with a matrix of deliverables and performance expectations with the project statement. Table 3 presents a possible matrix for some of the project deliverables. The combination of this matrix with the first two modifications should result in much higher quality projects and streamline grading of the projects.

5.0 Project Design Suggestions

The primary challenges in the design of a project are ensuring that the project will cover the desired topics and that the students demonstrate knowledge of the desired topics in their final product. In many cases, the topics a course must cover are predetermined by the curriculum set forth by the school, college, or department. The instructor is then responsible for covering the required topics. When using a project to drive the course, it will be imperative to ensure that the project addresses all of these topics without making them look like obtuse or frivolous add-ons. Determining which course topics a project does and does not address can be easily and quickly determined by creating a table with two columns, one for the project deliverable and one for the course topics. The deliverables and course topics can then be matched to one another. Any topics that do not match with a deliverable will then be obvious. A method to cover these topics either within or outside of the project can then be developed. Some topics that do not fit with in the project can still be covered under the project umbrella. For instance, barometers were a topic that required coverage under the current hydraulics curriculum and they did not fit well with the project. However, they did fit very well with the discussion of pressure exerted by a fluid, a topic that must be covered in order to understand the forces on a submerged surface.

Once all of the required topics have been built into the project, a method to ensure that the students demonstrate knowledge of these topics must be developed. The matrix of project deliverables and performance expectations discussed in the previous section may be used in this capacity. This matrix should quickly and clearly explain to the students what needs to be submitted to document each deliverable and the grading criteria for each deliverable. Ideally, this matrix will be distributed with the project statement. Providing an accurate and complete matrix will be a challenging task the first time a project-based course format is used. Students should be forewarned that the project deliverables and components associated with the deliverables might change. When changes are made, they should be made in writing.

Table 3. Matrix of project deliverables and performance expectations.

Deliverable	Weight	Components	Grading	
Reservoir Dimensions	10	-Length -Width	Excellent (>90)	Correct Computations
		-Downstream release rate	Good (80 - 90)	Computational errors
			Fair (70 - 80)	Errors, bad data
			Poor (<70)	Incomplete, errors, bad data
Pipe Network	15	-Pipe sizes -Pipe flow rates	Excellent (>90)	Correct computations, good drawing
		-Pressures at nodes -Schematic	Good (80 - 90)	Computational errors, good drawing
			Fair (70 - 80)	Errors, poor drawing
			Poor (<70)	Incomplete, errors, poor drawing
Design Checks	10	-Check #1 - Reservoir	Excellent (>90)	Ahead of Schedule
		-Check #2 - Pipe and Pump	Good (80 - 90)	Slightly behind
			Fair (70 - 80)	On schedule
			Poor (<70)	Significantly behind

6.0 Conclusions

Project-based teaching is a very exciting and useful teaching technique that can be used to draw diverse course materials together into a cohesive unit. Furthermore, a just in time teaching format can be developed by breaking the overall project down into sub-tasks.

New challenges will be faced when utilizing project-based teaching. Many students will have to be motivated to keep pace with the design and encouraged to struggle when an answer does not readily present itself.

Mechanisms to demonstrate that the project covers the required course topics and to assess student mastery of these topics must be developed. One mechanism which may be used is a matrix of project topics, deliverables, and grading criteria.

References

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