AC 2009-905: AN INNOVATIVE APPROACH TO TEACHING WATER RESOURCES DESIGN

Diane Bondehagen, Florida Gulf Coast University
Assistant Professor of Environmental Engineering Department of Environmental and Civil Engineering U.A. Whitaker School of Engineering Florida Gulf Coast University

Simeon Komisar, Florida Gulf Coast University
Associate Professor and Environmental Engineering Program Director Department of Environmental and Civil Engineering U.A. Whitaker School of Engineering Florida Gulf Coast University

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Abstract
A first semester, senior level civil and environmental engineering course, Water Resources Design is, for most, the first experience for students at Florida Gulf Coast University in working with non-trivial design projects. To make the course experience as transferable as possible to future graduate engineering employment, students learn and apply hydraulic software to project development and execution. The course takes an innovative case study approach with 5 design projects required with rotating teams assigned to each project. The projects are taken from "real world" engineering problem assignments which impart to students an appreciation of the constraints and uncertainties inherent in the design process. Project 1 necessitates a quantification and comparison of Capital costs and Operation and Maintenance Costs; Project 2 involves sizing of pipes, pumps and storage for a water distribution system; Project 3 requires a water treatment plant analysis to address two plant operation problems; Project 4 simulates a watershed; and the final design project is a detention pond design. The students soon realize that although there are specific goals to be met in a design, there are also inexplicit objectives requiring an evaluation of engineering uncertainties and engineering judgment in decision-making. The students are therefore challenged to base their decisions on sound engineering reasoning and forecasting methods, including multiple iterations of a design with different approaches, and to justify these decisions logically and convincingly in a formal engineering report format. To this end, throughout the course, consultation with other student teams and outside professionals/experts is encouraged.

Numerous assessment techniques are employed in course outcome evaluation. The students themselves complete a course evaluation survey which indicates their perception of learning outcome success. Additional assessment methods include faculty review and grading of design project reports as well outside evaluation of the final student design project by an experienced practicing engineer. Two rubrics, designed for the course, are employed in the overall assessment scores. The assessment will report on whether students have met or exceeded expectations in development of design ability, hydraulic software mastery, and an overall synthesis of skills and abilities required to deliver a soundly engineered project solution and formal design report.

Introduction
The newly drafted Environmental Engineering Body of Knowledge (AAEE, 2008) acknowledges the importance of water and water resources engineering as a vital subject area for Environmental Engineers, and stresses the need for competence in this field as a cornerstone of Environmental Engineering education in preparation for the needs of the next century. Currently, two billion out of six billion people worldwide do not have access to clean water (UNEP, 2007) and this absolute number and the underlying ratio may grow larger by 2025. Increased loading of green house gases to the atmosphere may be creating a changed climate, increasing the frequency of extreme weather events, including drought and storm conditions leading to floods. Even in areas with developed infrastructure, systems may fail far more often than can be tolerated even by those with an understanding of risk. We do not need to look farther than the U. S. Gulf Coast to see population expansion, potable water scarcity, and extreme weather all poised on a knife's edge.

As part of our efforts to draft and deliver a new BS EnvE program at Florida Gulf coast University, we have created a three course sequence in water resources that culminates in a design oriented course. Other Environmental Engineering degree programs offer a third course in a sequence that includes Fluids Mechanics and Hydraulics with Hydrology, while trying to incorporate design experiences along with the teaching of basic concepts, underlying physics and statistical analyses. We specifically target design in this third course in our sequence to tie together and reinforce the conceptual information with **real world design experiences**. This course was offered for the first time in Fall 2008 with 19 students enrolled.

Projects

Outcomes (for all projects):
Several learning outcomes are supported by the projects. They include the ability:

1. to function in teams;
2. to communicate with clients;
3. to obtain information not in textbooks or lectures;
4. to demonstrate in-depth competence in the field of hydraulic engineering
5. to include ideas of risk, reliability and uncertainty
6. to be able to formulate a complex problem and analyze it conceptually, comparing alternatives

In particular, in supporting these outcomes, we focus on the following demonstrated abilities:

- an ability to identify and define a problem "ambiguously" worded: for example, "there's an operational water treatment problem (plant has decreased output), solve the problem"
- An ability to design a system with multiple constraints
- An ability to technically communicate

Evaluation of Outcomes
The main assessment tool for quantitative evaluation included two rubrics (Appendix A) modified and designed for this particular course. The first rubric was used to score Projects 1-4; the second rubric was used to score the final project and poster presentation. The faculty review and grading of design projects reflected this rubric, and evaluated outcomes and student progression in demonstrating the abilities most important to long-term career success (note the emphasis on technical communication skills in the rubrics). Also, outside evaluation of the final student design project by an experienced practicing engineer was incorporated in our final project quantitative results. Our overall assessment results report on whether students have met or exceeded expectations in development of design ability, hydraulic software mastery, and an overall synthesis of skills and abilities required to deliver a soundly engineered project solution and formal design report. As we progressed through the semester, projects increasingly challenged the students to evaluate uncertainties and employ sound engineering judgment, justifying their decisions in detail. Our results are used to measure increased student ability to meet these challenges.

Project I Description

Cost optimization in water resources is an important issue. We use this first project to give students real world experience with obtaining prices for construction, land acquisition, materials selection (pipes, valves, pumps). Students are asked to form teams and respond to an RFP seeking to design and construct a pipeline to feed water from one of two new sources - an upland reservoir employing gravity flow at some distance and a pumped groundwater source nearer to point of use. Their deliverable is a report that compares alternative designs on a Present Value basis. Given a design life of thirty years, peaking factors to cover fire flow, pressure constraints, and an interest rate, student teams must project population, determine demand for water, compute head losses, pressures and flows, size pumps where needed, compute power demands and estimate costs for these different scenarios. The trade-off between capital expenditure for the distant upland source and the energy costs incurred in pumping the groundwater quickly becomes apparent. Students obtain costs for pipe materials at different sizes, installation costs as a function of that sizing, and costs for pumps, valves and appurtenances for a functional pipeline. No discipline specific software is used for this project - Microsoft Excel becomes their design tool. *For this project, focus was placed on Outcomes 3 and 6.*

Project 1 Assessment Results

Assessment Tool / Course Outcome	Project 1 Grading/Rubric	Results
1.Function on Teams	Goal: 40 % of the students score 85% or above	88%
	75% score 70 or above	100%
	90% score 65% or above	100%
2. Communicate with Clients	Goal: 40 % of the students score 85% or above	90%
	75% score 70 or above	90%
	90% score 65% or above	100%
3. Obtain information not in textbooks and lectures	Goal: 40 % of the students score 85% or above	100%
	75% score 70 or above	100%
	90% score 65% or above	100%
4. Demonstrate in-depth competence in the field of Hydraulic engineering	Goal: 40 % of the students score 85% or above	50%
	75% score 70 or above	75%%
	90% score 65% or above	90%
5. Ability to include ideas of risk reliability and uncertainty	Goal: 40 % of the students score 85% or above on the	75%
	75% score 70 or above	90%
	90% score 65% or above	100%
6. Formulate a complex problem and analyze it conceptually, comparing alternatives	Goal: 40 % of the students score 85% or above on the	50%
	75% score 70 or above	75%
	90% score 65% or above	90%

Project 2 Description

This project gives students the opportunity to develop the ability to understand the design constraints and tradeoffs encountered in real-world design as well as use hydrologic software. Using the software (Haestad Methods software: Flowmaster, WaterGEMS) gives students a real appreciation of the limitations and need to critically analyze results. For this project, students again work in teams and review plans for a water distribution system. They are provided junction flows and demand patterns for water use, control strategies, tank, pump and pipe specifications. Their deliverables includes a report analyzing flows and pressures and suggesting optimizing changes that may be made to the original design. Fire demand is also included as well as chlorine concentration and water age determinations. The report includes details of all design constraints and design estimates. *For this project, focus was placed on Outcomes 4, 5 and 6.*

Project 2 Results:

Results showed the following for Project 2. *As described previously, a similar quantitative assessment was performed for each project*

1. **Function in teams** ranked at 90% or above level for all students
2. **Communication with Clients** ranked at a 90% or above level for all students
3. **Obtaining information not in textbooks or lectures** ranked at 100% for all students
4. **Learning design skills for water distribution** systems ranked at 70% or above for all students
5. **Learning ideas of risk, reliability and uncertainty** ranked at 80% or above for the class
6. **Formulating a complex problem and analyzing it conceptually, comparing alternatives** ranked at 60% or above for all students

Project 3 Description

This project gives students the opportunity to hydraulically analyze a water treatment plant which does not meet design flow criteria and exhibits floc carry-over from the sedimentation tank. Students calculate head losses and flows at different sections of the plant and determined critical areas to solve the problems. For this project, student teams meticulously analyze pipe sections and then construct a hydraulic grade line (HGL) throughout the entire plant. Students then compare the HGL to the elevations of the physical structures of the plane and recommend improvements such as pipe replacement, weir elevation changes, and valve replacements. Their deliverables includes a report showing calculations and methods used as well as recommendations to the client. *For this project, focus was placed on Outcomes 3, 4, 5 and 6*

Project 3 Results:

Results showed the following for Project 3. *As described previously, a similar quantitative assessment was performed for each project.*

1. **Function in teams** ranked at 90% or above level for all students
2. **Communication with Clients** ranked at a 95% or above level for all students
3. **Obtaining information not in textbooks or lectures** ranked at 100% for all students
4. **Analyzing water treatment plant operational problems and making design changes to solve the problems** ranked at 80% or above for all students
5. **Learning ideas of risk, reliability and uncertainty** ranked at 88% or above for the class
6. **Formulating a complex problem and analyzing it conceptually, comparing alternatives** ranked at 70% or above for all students

Project 4 Description

This project gives students the opportunity to work with the U.S. Army Corps of Engineers HEC-HMS modeling program software to analyze a watershed. Actual rainfall data is provided for calibration. The students create synthetic hydrographs and create an optimized model that matches the total run-off volume. The students learn about the different SCS/Snyder's unit hydrograph methods and gain valuable experience in their application. They try varying combinations of unit hydrograph/loss methods, design storm frequencies, and work with the best calibrated models to predict how the watershed would respond to a new verification storm. Their deliverables includes a report showing model graphic and tabular outputs and a comparison of method combination results. *For this project, focus was placed on Outcomes 4 and 5.*

Project 4 Results:

Results showed the following for Project 4. *As described previously, a similar quantitative assessment was performed for each project.*

1. **Function in teams** ranked at 90% or above level for all students
2. **Communication with Clients** ranked at a 92% or above level for all students
3. **Obtaining information not in textbooks or lectures** ranked at 100% for all students
4. **Learning design skills for water distribution systems** ranked at 75% or above for all students
5. **Learning ideas of risk, reliability and uncertainty** ranked at 90% or above for the class
6. **Formulating a complex problem and analyzing it conceptually, comparing alternatives** ranked at 70% or above for all students

Project 5 Description

This project gives students the opportunity to work with stormwater modeling software (PondPack) to design a retention pond for a local property in Southwest Florida. An engineer from a local engineering firm provides the site plans and the specifications for the building site. Students are able to integrate pre and post development conditions to locate and create alternative pond designs. They work with pond volume calculation methods and calculate peak discharge and create hydro graphs. They receive first hand information from experienced engineers who oversee their plan development including practical guidelines to follow in design creation. Their deliverables include a poster presentation to faculty and invited local engineers who assess the project outcomes. *For this project, focus was placed on Outcomes 1, 2, 4, 5 and 6.*

Project 5 Results:

Results showed the following for Project 5. *As described previously, a similar quantitative assessment was performed for each project*

1. **Function in teams** ranked at 90% or above level for all students
2. **Communication with Clients** ranked at a 95% or above level for all students
3. **Obtaining information not in textbooks or lectures** ranked at 100% for all students
4. **Learning design skills for stormwater modeling and retention pond design** ranked at 75% or above for all students
5. **Learning ideas of risk, reliability and uncertainty** ranked at 90% or above for the class
6. **Formulating a complex problem and analyzing it conceptually, comparing alternatives** ranked at 80% or above for all students

Discussion and Conclusions

This course was delivered for the first time with great success. Our assessment results showed that student performance improved with each new assigned project.

This course, as the final course in our 3 course sequence, effectively draws together basic science/engineering course knowledge and combines it with economic, social and political constraints. The students worked with these constraints on real world projects and gained valuable design software experience. Meeting our learning outcomes was facilitated with this new approach - especially our ABET outcomes c and e: "ability to design a system, system component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability in more than one civil/environmental engineering discipline and an "ability to use the techniques, skills, and modern engineering tools necessary for civil engineering practice".

Most importantly, they learn and appreciate the complexities and uncertainties involved in engineering design. This course is not exam-based and at first the students experience some discomfort with the workload. However, the students eventually enjoyed the learning experiences and felt ready to be "real engineers" in the engineering community (in particular, local design firms regularly provide our students with internships, and the students felt they could now truly apply this course to their engineering project assignments).

Recommendations

Future direction in this course would include raising the level of complexity on certain projects and inviting additional practicing engineers to present design projects to the students. The instructors also need to work more closely with our local engineers so that they understand our students' background and can design and present projects accordingly which will challenge the students to a greater degree.

References

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Appendix A. Rubric Used to Assess Water Resources Design Project Reports 1-4

CRITIQUE AREA	Accomplished (10-9)	Competent (8-7)	Developing (6-5)	Beginning (4-0)
OVERALL ORGANIZATION /FORMAT	• Has all appropriate sections present with correct formatting and professional use of typography (incl. title pg., abstract, tbl. of contents, body of report, references, and appendices).	Most characteristics of organization and formatting were met	Several characteristics of organization and formatting were met	Few, if any, characteristics of organization and formatting were met
INTRODUCTION	• Has a concise statement of purpose and background of problem, indicating why the design or analysis was performed. • Has strong support from previous work accomplished (citations). • Listed specification, requirements & constraints of design (if applicable).	Most characteristics of introduction were met	Several characteristics of introduction were met	Few, if any, characteristics of introduction were met
ASSUMPTIONS	• Has concise list of conditions and facts relative to the overall problem.	Most characteristics of assumptions were met.	Several characteristics of assumptions were met.	Few, if any, characteristics of assumptions were met.
GENERAL APPROACH	• Has completely explained the logical, theoretical, approach to solving the design or analysis problem. • Illustrates a logical approach to the problem • Completely explains methodology without a cookbook context to the solution technique used.	Most characteristics of general approach were met.	Several characteristics of general approach were met.	Few, if any, characteristics of general approach were met.
RESULTS & DISCUSSION	• Clear presentation of results, which are discussed and compared in factual manner • Data presented in tables or graphs as appropriate • Suitable discussion of validity of results and effects of assumptions made	Most characteristics of results and discussion were met.	Several characteristics of results and discussion were met.	Few, if any, characteristics of results and discussion were met.

CONCLUSIONS & RECOMMENDATIONS	• Summary emphasizes findings of work concisely and contains the answer to the problem statement originally addressed, with no new information presented. • For design problem states final design problem selected with complete engineering specifications • Recommendations, if any, are drawn from conclusions, and have a bearing on the problem statement.	Most characteristics of references were met	Several characteristics of references were met	Few, if any, characteristics of references were met
REFERENCES	• Uses primarily scholarly publications, with few, if any web citations. • Appropriately cites of all work in document. • Formatting of reference section follows journal formatting.	Most characteristics of references were met	Several characteristics of references were met	Few, if any, characteristics of references were met
GRAMMAR (VISUAL)	• Few, if any, spelling/grammar errors (≤ 2) • Has no errors in voice & tense • Always uses appropriate terminology	Most characteristics of grammar were met	Several characteristics of grammar were met	Few, if any, characteristics of grammar were met
EQUATIONS, NUMERICAL USAGE, AND ILLUSTRATIONS	• Short sample calculations included in Approach section. Longer calculations included in appendix and/or referred to appropriately. • Tables, graphs, and figures correctly labeled, titled, and explained	Most characteristics of equations and images were met	Several characteristics of equations and images were met	Few, if any, characteristics of equations and images were met

Appendix B. Rubric Used to Assess Water Resources Final Design Project 5 (Poster presentation)

	Accomplished (10-9)	Competent (8-7)	Developing (6-5)	Beginning (4-0)	Score
Oral Presentation Skills					
Organization	Gives a clear overview of project. Remains focused throughout the presentation. Ties the entire presentation together with the conclusion.	Most characteristics of accomplished organization were met.	Several characteristics of accomplished organization were met.	Few, if any, characteristics of accomplished organization were met.	
Delivery	Introduces team members. Includes smooth transitions between team members. Talks without reading directly from poster. Engages the audience, including looking at all of them. Speaks clearly so audience can hear and understand presentation. Has clearly practiced the presentation. Has a natural, confident delivery that does not just convey the message but also enhances it. Answers questions confidently and effectively.	Most characteristics of accomplished delivery were met.	Several characteristics of accomplished delivery were met.	Few, if any, characteristics of accomplished delivery were met.	
Professionalism	Wears appropriate clothing. Is professional in demeanor, e.g. stands up straight, does not chew gum, does not fiddle with things in his/her pocket or her/his hands, etc.	Most characteristics of accomplished professionalism were met.	Several characteristics of accomplished professionalism were met.	Few, if any, characteristics of accomplished professionalism were met.	
Written Presentation Skills					
Quality of Poster	Uses a color scheme and template design that make it easy for the audience to read. Uses a font size and type that are easy to read. Tables, graphs, and figures correctly labeled, titled, and explained so reader understands graphic without referring to text.	Most characteristics of accomplished quality of poster were met.	Several characteristics of accomplished quality of poster were met.	Few, if any, characteristics of accomplished quality of poster were met.	

Technical Content – Abstract Background	Informative, clear and concise Concise statement of purpose and background of poster theme, indicating why the project was performed. Concise list of conditions and facts relative to the overall theme.	Most characteristics of technical content were met	Several characteristics of technical content were met	Few, if any, characteristics of technical content were met	
Technical Content – Methods Results	Completely explained the logical, theoretical, approach to design/problem/theme. Writing clearly illustrates a logical approach to problem Completely explains any methodology(ies) without a cookbook context to the solution technique used. Clear presentation of results (if any), which are discussed and compared in factual manner Data presented in tables or graphs as appropriate	Most characteristics of technical content were met	Several characteristics of technical content were met	Few, if any, characteristics of technical content were met	
Technical Content – Discussion Conclusion Recommendations	Suitable discussion of validity of results (if any) and effects of assumptions made Summary emphasizes findings of work concisely and contains the answer to the problem statement originally addressed, with no new information presented. For design problems, states final design problem selected with complete engineering specifications Recommendations (if any) are drawn from conclusions, and have a bearing on the problem statement.	Most characteristics of technical content were met	Several characteristics of technical content were met	Few, if any, characteristics of technical content were met	