AC 2010-2062: A DEVELOPING-COUNTRY CASE-STUDY APPROACH TO INTRODUCING ENVIRONMENTAL ENGINEERING STUDENTS TO NONTECHNICAL SANITATION CONSTRAINTS IN DEVELOPED COUNTRIES

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A Developing-Country Case-Study Approach to Introducing Environmental Engineering Students to Nontechnical Sanitation Constraints in Developed Countries

Abstract

By studying only closed-ended technical problems, environmental engineering students often fail to appreciate critical interrelations between technical and nontechnical aspects of sanitation. To address this deficiency, a case-study module on sanitation for the developing world was implemented in a senior/graduate level onsite water reclamation course. The goal was to increase student awareness of the interplay between technical and nontechnical complexities when designing and implementing sanitation systems in both the developed and developing world. Learning objectives included increasing student familiarity with (1) perceptions and treatment options of sanitary waste in developing countries and (2) nontechnical constraints and issues (such as economic, social, cultural, political, and ethical) associated with sanitation.

Content was integrated into the course using a case-study approach. Between weeks three and seven of a 15-week semester, students investigated and contrasted common sanitation practices in the U.S. and developing nations and then began work on mini-case studies focused on specific communities in developing countries. Guest speakers supplemented instruction by sharing experiences from living and working in such communities and overseeing sanitation-engineering projects. In week nine, student teams described their chosen community, its relevant demographics, current sanitation practices, and the team's initial sanitation options. In week 12, student teams identified key community stakeholders, conducted a sanitation options assessment, and assembled evidence to support their recommended option.

The same test was administered in the second and 14th weeks of the semester to assess student understanding of technical and nontechnical issues associated with sanitation engineering in both developed and developing contexts. This paper presents the case-study module design and implementation, measurement instruments used to detect change and a detailed statistical analysis of the case-study module's impact in the classroom. Nonparametric statistical analysis measured statistically significant increases in student responses regarding technical and nontechnical sanitation issues, similar to a previous wastewater engineering class in which significant increases were also detected. The results of this investigation support the potential for broader use of this case-study module beyond the course for which it was developed.

Introduction

Upper-division undergraduate and early graduate students are often unfamiliar with issues involved in sanitation outside the developed world. Students thus regularly extrapolate technical solutions from the developed to the developing world, often without appreciating the problematic gap between the two contexts. From a technical standpoint, centralized sanitation approaches are common for urban areas and population centers in the U.S. and other developed nations. But in many situations within the U.S., and more so in developing countries, such options are neither cost-effective nor sustainable due to low-density development, rugged topography, limited water and energy supplies, lack of skilled labor, or cultural traditions. In these instances, decentralized onsite treatment systems can be used to protect public health and environmental quality; such systems may have low energy and chemical requirements and enable beneficial reuse of water and nutrients.

By studying solely closed-ended technical problems, students may not learn to appreciate the nontechnical aspects of sanitation or the critical interrelationship between technical and nontechnical dimensions of the engineering problem in both developed and developing world contexts. Adequate worldwide sanitation, which embodies the two issues of developed/developing world contexts and technical/nontechnical interrelationships, has been a goal for organizations worldwide since the 1970s. Progress toward this goal has been "glacial", with 2.6 billion people continuing to lack adequate sanitation in 2006.[1] Limited progress in this area is not due to a lack of appropriate technology. Rather, sub-optimal options are often imposed in developing areas by ill-informed, but well meaning, developed-world organizations. As Feachem argues in *Sanitation and Disease*:

"Those whose job is to select and design appropriate systems for the collection and treatment of sewage in developing countries must bear in mind that European and North American practices do not represent the zenith of scientific achievement, nor are they the product of a logical and rational design process. Rather, treatment practices in the developed countries are the product of history…. These practices are not especially clever, nor logical, nor completely effective – and it is not necessarily what would be done today if these countries had the chance to start again".[2]

The U.N. Human Development Report 2006 delineates the following barriers to improved sanitation: national policy, behavior, perception, poverty, gender, and supply.[1] "Supply," which refers to oversupply of unsustainable or culturally inappropriate technology as well as the disconnect between user needs and typical developed-world offerings, is the only barrier with some technical basis. Nontechnical barriers such as those identified by the U.N. generally receive little emphasis in engineering education. Two recent U.S. National Academy of Engineering reports have also recognized lack of contextual and global understanding as weaknesses in contemporary engineering education.[3,4] The present study is designed to directly address such weaknesses in undergraduate environmental engineering education.

In fields such as business, law, and education, case studies have long been used to facilitate student discoveries in the areas of theoretical and practical understanding, reasoning, metacognition, beliefs, and social, ethical and epistemological growth.[5] Adapted to engineering education, the case method often involves multifaceted, team-based, open-ended problem-solving that requires synthesis of technical and nontechnical information from diverse sources.[6-9] Despite recognition that engineering curricula traditionally create gaps in critical nontechnical areas such as communication, teaming, customer focus, human resources, and public policy,[8-12] the use of cases that address these gaps in engineering education have fluctuated over time.[8] The present study examines the use of a case-study approach to facilitate environmental engineering students' understanding of nontechnical issues involved in identifying sanitation solutions for application in developing nations.

As described in a previous article written by a subset of the current authors,[13] a case-study module on sanitation engineering for the developing world was created by a team of engineering and liberal arts faculty and implemented in a senior/graduate level course in traditional wastewater engineering. The goal of the case-study module was to increase student appreciation of the technical and nontechnical complexities of the subject area and their interplay when designing and implementing sanitation systems in both the developed and developing world. Learning objectives included increasing student familiarity with (1) perceptions and treatment methods of waste in developing countries and (2) nontechnical constraints and issues (such as economic, environmental, social, cultural, political, and ethical) associated with sanitation in developed and developing countries. Statistically significant increases in student responses regarding technical and nontechnical issues in developed and developing countries, as well as substantial consideration of such issues in team design reports, were observed following completion of the case-study module.

In the current investigation, different liberal arts faculty and the same engineering faculty implemented the same case-study module in a senior/graduate level course in onsite water reclamation and reuse, to examine the transferability of the case-study module to a new course. The course focused on the selection, design, and implementation of onsite and decentralized systems for water reclamation and reuse. Results from this alternate implementation are presented here and compared with the previous case-study module results.

The research question investigated here is: Can the case-study module developed in a previous study be transferred to a new course, with a different set of instructors, and result in comparable learning gains as were witnessed in the original study?

Methods

I. Curriculum

Prior to its current use, the case-study module on sanitation engineering was co-developed by environmental engineering and liberal arts faculty for implementation in a traditional wastewater engineering course.[13] The modular approach stemmed from an ambition to help students acquire a richer, more complete appreciation of the complexities inherent in designing, implementing, and working with sanitation treatment systems in the developed and developing world. Both offerings of the case-study module involved two team assignments, a small-scale case study of a community in a developing country and a major semester-long design project focused on a U.S. community, as detailed in the sections that follow. The nontechnical content was intentionally integrated into the course using a case-study approach. This section summarizes the design and implementation of the instructional activity.

Course Instructors. To support student learning with respect to both the technical and nontechnical issues, three instructors collaborated on case-study module implementation. The first instructor was the environmental engineer involved in developing the case-study module; the onsite course was part of her regular teaching load. The other two instructors, not involved in the initial case-study module development, were recruited from liberal arts faculty to provide perspective on cultural, communication, and global issues.

Subjects. The onsite course involved 20 students, 11 of whom are female. Two of the students (one male, one female) were environmental engineering graduate students, while the other students were engineering undergraduates (one civil, remainder environmental). Students self-organized into teams of three to five members each, forming six teams total. Each team consisted of both male and female students, with both graduate students on one team. Of the 20 students, one undergraduate and one graduate student, both female, completed only the pre-test and not the post-test described in the Measurement section and so were not included in the matched-pairs statistical analysis.

Intervention Overview. Prior to formally implementing the case-study module, students were provided with general background regarding perspectives and wastewater characteristics for onsite sanitation. In week three, student teams were provided the opportunity in class to investigate common sanitation practices in both the U.S. and developing nations. This activity focused on multiple perspectives in wastewater engineering, including the following:

- Examining the history of and assumptions in water-borne domestic waste disposal in the U.S. (e.g., gallons/flush, why flush?),
- Investigating what alternatives exist globally to water-flushing toilets (e.g., what percentage of people worldwide use flush toilets?), and
- Discussing what domestic waste treatment methods are common in different communities in diverse parts of the world (e.g., what distinctions, where applicable, need to be made between urban vs. rural areas, relatively richer vs. poorer areas?).

Between weeks five and 12, students began work on a mini-case study focused on a specific community in a developing nation of their choice. This learning process included a visit from a guest speaker who described efforts to implement sanitation engineering projects in such communities, with topics of discussion including community participatory action research, indigenous knowledge, and sustainability. Students were also provided with campus faculty and administrator contacts with experience living and working in those countries. In week nine, student teams completed part one of their case study, describing their chosen community and its relevant demographics, current sanitation practices, and the team's ideas for potential sanitation options. In week 12, student teams turned in the second part of their case study, identifying key stakeholders in their chosen communities along with a sanitation options assessment and evidence to support their recommended sanitation option. During the almost weekly discussions of the case study, both the regular (technical) course instructor and the liberal arts (nontechnical) instructors met with students in class to coach them through the process of writing a case study as well as to elicit feedback on the case-study module process. A timeline of the case-study module activities is summarized in Table 1. The weeks without content in this timeline covered technical course material. As the timeline indicates, elements of the case-study module spanned most of the semester, allowing students the opportunity to revisit these concepts throughout the course.

Table 1. Case-Study Module Timeline

Week	Activity
1	
2	Pre-case-study module test
3	In-class intervention: sanitation practices in U.S. and abroad; Semester-long design project assigned
4	
5	In-class intervention: introduction to mini-case study
6	
7	In-class intervention: mini-case study research
8	
9	In-class intervention: technical options assessment; Mini-case study, Part I due
10	In-class intervention: guest speaker
11	In-class intervention: nontechnical considerations
12	Mini-case study, Part II due
13	
14	Post-case-study module test
15	Semester-long design report due

In addition to the case-study module, students were assigned a semester-long collaborative design project (Appendix A), for which each team designed a sanitation solution for a community in the U.S. The design project focused on decentralized sanitation in a small (400-resident) remote community in the U.S.; to facilitate comparisons with the previous case-study module offering, the same design project for the same community was assigned in both courses. Although desired but not explicitly intended, the case-study module and design project were complementary: students applied several concepts learned in the case study to their major design projects, as described in the section that follows.

Mini-Case Study Assignment. The case study assignment fostered open-ended problem solving of a sanitation issue in a specific developing or underserved community. In this context, the term "community" referred not to a continent like Asia or a country such as Nepal, but a specific village in Nepal. Students were allowed to freely choose any community for which they could obtain sufficient information to complete the case study.

To complete this assignment, students were asked to follow (not necessarily sequentially) several steps:

1. Identify the *community* and describe its relevant *demographics* (such as population, population density, sanitation water sources if any exist, piped water if applicable, rural or urban, etc.)
2. Identify the community's *current sanitation methods and practices*
3. Brainstorm as many initial *sanitation options* as possible for this community, including not changing current practices, without eliminating any options based on technical or non-technical constraints (for now)

4. Identify at least one contact person who has fairly extensive knowledge of that country, and preferably the region or village in question. Via this contact person, try to identify (and contact if possible) the *key stakeholders* in the community. {campus contact list provided}
5. Conduct a *sanitation options assessment*, identifying some potentially viable sanitation options for the community; the criteria should include non-technical constraints, including social, cultural, and others
6. Using criteria you describe, eliminate the less viable options and select the most appropriate one, and note the limitations of your *recommended option* (including knowledge you could not obtain, etc.)

Each team wrote two brief (<5 pages) reports, each worth one homework assignment; the first report described the results of steps 1-3, and the second built on the first report to synthesize the results of the entire process. Through this mini-case study process, students first identified all potential sanitation options, without considering any technical or nontechnical constraints. Subsequently, by contacting stakeholders in the community or someone with first-hand knowledge of those stakeholders, students discovered constraints to those options. Although more direct contact such as a visit with local community members would have been ideal, such communication was outside the scope of this mini-case study.

II. Measurement

Pre- and Post-tests. Prior to formally introducing either assignment, in the second full week of the course we administered a test to establish a baseline of student knowledge concerning technical and nontechnical issues associated with sanitation engineering in developed and developing contexts. This test was administered before any significant instruction on wastewater or sanitation had occurred. In week 14, after completing the case study and receiving instruction on wastewater and sanitation, students completed the same test. The questions that comprised this instrument were as follows:

1) List as many **major technical issues** as possible associated with sanitary engineering in developed nations such as the U.S., Canada, and W. European nations.
2) List as many **major nontechnical issues** as possible associated with sanitary engineering in developed nations such as the U.S., Canada, and W. European nations.
3) Which of the issues listed in questions 1 and 2 **ARE** relevant in developing nations such as those in parts of South America or Africa?
4) List additional major technical and nontechnical issues that may arise in such **developing** nations.

Coding and Double-Scoring. Student responses were categorized in two manners. First, the number of distinct, nonredundant responses to each question was counted. Second, responses were scored as “advanced,” “basic,” or “incorrect” as follows:

- **Advanced**: Advanced responses are concepts or ideas that were not covered in the prerequisite course nor in the wastewater course itself. For example, a response of “population distribution” was considered an advanced response because the concept of population size is covered but not population distribution. A response could also be designated advanced if the topic was included in one or both courses but the response represented a deeper, richer, or more analytical level of thinking. For example, we discussed governments setting regulatory standards but not politics as it involves decision-making regarding various sanitation options. If a student identified that political stakeholders influence sanitation options, this was considered an advanced response.

- **Basic**: Basic responses reflect course concepts from either the prerequisite course, the wastewater course or both. For example, "regulations" and "treatment processes" were covered in the prerequisite class.
- **Incorrect**: An inaccurate technical or non-viable nontechnical response was considered incorrect. For example, students suggested that "time" and "cleanliness" are sanitation issues in developed countries.

For both scoring schemes, responses were double scored and averaged for subsequent analysis. The first scoring was completed by the course instructor, the second by an independent member of the faculty who had taught the prerequisite course.

Design Reports. The sanitation engineering case study was not explicitly linked with the semester-long design reports. However, case study influences on the design reports were assessed by comparing the frequency of reference and weight assigned to nontechnical constraints in the design reports. This methodology was also used to evaluate six team reports collected in the prior investigation of the case-study module and for 13 team reports collected prior to the development of the case-study module (collected over four semesters in the traditional version of the wastewater engineering course). These prior two collections of reports provide comparison data for the current investigation.

Results and Discussion

Case Studies. As summarized in Table 2, student teams selected various communities for which they developed case studies describing the demographics, current sanitation methods, and identifying and ranking alternative sanitation options. Technical and nontechnical constraints, including areas about which teams identified a need for additional information, are also provided in Table 2.

Table 2. Summary of Case Studies Developed by Student Teams

Community	Population	Current sanitation methods	Alternatives ranked in order of ultimate recommendation	Technical constraints considered	Nontechnical limitations identified
Chayangba, Nepal	400	Pit composting toilets	1. Consolidation to smaller number of composting toilets 2. Septic tank/soil absorption systems 3. Septic tanks/packed sand biofilters	• Water supply and use • Climate • Technical expertise • Material availability • Cost	• Acceptance of sanitation system • Incentive for change: lower-class/caste area most impacted
Colinas de Suiza, Honduras	10,000	Pit latrines	1. Ventilated improved pit (VIP) latrines 2. Composting toilets 3. Pour-flush toilets 4. Recirculating latrines 5. Reed bed filters 6. Holding tanks 7. Bio-latrines 8. Simplified sewerage 9. Oxidation ditch	• Cost • Maintenance • Training • Geography • Resources • Transportation • Power • Land requirement • Sustainability	• Community needs • Community acceptance • Social inequity • Regulations • Politics
Foutaka Zambougou, Mali	1700	Latrines	1. Composting toilets 2. VIP latrines 3. Double pit VIP 4. Pour-flush toilets 5. Holding tanks 6. Aqua-privy 7. Septic tanks 8. Shallow sewer system 9. Conventional sewer system	• Water supply • Location • Training • Maintenance • Cost • Treatment effectiveness	• Traditions and history • Social and cultural preferences

Table 2. Summary of Case Studies Developed by Student Teams (cont.)

Community	Population	Current sanitation methods	Alternatives ranked in order of ultimate recommendation	Technical constraints considered	Nontechnical limitations identified
Khayelitsha, South Africa	1.5 million	Bags	1. Holding tanks/privies 2. Imhoff tanks 3. Composting toilets 4. Septic tanks 5. Pit latrines 6. VIP latrines	• Flooding • Water supply • Energy requirements • Material availability • Construction feasibility • Land requirement • Transportation • Maintenance • Treatment effectiveness • Environmental impact • Lifespan	• Cultural acceptance
Uluthe/Mungao, Kenya	8000	Pit latrines	1. Pit latrines 2. Vegetative subsurface beds 3. Lagoons 4. Septic tanks 5. Constructed wetlands 6. Trickling filters 7. Digesters 8. Activated sludge 9. Membrane bioreactors	• Water supply • Terrain • Material availability • Training • Maintenance • Ease of installation • Safety • Cost • Treatment effectiveness • Energy requirements • Climate • Capacity	• Cultural and societal understanding • Community sanitation preferences • Community willingness to maintain sanitation systems

Pre and Post-tests. Given the small sample size for paired comparisons, a non-parametric statistical test was selected for analysis purposes. The Wilcoxon matched-pairs signed-ranks test is appropriate for one-group pre-test/post-test analysis, as it is applied to discrete data[14] and minimally requires only six paired differences.[15] For the 18 students who completed both pre- and post-tests, one-tailed Wilcoxon signed-ranks tests indicated that the number of advanced responses increased significantly from pre- to post-test ($\underline{p} = 0.0005$). The number of correct responses and total responses also increased significantly from pre- to post-test ($\underline{p} = 0.0087$ and 0.018, respectively). In other words, comparison of pre- and post-test responses indicates that student performance with respect to the areas assessed had improved. These results are consistent with the first case-study module offering, in which the number of advanced ($\underline{p} = 0.0057$), correct ($\underline{p} = 0.012$) and total ($\underline{p} = 0.036$) responses increased significantly from pre- to post-test.[13]

Design Report. In contrast with the first offering of the case-study module, in which all three student design teams included explicit and prominent consideration of nontechnical issues such as social, political and environmental constraints, a smaller proportion of the student teams participating in the second case-study module offering did so. Two of the six reports considered the relevance of community perspectives in a generic manner but did not report specific input, as illustrated in the following quote.

"Nontechnical constraints, though oftentimes disregarded or left out of engineering analysis, play a significant role in implementing a project that is both sustainable and effective. In any engineering project involving individual communities, the goal is to develop and apply engineering solutions while being cognizant of local aspirations and cultures…. Overall, to properly assess the nontechnical constraints of the project, more information is needed on the community's response to the … plan and how their knowledge is being integrated into the … design and implementation."

In addition, one other team reported contact with a stakeholder in the community (county government official). During the sanitation engineering case-study module, students read and heard numerous accounts of the importance of community participation in decision-making, focused on the developing world. Yet only half of the student teams in the current study explicitly included this concept in their design considerations for the developed world. One reason for the decrease in percentage (from 100% to 50%) of teams considering community input between the earlier and current implementations may have been the construction of a new sanitation facility in the U.S. community targeted by the design project. Construction began after the first implementation of this case-study module offering and was in progress during the second case-study module offering; because this facility was the *de facto* solution, student teams may have been less inclined to consult with community stakeholders. In addition, delivery of the case-study module by faculty not involved in its development may have unintentionally impacted consideration of community input by the student teams. Despite the drop, this consideration of community perspectives was more prevalent than in previous offerings of the traditional wastewater engineering course which did not include the case-study module. Of those 13 reports, the only nontechnical issue consistently considered was cost. A few reports considered population growth as it related to design flow rates, or possible limitations due to space or existing infrastructure. Three of the 13 reports referenced contacts at the project facility, and none cited contacts in the community.

Conclusions

The process of understanding community needs and perspectives as they relate to an engineering project is often marginalized in engineering practice; engineers tend to talk to the powers in charge (or those paying for the work), determine their needs, and complete the project, independent from other community input. The same tends to occur in efforts in developing countries—engineers talk to a few people (leaders, NGOs, etc.) to identify the problem, then the engineers come up with a solution based on their experience.[16-17] Such an approach can lead to a dominant voices bias, wherein only dominant stakeholder perspectives are represented while other perspectives are ignored or never accessed.[18] By contrast, sustainable community development projects factor in a wider array of community perspectives.[17] The students demonstrated efforts to include community perspectives in their decision-making as well as increased ability to identify more issues covering more advanced concepts associated with sanitation in developed and developing countries. This effect occurred across two offerings of the case-study module in two different courses involving different faculty, suggesting that the case-study module may be relatively portable.

Like any study, this one has limitations. One limitation involves sample size. This study focuses on one course of 20 students, 18 of whom completed all assessments, and comprised six teams. Comparisons are made to a different course with a similar treatment, which had 13 students divided into three teams, and four previous iterations of that course without a treatment, with thirteen student teams. In addition, the focus of this particular course on decentralized sanitation, as well as the design project focus on a small community, may have encouraged the students to consider community input. Because generalizations made on such a limited sample size are problematic, we are currently implementing an investigation that includes a control group not involved in the case-study module. These results will form the basis of a follow-up article.

Based on the study results, students augmented their awareness of and familiarity with sanitation perceptions and treatment methods in developing countries and with nontechnical constraints and sanitation issues in developed and developing countries. The design reports and test responses demonstrated evidence that students also understood interplays between nontechnical and technical constraints as well as between developing and developed country contexts. Student teams considered community viewpoints to be a significant factor when evaluating sanitation options, a clear lesson from the case study exercise that carried over to the design reports.

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Bibliography

1. Watkins, K. (lead author), *Human Development Report 2006*, United Nations Development Programme, 2006, 428 pp.
2. Feachem, R. G., D. J. Bradley, H. Garelick and D. D. Mara, *Sanitation and Disease: Health Aspects of Excreta and Wastewater Management*, New York: John Wiley & Sons, 1983, 501 pp.
3. National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*, Washington, DC: National Academies Press, 2004, 118 pp.
4. National Academy of Engineering, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century,* Washington, DC: National Academies Press, 2005, 208 pp.
5. Lundeberg, M. A., “”Discovering Teaching and Learning Through Cases”, in Lundeberg, M. A., B. B. Levin and H. L. Harrington, eds., *Who Learns What From Cases and How? The Research Base for Teaching and Learning with Cases*, 1999, pp. 3-23.
6. Chinowsky, P. S. and J. Robinson, “Enhancing Civil Engineering Education Through Case Studies”, *Journal of Engineering Education*, 86, 1, 1997, 45-49.
7. Russell, J. S. and B. G. McCullouch, “Civil Engineering Education: Case Study Approach”, *Journal of Professional Issues in Engineering*, 116, 2, 1990, pp. 164-174.
8. Raju, P. K. and C. S. Sankar, “Teaching Real-World Issues through Case Studies”, *Journal of Engineering Education*, 88, 4, 1999, pp. 501-508.
9. Richards, L. G., M. Gorman, W. T. Scherer and R. D. Landel, “Promoting Active Learning with Cases and Instructional Modules”, *Journal of Engineering Education*, 84, 4, 1995, pp. 375-381.
10. Lima, M., “Engineering Education in the Wake of Hurricane Katrina”, *Journal of Biological Engineering*, 1:6, 2007.
11. Meier, R. L., M. R. Williams and M. A. Humphreys, “Refocusing Our Efforts: Assessing Non-Technical Competency Gaps”, *Journal of Engineering Education*, 89, 3, 2000, pp. 377-385.
12. Whitman, L., D. Malzahn, V. Madhavan, G. Weheba and K. Krishnan, “Virtual Reality Case Study throughout the Curriculum to Address Competency Gaps”, *International Journal of Engineering Education*, 20, 5, 2004, pp. 690-702.
13. Munakata-Marr, J., J. A. Leydens and B. M. Moskal, “Beyond Technical Issues: A Case-Study Approach to Introducing Environmental Engineering Students to Nontechnical Wastewater Engineering Constraints”, *ASEE/IEEE Frontiers in Education Proceedings,* 2009, T2D1-5.
14. Sheskin, D., *Handbook of Parametric and Nonparametric Statistical Procedures*, Boca Raton, FL: Chapman Hall/CRC, 2004, 1193 pp.
15. Sokal, R. R. and F. J. Rohlf, *Biometry*, New York: WH Freeman, 1981, 859 pp.
16. Lucena, J. and J. Schneider, “Engineers, development, and engineering education: From national to sustainable community development”, *European Journal of Engineering Education*, 33, 3, 2008, pp. 247-257.
17. Schneider, J., J. Leydens and J. Lucena, “Where is ‘community’? Engineering education and sustainable community development”, *European Journal of Engineering Education*, 33, 3, 2008, pp. 307-319.
18. Slim, H. and P. Thomson, *Listening for a Change: Oral Testimony and Community Development.* Philadelphia, PA.: New Society Publishers, 1995, 167 pp.

Appendix A

Term Project: Wastewater Treatment Design
Onsite Water Reclamation and Reuse

As the Environmental Protection Agency increases its pressure to improve water quality, many communities find that they need to upgrade their treatment facilities. The sanitation industry relies on many technologies to treat domestic wastewater, from decentralized processes such as septic systems to centralized treatment relying on sedimentation and activated sludge. This project offers an opportunity to design and evaluate a variety of strategies for wastewater treatment based on the unit operations discussed in the classroom.

Purpose: Eldorado Springs is a small rural community located between Boulder and Golden. Historically the community has been served by onsite wastewater systems. However, Boulder County was concerned that these onsite systems are not functioning as needed to protect the water quality in nearby Boulder Creek. More than 80% of the systems were built around 1900 and are not documented; of those that are documented, half are simple vault systems. In addition, about 2/3 of the community relies on groundwater wells for drinking water (the remainder use artesian springs); a few of the wells have been sampled, of which half had high fecal coliform levels. A feasibility study conducted in 2001 recommended sewering the community and building a centralized treatment facility nearby. The objective of this project is to re-evaluate the recommendation for the centralized plant to meet Eldorado Spring's wastewater treatment needs (current and future) and to prepare a written report to support your assessment and proposed solution.

Through this project, you will develop your technical and communication skills. In addition, you will work in teams of four or five students; environmental work is often conducted in interdisciplinary teams, because such diversity provides valuable perspective in an interdisciplinary field.

Your team is requested to propose a treatment strategy and to investigate technical and nontechnical issues of sanitation design. You should identify feasible process operations to treat the wastewater, based primarily on an assessment of the flow, water chemistry and treatment goals.

Audience: The audience for your design report is an engineering team, consisting of members that are scientifically trained and generally familiar with, but not necessarily with a detailed technical understanding of, wastewater treatment processes.

This project provides an opportunity to compare your design strategy with other alternatives, based on a common set of constraints. You must describe your complete treatment train, illustrated in a process flow diagram, and should assess the technical performance of the various unit operations. Your final report should compare and discuss both advantages and disadvantages of your selected design.

The 7-10 page summary of your design should:

- present the problem and your treatment goals/approach
- describe the treatment process (include a process flow diagram)
- list the major equipment (include specifications and cost estimates)
- summarize the advantages and disadvantages of your design
- recommend a future course of action

The format for your report is your choice, but the style of the report should be uniform throughout. Be sure to include in a bibliography any references consulted. Specific calculations need not be included in the body of the report but should be placed in appendices.

In order to alleviate procrastination, disagreement and end-of-semester panic, several short (<1 page) reports will be due during the course of the semester. By Feb. 10, each team should turn in a "working plan" that identifies (at least) team members, distribution of tasks, projected target dates for completion of different tasks, and grievance-handling procedures. Progress reports will be due from each team on Feb. 24 and Apr. 7; reports should describe what's been done, what's left to do, and what plan and schedule the group has for the remaining work. In addition, if your team would like to meet with me as a group, we can schedule such meetings, and team members can always meet with me individually. If your team has a draft report for which you'd like my feedback, I can provide input if your draft report is turned in to me by 3:15 p.m. on April 16th. Finally, you will do an intermediate peer review of your teammates in late March, the feedback from which will be anonymously provided to each team member. You will also do a final peer review, the results of which will count for 10 percent of the project total. The presentation describing your project will count for 20 percent of the project total; additional guidance regarding presentation structure and metrics will be provided later.

The final project report should be submitted during the week of April 27th (no later than noon on April 30th).

Information about Eldorado Springs and the ongoing wastewater treatment plant construction are available online:
<http://www.bouldercounty.org/health/environ/water/ows/communityProjects/eldoradoSprings/>
<http://www.eldoradowwtp.com/default.html>
<http://www.frachetti.com/file.php/83/FEI+Project+Profiles+-+Eldo-2.pdf>