AC 2010-1452: HYDROTOPIA: INTEGRATING CIVIL ENGINEERING AND HUMANITIES TO TEACH WATER RESOURCES ENGINEERING AND MANAGEMENT

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Hydrotopia: Integrating Civil Engineering and Humanities to Teach Water Resources Engineering and Management

Abstract

This paper describes a unique integration of civil engineering and philosophy disciplines to create an interdisciplinary learning experience for a multi-discipline set of students from predominantly civil engineering and disciplines in the humanities and social sciences interested in professions in water resources. The course was developed and co-taught by professors from civil engineering and philosophy at the University of Utah with the goals of (1) cultivating in the next generation of civil engineering professionals – those responsible for planning, designing, managing, and operating water resources systems – a broader sensibility about the cultural climate in which they will operate, and (2) developing in humanists, social scientists and others who will be responsible for shaping and articulating that cultural climate a more grounded understanding of the practical water problems facing society and the constraints limiting engineering and technological solutions. Our pedagogical approach was to engage the students in case study analyses and mediated discussions of historical and emerging water engineering issues and projects in the western United States. Within the context of the case studies, students were exposed to philosophical and legal concepts, hydrologic principles, water resources engineering design and management techniques, water management modeling and analysis tools, social and behavioral science theories, water law, and more. One unique aspect of the course was the use of position papers with random assignment of position that forced students to analyze and argue points from perspectives outside of their discipline and sometimes against their personal beliefs. The outcomes of the course were assessed through a written survey, informal student discussions, and end-of-course ratings and comments. The collective feedback clearly indicated the civil engineering students broadened their understanding of the local, regional, and global context of water resources engineering projects and learned to decompose problems and develop logical arguments based on a broad base of knowledge. Most interesting, the civil engineers learned to analyze engineering issues using tools and constructs rooted in philosophy, while the philosophy students gained an appreciation of the challenges faced by engineers and the constraints of modern society related to water resources engineering projects. An unexpected outcome of the course was noted by the end of the semester with the engineers arguing their position papers from humanist perspectives and vice versa – humanists basing their arguments on traditional engineering approaches, e.g., cost-benefit analysis.

Introduction

Water in the American West can be understood best by seeing *aridity* as its defining physical feature; this is because one can most fruitfully describe the culture of the west -- its past, its present, and its future -- as an hydraulic society[1]. The genesis of this society was a utopian vision of the transformation of the west into a new Eden, a transformation made possible through technology. Presently the inhabitants of the West are being forced to re-examine their relationship, both to the water and to the technology used to control it. Indeed, in the next half century, water in the West is anticipated to become a defining challenge requiring a combination of scientific, social, philosophical, technological, ecological, political, economical, and other

expertise and knowledge to devise the innovative solutions necessary to meet growing water demands in a complex coupled natural-human system within an arid region.

Traditional civil engineering courses in water resources do not provide the necessary broad understanding of the totality and complexity of water resources problems. In response to this shortcoming, Taylor[2] proposes a new era of water programs in graduate education that would bring together people in engineering, humanities, social and natural sciences, medicine, law, business, social work, theology, and architecture. He believes to solve today's water challenges, in the arid West and elsewhere, requires an intersection of multiple perspectives and approaches, to develop the new theoretical insights needed for the practical solutions to emerge. However, it remains uncertain how to best integrate disparate disciplines to address emerging complex problems in water resources. Herein, this problem is considered for the case of integration of humanities into civil engineering education.

For decades, both in the U.S. and internationally, there has been a clear need to broaden engineering education by incorporating humanities[3,4,5,6]. The importance of humanities in professional practice is also highlighted by the National Academy of Engineering's visions for engineers of 2020[7]. The need for humanities may be the most important for civil engineering compared to other engineering disciplines because of the connection between civil engineering, public works, and society. Recently, the role of humanities in civil engineering education has been identified as a valuable part of a balanced educational experience[8] and a foundational outcome for civil engineering education[9]. The current civil engineering Body of Knowledge (BOK2) published by the American Society of Civil Engineers (ASCE) includes one primary outcome related to humanities, to "demonstrate the importance of humanities in the professional practice of engineering"[9,10]. This outcome fits with the recently published vision of civil engineers in 2025 published by ASCE[11].

Given the overwhelming justification and support for incorporating humanities into civil engineering education, a common approach to accomplish it has been to require humanities courses to be taken as general education requirements as part of the Bachelor of Science degree. This approach does provide a means to create a balanced base of liberal learning, but might be improved by supplementing the humanities courses with additional instances of direct civil engineering-humanities ties in the civil engineering curriculum. This is especially important when considering the desire to provide civil engineers the context of problems they seek to solve. An approach to accomplish this objective is to incorporate humanities issues into existing courses in the civil engineering curriculum. It has been suggested that much of the exposure of civil engineering students to the humanities must come from civil engineering professors[12]. Hayes[12] highlighted the importance of having civil engineering professors broadly read in the humanities incorporate ethics, knowledge of engineering history, and broader societal concerns into the classroom at every opportunity as a means to provide civil engineering students exposure to the humanities[12]. In general, the civil engineering professors will be best at framing engineering problems and solutions for students from the humanist viewpoint and discussing the impacts from a humanist perspective as valuable elements of a case study or design project analysis and within the capstone design experience. Another approach to integrate humanities into the civil engineering curriculum is to introduce specific modules or blocks of learning into civil engineering courses. Shetty et al.[13] illustrated the potential of this approach for an

engineering design curriculum. They stressed the importance of involving faculty from a range of disciplines including engineering, mathematics, and humanities. One key for integrating modules of humanities knowledge into civil engineering courses is the interaction of engineering educators and humanities educators to provide a single educational philosophy[14].

Having civil engineering students take humanities courses and integrating in discussions on humanities topics and humanities modules into civil engineering courses are both important. Another avenue for integrating humanities into civil engineering education is through interdisciplinary courses. An interdisciplinary course can more deeply explore the interface of humanities and civil engineering rather than relying on tangents or short discussions to establish the relevance and importance of humanities in civil engineering practice. Furthermore, instructing such courses by a multi-discipline team may be the most effective approach to capture the previously identified need for interaction among educators from engineering and the humanities[14,15].

Following this spirit a new course has been developed and offered for the first time during the spring 2009 semester at the University of Utah. The course is a unique integration of civil engineering and philosophy disciplines to create an interdisciplinary learning experience for a multi-discipline set of students from predominantly civil engineering and disciplines in the humanities and social sciences interested in professions in water resources. The course was developed and co-taught by professors from civil engineering and philosophy. This paper describes the course goals, objectives, logistics, pedagogy, and assessment highlighting the multi-disciplinary team-teaching and student interactions.

Course Overview and Description

The integrated civil engineering-humanities course described herein combines concepts from water resources engineering and philosophy into an interdisciplinary course aimed towards future water resources professionals in both engineering and humanities. Philosophy and engineering education have long been linked through engineering ethics courses, but this is believed to be a unique integration of the disciplines to exercise critical thinking skills in civil engineering and humanities students in the study of historical and contemporary water resources issues, facilitate the exploration of the place of engineering problems within a humanist worldview, and improve the understanding of impacts of engineering solutions within social contexts. The course was developed with funding from the University of Utah, Office of Interdisciplinary Studies supporting one instructor from Civil and Environmental Engineering and one from Philosophy.

The goals of the course are to: (1) cultivate in the next generation of engineering professionals – those responsible for planning, designing, managing, and operating water resources systems – a broader sensibility about the cultural climate in which they will operate, and (2) develop in humanists, social scientists and others who will be responsible for shaping and articulating that cultural climate a more grounded understanding of the engineering technologies and solutions available to them. The course is designed to meet learning objectives for a multi-disciplinary student population and to be co-taught by a professor from civil engineering and a professor

from humanities. According to the course learning objectives, after completing the course students should be able to:

1. Explain complex water resources issues and concepts to non-technical people
2. Describe the multi-disciplinary and interdisciplinary elements of a water resources system or engineering project
3. Identify social concerns related to water resources projects
4. Analyze from a systems perspective the broader impacts of water resources planning, management, and engineering projects
5. Assess implications of technical and non-technical water resources system and engineering project decisions in a societal context
6. Judge and recommend creative multi-objective solutions to water resources challenges

The Civil and Environmental Engineering professor (Burian) involved in the course is an associate professor and has experience team-teaching interdisciplinary courses. His previous team teaching experience is in the area of sustainability working with geology, biology, architecture, and urban planning faculty members[15]. The Philosophy professor (Barbanell) is at the associate professor level with an interdisciplinary background. He has taught engineers in philosophy courses previously and has completed a dissertation and published a book on the topic of water law and water management in the west. This new course represents the first teaching collaboration between these two professors. The multi-disciplinary instructor approach in this course is viewed as an essential component. It provides a way to effectively role model critical thinking and a way to elucidate complex humanist and social contexts within which engineering solutions reside.

The initial course offering in the spring 2009 semester was listed at both the undergraduate and graduate levels in both the Philosophy and the Civil and Environmental Engineering Departments at the University of Utah. The course content was designed to be valuable for both undergraduate and graduate students. Creating exposure to humanities for graduate students in civil engineering was identified as an especially important aspect because of the lack of other exposure opportunities beyond the undergraduate program. The spring 2009 course had 21 students registered for credit and one graduate student auditing. Of the 22 students, ten were civil engineering (four graduate students), five philosophy (one graduate), two environmental studies, one economics, one city planning, one communications, one political science, and one environmental engineering.

Our pedagogical approach was to engage the students in case study analyses and mediated discussions of historical and emerging water engineering issues and projects in the western U.S. Within the context of the course assignments and discussions, students were exposed to philosophical and legal concepts, hydrologic principles, water resources engineering design and management techniques, water management modeling and analysis tools, social and behavioral science theories, water law, and more. Specific topics covered were engineering and humanities perspectives of water, water scarcity, water law and water rights, hydrologic cycle, water management principles and entities, climate change, river systems and hydropower, water-energy nexus, urban growth and planning, water conservation, rainwater harvesting, and water reuse. These topics were presented using a wide array of classroom and outside activities

including assigned readings, instructor-facilitated discussions, technical and non-technical presentations on specific topics and water projects, guest presentations, organized debates, and movies. The guest speakers were prominent water resources professionals (and mostly civil engineers) including the Executive Director of "Citizens for Dixie's Future" (a group opposing a proposed billion dollar water pipeline project in Southern Utah), the Executive Director of the Upper Colorado River Commission, the Utah State Engineer, and the Director of Salt Lake City Public Utilities. Their presentations and discussions were carefully defined to provide an overview of their job and to clearly explain their thoughts (and experiences) on the role of the humanities and social sciences in managing water in the west and the implications of water resources technical and non-technical decisions on society.

Assignments included (1) a written definition of "Hydrotopia", (2) position papers on emerging water resources issues, and (3) semester case study team project. The general learning objectives for the assignments were to stimulate critical thinking, to encourage students to explore the context of water resources problems beyond their disciplinary perspective, to encourage interaction among the disciplines, and to acquire knowledge about important water resources topics. Writing and speaking skills were stressed and reinforced in all assignments. Written submissions were required and graded by both instructors. All submitted written assignments were the topic of classroom debates (position papers), discussions ("Hydrotopia" definition), or formal presentations (project).

The "Hydrotopia" definition assignment was a particularly unique activity. Assigned the first class period, the requirement was to craft a 1-page definition of hydrotopia. Students were instructed to create a concise vision of a realizable hydrotopia in the western U.S. considering all parts to the solution (infrastructure, ecology, society, politics, culture, etc.). Students could address both demand side (e.g., water conservation needs) and supply side (e.g., reservoirs, pipelines, reuse) issues in their statements. Definitions had to be supported with facts and logical reasoning. The instructors used the initial submission to establish the range of perspectives to be encountered in the class and to teach students the concept of worldview and how to support a position with facts and logical reasoning. The initial classroom discussion provided an initial exposure for the students to a range of perspectives surrounding the water resources profession in the western U.S. After students established their initial definition, engaged in classroom discussion, and received feedback from the instructors they were given two additional deadlines for submissions of revised hydrotopia definitions. The second submission was due at the middle of the semester and the final version was due at the end of the semester, which culminated with a classroom consensus building exercise where the instructors facilitated the students' development of a single hydrotopia definition on which all the students could agree. In the two statement revisions, students had not only to establish the vision, but also to specify a defensible action plan for achieving the vision. Students needed to address both system changes (e.g., make systems more efficient through technological solutions) and social changes (e.g., use less water through lifestyle changes). Students were encouraged to seek examples at the small scale (e.g., a city implementing a practice) or national level, including examples in other countries that might be relevant to their proposed plan.

The position papers provided a very interesting and unique opportunity for civil engineers and humanists to argue for and against real water resources engineering projects. The four position

paper assignments were on the topics of the Lake Powell Pipeline (a proposed billion dollar water supply pipeline in Southern Utah), dam removal on the Klamath River in Oregon/California (to restore habitat for endangered salmon), Las Vegas' proposal to tap the aquifer at the Nevada-Utah border (Snake Valley), and San Diego's proposal, aptly but unfortunately identified as "toilet to tap", to recycle municipal wastewater for drinking. These topics were purposely selected to be contemporary and controversial where clear opinions could be established for or against the project. Positions were randomly assigned such that students might be forced to argue for a position they personally disagreed with or against a position they favored. Positions were monitored to be sure all students were assigned at some point in the semester to be for and against projects. This was interesting because civil engineering students favoring water resources engineering projects might have to argue against the projects from a humanist perspective, and vice versa – humanist students were forced to argue in favor of projects from a technical perspective. The in-class discussions for these assignments were conducted as moderated debates between the 'for' and 'against' positions.

Team projects were also assigned that sought to mix the philosophy and civil engineering students. The project assignment was to prepare an interdisciplinary case study analysis of a significant water project, "significant" in terms of its scope, impact, precedent, technology, novelty, promise, threat, peril, etc. Topics selected included water privatization in Bolivia and globally (two projects), new dam construction, effectiveness of elementary school level water education, water-energy interdependencies, photo tour of a major western water supply project (included dams, reservoirs, and pipelines), desalination in Southern California, and free-flow turbines for hydropower generation. In both a written report and a formal oral presentation students had to address the following aspects of their case study project/issue: technological practicality, economic viability, political feasibility, historical continuity, social acceptability, environmental sustainability, community/culture/natural impacts (immediate vicinity), community/culture/natural impacts (globally), and resource use, both water and other resources.

Assessment

The outcomes of the course were assessed with observations from assignments, a written survey, informal student discussions, and end-of-course ratings and comments.

Observations from Assignments

All of the assignments (hydrotopia definition, position papers, and project) were designed to force the students to think beyond their disciplinary silos to address current water resources engineering and management problems in the western U.S. Review of the submissions for the three types of assignments documented students expanding their base of knowledge beyond their disciplinary silo.

One noteworthy observation from the hydrotropia definition was the relative amount of technological solutions versus non-technical (predominantly humanist) solutions identified as necessary to move towards their definition of hydrotropia. As the semester progressed it was also noted the greater value the civil engineering students placed on non-technical solutions. For example, one student commented on his second version of the Hydrotopia definition that he

originally thought technology could solve the problems of water in the west, but he realized engineers needed to work with people and institutions to embrace technology and that technology is not a stand-alone solution. The same broadening was also evident in the humanists as many of the philosophy and environmental studies students started to find balance in their proposed path to hydrotopia by including technological solutions in addition to lifestyle changes to achieve a sustainable water resources solution in the future.

One noteworthy learning outcome for the civil engineering students exercised through the position papers was the comprehension and application of the concept of a worldview. This was, for most of them, the first time they were introduced to and forced to apply the concept of a worldview establishing the larger context of engineering projects. In the beginning, the engineers mostly focused their position papers around facts and data while the humanists focused on values. Later in the semester there was a mix, where we saw more engineers focusing their positions on values and the humanists doing cost-benefit calculations. This change in perspective reflected the students realizing the value or from some perspectives the moral obligation of the approach not previously covered in their discipline.

Another noteworthy learning outcome from the position papers was the incredible transformation in critical thinking from the civil engineering students. Many of the initial positions for the engineering projects were argued in an arbitrary and biased manner with inadequate support or facts and without considering the larger context of the project. But by the third position paper submittal the civil engineering students generally approached their positions in a more unbiased manner, were more objective in the analysis of the issue, and developed clear positions based on facts and logical reasoning even if the position did not agree with their personal beliefs.

Written Survey

A written survey was administered during the final week of the semester. The anonymous surveys requested basic optional background information (major, graduate or undergraduate student, etc.) and requested answers or comments to the following questions:

1. At the beginning of the semester did you see yourself aligned as a humanist or technologist when considering solutions to water resources challenges? Do you feel your attitudes have changed such that you might align more or less with the other group?
2. Which topic/discussion provided you the greatest insight into the other group (humanist or technologist)?
3. As a result of this course, do you feel you better understand and can articulate the position of perspectives different than yours as they relate to water resources engineering projects?
4. List one concept outside of your disciplinary major that you learned in this course. Do you feel it will be helpful for you in your future career? How so?
5. Did the course alter your personal habits related to water – for example make you more aware of water conservation, take action, etc.? Would you have taken this action before the course?
6. Did the position paper assignments improve your ability to construct arguments you may not necessarily personally agree?

7. List one or more topics included in the course that you did not find interesting or valuable.
8. List one or more topics that were not included in the course that you wish would have been covered.

Nineteen surveys (of 22 possible students) were completed. As expected most students saw themselves as aligned with their disciplinary perspective at the beginning of the course – humanities and social sciences majors were humanists and engineers were technologists. Interestingly, the city planning and political science students defined themselves as mixtures of humanist and technologist perspectives, the only two students to do so. Only one student felt their perspective was completely changed – a technologist (civil engineering major) felt by the end of the course that technological solutions are now so deeply dependent on social, political, and ecological contexts that a humanist viewpoint must be an important factor considered in all solutions to water resources issues. Only three students indicated their perspective was not changed. Most students (15) felt their perspective was somewhat changed. Most students identified an "expanded" understanding of water resources issues and solutions. Several students stated the course helped them understand the other side better to help bridge the gap between the two sides and find common ground solutions based on compromise and cooperation.

From the student responses the concept outside of their major most often identified, regardless of major, was the need to integrate disciplines to arrive at sustainable solutions. Among the engineers, the most often identified specific concepts from the philosophy discipline were (1) the slippery slope argument (giving an inch can lead to giving a mile) and (2) the complexity of and challenges of changing human behavior. Several of the civil engineering students noted how they never realized water supply projects (reservoirs and pipelines) could be so strongly opposed and for reasons they could comprehend and in some cases agree. One student that is a working professional (most senior level students in civil engineering at the University of Utah have at least a part-time job in civil engineering practice) noted how this course made it more difficult to practice their particular area of water engineering because the student could now see the flawed logic in some of the projects they are hired to complete. This student felt their broadened understanding of the larger context of the problem made them realize the solutions they design may not be the best approach when the problem is considered more broadly. But unfortunately, standard engineering practice does not typically consider other options if it may impact their business.

Eighteen out of nineteen responses indicated the position papers helped them to construct arguments outside of their discipline. The one student that responded that it did not was an engineer and indicated this was part of her undergraduate education in Europe. This was an especially interesting (although only a single response that cannot be generalized) observation of European undergraduate engineering education versus U.S. (as narrowly represented by the University of Utah)). The majority of comments reinforced the comments from other survey questions, which suggested the position papers were the most helpful to understand other perspectives. In addition, the students predominantly noted the value of integrating the disciplines in the course.

End-of-Course Comments and Informal Feedback

Student comments collected with the standard end-of-course rating forms were analyzed for key points. In addition, informal feedback from students from discussions outside of class was also considered. The most common item included in the anonymous end-of-course rating and comment form was the desire to have even greater interaction with the other disciplines. An excellent suggestion was to incorporate more discussions in small groups composed of different disciplines in addition to the general discussions. The small group discussions that were commonly conducted in the course were not arranged to create small groups of different disciplines. They were simply grouped by proximity, which unfortunately led to a bias in those small important discussions since typically the civil engineers are friends with civil engineers and would sit next to their civil engineering friends, and vice versa for the humanists. This was one important point made that will be incorporated into subsequent course offerings.

A small fraction of the engineers felt the class was too oriented towards humanities – they were seeking more technical knowledge. They unfortunately grouped the management and policy (a significant part of the course) aspects into humanities. This is a problem faced in teaching management and policy to engineers – they perceive it as non-technical and thus non-engineering. But, again this is an excellent comment to build on - to clearly show how engineering design is not just about performing a calculation, running a model, or creating a technical drawing. Another adjustment based on this stream of comments will be to require greater use of technical tools in the course, specifically water management computer models that can be applied by the engineers and humanists equally well.

A final interesting point was made by several students through informal feedback. Several of the civil engineering students indicated the course made them more pessimistic about the prospects for achieving water resources sustainability in the western U.S. This conforms to the general observation that students less informed about environmental science are the most optimistic about sustainability solutions. This will be something that will be specifically included in the written survey in future offerings.

Summary and Conclusions

This paper described a new interdisciplinary teaching approach to integrate humanities and civil engineering education to provide a unique opportunity to broaden the understanding of engineering in humanists and the understanding of humanities in engineers. Specifically, the course sought to explore the role of humanities in water resource engineering projects. The paper provided an overview of the course, described the pedagogical methods, and presented a summary of the assessment of the effectiveness of the course for meeting the civil engineering and humanities learning objectives.

An objective of integrating humanities into civil engineering education is to enable engineers to be critical thinkers and to help them recognize impacts of engineering solutions in humanistic terms within social contexts. Considering this objective, the course was a major success, not only from the instructor perspective, but also the students. The course assessment suggested the civil engineering students broadened their understanding of the local, regional, and global context of

water resources engineering projects. In addition, many of the civil engineering students increased the bounds of their worldview beyond technical issues to consider human and natural systems. Students were exposed to a wide range of disciplinary perspectives and were forced to analyze water management issues and water engineering projects from perspectives outside their own. The engineers and technical students learned how to decompose problems and analyze them and develop logical arguments based on facts and not emotion – they learned to do this using tools from philosophy. And the humanists gained an appreciation of the challenges faced by engineers and the needs and constraints of modern society. In fact, by the end of the semester the engineers were arguing their position papers from humanist perspectives and vice versa – humanists basing their arguments on cost-benefits and practical reasoning.

A conclusion based on the review of the course assessment and reflection was the necessity to develop and facilitate the course with a multi-disciplinary group of students and a team taught approach representing not only engineering but also a humanistic perspective. Survey responses from the civil engineers clearly indicated the humanities students provided example applications of critical thinking and a broadened worldview previously unseen in engineering and other general education courses. Furthermore, the peer effect was strong providing a different perspective from fellow students that became friends over the course of the semester.

Another key conclusion related to the multi-disciplinary perspective of the course was the co-teaching approach. The end of course comments mentioned the discussion points offered by the two instructors helped the students to not only see the engineering or humanist perspective but also to see how professionals could view a problem or solution without the bias of their perspective clouding their judgment.

Overall, this course received excellent ratings from students, positive comments from faculty colleagues in both engineering and humanities, and a positive response from the Office of Interdisciplinary Studies that provided the funding to create and offer the course. The course is currently included in the course plans for both the civil engineering and philosophy departments and the teaching plans for the co-authors of this paper. Numerous students from both civil engineering and philosophy heard about the course and indicated to the professors their desire to take the course the next time it is offered. Modifications will be made to the next course offering and additional assessment of the course effectiveness will be made and reported in the future.

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