AC 2008-2327: DRINKING WATER ACTIVITY FOR HIGH SCHOOL OUTREACH PROGRAM

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Drinking Water Activity for High School Outreach Program

Abstract

Environmental engineering needs to recruit more students to meet the high demand projected for the profession. Interest may be on the upswing, as noted by increased freshmen enrollments at the University of Colorado at Boulder. During the High School Honors Institute (HSHI) in 2007, a new activity on drinking water was introduced in an effort to make students aware of the importance of environmental engineering in daily life. A pre-survey was given in the first morning session to stimulate student thinking on the topic. This survey indicated that of the 37 students, 32 frequently drank tap water or tap water with further treatment, and 12 frequently drank bottled water. The most significant factor influencing this choice was convenience, followed by taste, cost, and perceived safety. About half of the students did not know the source of origin of the water that they drank most often. These survey results were then incorporated into an activity later in the day and used to assign students to research different waters: a municipal tap water derived from surface water, a municipal tap water derived from ground water, and two different bottled waters. In the course of the activity, the students looked at factors that influence the quality of the water – both at the source, through various treatment processes, and during transport and storage. For example, the leaching of toxic chemicals from plastic bottles was discussed, and many of the students indicated that they were previously unaware of this potential hazard. Students also evaluated the taste of the various waters. The activity as designed was too long to fit into the hour timeslot, and modifications are recommended to shorten it and retain the most interesting parts. Results from student evaluations are included. Even if students do not choose to major in environmental engineering, all citizens should be interested in the safety and environmental impacts of their choices regarding drinking water.

Background

Demand for environmental engineers is expected to grow significantly in the coming years. The U.S. Bureau of Labor Statistics predicts that the demand for environmental engineers will grow by 25% between 2006 and 2016; this is the highest percentage increase for any of the types of engineers.[1] To meet this demand, it is important that more students are recruited to major in environmental engineering (EVEN). Waiting until students are enrolled in college may be too late to recruit EVEN students. In particular, many students interested in environmental issues often elect to major in a variety of sciences (such as chemistry, ecology, atmospheric studies) or environmental studies. These students might make great environmental engineers but they are unaware of this career path.

In an effort to recruit more students into environmental engineering, the multidisciplinary EVEN program at the University of Colorado at Boulder participates in the High School Honors Institute (HSHI) sponsored by the College of Engineering. The HSHI is in the summer, with the participating students either rising seniors or juniors. About 250 students typically participate. Students are allowed to self-select two main topics of interest, and spend a full day each learning about those two majors. The students also select three other engineering majors and attend a 45-

minute session learning about each of those majors on the third day of the HSHI. The demographics of the HSHI participants overall and the students who selected EVEN as a focus topic in 2007 are summarized in Table 1. In 2007 a higher percentage of women and juniors chose EVEN compared to the typical HSHI participant. The students who selected the EVEN topics were performing very well in High School, with an average grade point average of 3.7.

Table 1. Demographics of HSHI participants (based on post survey responses) and specifically those participating in the EVEN day-long program

Year	2004	2005	2006	2007	2007 EVEN
Total # students	262	197	262	247	37
% female	32	32	23	25	38
% minority	NR	NR	NR	NR	16
% seniors	59	65	62	63	51
% juniors	38	34	37	37	49

NR = not reported

There are two potential strategies that can be employed when developing activities for the HSHI. One is to select activities and present information that most accurately represents EVEN. The second is to present activities and information that are the most exciting and entertaining. Each of these strategies is discussed further below.

It is difficult to determine how to most accurately represent EVEN to students. EVEN is a very diverse field of engineering that is still evolving. As an example, the Professional Engineering (PE) exam for licensure only included EVEN as a discipline in 2000. There is currently no single professional engineering society for EVEN. EVEN emerged as its own discipline largely from roots in civil engineering (the so-called "sanitary" engineering side), chemical engineering (primarily industrial processing issues), and mechanical engineering (primarily the air pollution aspects). Today, EVEN is also expanding to include sustainability, life cycle analysis, and energy issues. Professionals in EVEN still debate what constitutes the core areas of EVEN. However, many of our core competencies deal with waste – municipal wastewater, municipal solid waste (aka. trash), and industrial liquid, solid, and air wastes. These waste-related topics are often unappealing to students. One example of this is the comparative unpopularity of the waste water treatment plant tour in 2006 compared to the power plant tour (see Table 2). As another example, in the freshman introductory course many students stated that they disliked the team project which focused on municipal solid waste. The project encompassed recycling, landfill design, methane recovery from the landfill for energy off-set, and biodiesel use in collection vehicles. Despite the fact that the project included ground water contamination, air pollution, and energy aspects, the central theme of "trash" seemed to blind many of the students to the broad implications. One student's comments regarding the project on his reflective essay at the end of the semester sums it up: "I felt that the landfill project in particular was a definite turn-off from the major. I feel that, in general, incoming Environmental Engineering students are not particularly excited about designing landfills, they would rather do something flashier and more entertaining. I understand (and understood) that landfill design is a sector of Environmental Engineering, but I personally have absolutely no interest in it, and I feel most of my peers share this point of view."

Designing fun hands-on activities is somewhat challenging for EVEN. Many of the things that we do most commonly in the laboratory involve dangerous chemicals or expensive and fragile equipment. EVEN deals a lot with pollution, but most harmful chemicals and microorganisms in water and air can't be readily "seen". Some hardy equipment designed for use in the field can be purchased. But this equipment is rather expensive so only a few are generally available – not enough for an entire group of 20 to 30 students.

Another important aspect of designing activities for high school students is the length of time the unit requires. Given the short attention spans of most high school students, 50-minutes is the recommended activity length. This allows for a number of activities throughout the course of the day. Up through 2006, the EVEN activities were generally longer – about 90 minutes each. We were advised to shorten our activity length to 50-minutes, which would be similar to the activity duration in the other engineering majors.

In 2003 and 2004, EVEN presented two major hands-on activities during the day long focus session of the HSHI. A single professor led the group through the entire day. In 2005, a tour to the local municipal wastewater treatment facility was substituted for one of the activities. In 2006, there was one activity and one tour, but different tours on the first and second day of the EVEN emphasis. The tour to a local coal-fired power plant with an emphasis on its air pollution controls was significantly more popular than the tour to the wastewater treatment facility. In 2007, EVEN re-designed its activities to align with the other majors, scheduling three shorter activities and the power plant tour. In 2005 through 2007, 2 to 3 different mentors led the sessions. Students rated the sessions on a scale of 1 (bad) to 5 (excellent), with results shown in Table 2. The most popular activity of the day is highlighted in bold.

In 2006 and 2007, the tour of the power plant was the most popular activity. Of the other non-tour activities, the surface water unit was the most enjoyable. This activity allowed the students to get outside and collect samples from a local creek, which may be more appealing than being in a classroom or laboratory. The two "indoor" activities related to air and drinking water were about equally popular, and had similar student ratings from 2004 through 2006. The 2007 drinking water activity is described in more detail below.

Table 2. Summary of student ratings of the EVEN activities at HSHI (5 = excellent, 4 = good, 3 = fair, 2 = poor, 1 = bad)

Year:	2003	2004	2005	2006	2007
Number of students:	35	36	26	47	37
Activity:					
Overview of EVEN	**4.11**	**3.91**	**3.89**	3.67	3.72
Air activity	3.00	3.67	3.76	3.53	3.72
Surface water activity	3.57	3.42	n/a	n/a	**4.23**
Drinking water activity	n/a	n/a	n/a	n/a	3.80
Tour Power Plant	n/a	n/a	n/a	**3.84**	**4.52**
Tour Wastewater Plant	n/a	n/a	3.57	3.14	n/a
Wrap up	n/a	n/a	n/a	3.19	4.00

n/a = not available; the activity was not completed in that year

Drinking Water Activity in 2007

Everyone drinks water every day. Everyone should be concerned about the safety of the water that they drink, although it is unclear if most high school students consider this. In the U.S. stringent regulations govern the quality of public drinking water supplies. However, many people now drink bottled water on a routine basis. The reason for this may be a combination of convenience and the perception that the bottled water is of higher quality.[2] The bottled water industry is significantly less regulated than public water supplies. In addition, the plastic containers may degrade the water quality by leaching small amounts of harmful chemicals into the water. These chemicals can have a variety of harmful effects at very low concentrations and many are termed “endocrine disruptors”.[11,12,13,14] It should be of interest to students to learn about these ideas, and try to conduct lifecycle related cost:benefit analyses, similar to the activities of environmental engineers. This drinking water activity also did not focus on a waste related topic.

A pre-survey on drinking water was developed. The questions on the survey are listed in Table 3. This pre-survey was given at the end of the initial information session that started the day of the EVEN focus. The results from the survey were incorporated into the slides that went with the drinking water activity lecture later in the day. Based on the primary source of the water that the students’ indicated that they drink, similar students were grouped into teams for the activity. The water that they were assigned to explore was also assigned based on the survey results. For example, those students who reported that they frequently drank bottled water and rarely tap water were grouped together and assigned to examine one of the bottled waters. The pre-survey also included an open-ended question asking the student the source of origin of their drinking water. Many listed “don’t know”; some knew that it was a specific lake, ground water or well.

Table 3. Number of student responses to the pre-survey questions in each category

Question: Response:	Frequently	Sometimes	Rarely	Never
Do you drink water straight from your home tap?	17	13	5	2
Do you drink tap water after it has been treated at your house (Brita water filter, faucet filter, etc.)	15	6	8	8
Do you drink bottled water?	12	15	8	1
Question: Response:	Significant	Somewhat	Very little	None
Do you think that drinking water quality can affect you health?	29.5	7.5	0	0
Rate how much knowledge you feel you have on the quality/safety of the water you drink	5	19	13	0
Which of the following factors influence what water you drink:				
Convenience	25	10	2	0
Cost	12	17	6	1
Overall Environmental Burden	7	13	13	4
Perceived safety	8	16	11	1
Taste	15	17	4	1

To make the activity personal, information on the drinking water source for municipal water in the hometowns of the students was compiled in advance of the HSHI. This information was summarized and given to students as a handout, which included the URLs to get more information on their drinking water quality. It was unclear if this information was appreciated by the students. It was fairly time-consuming to find this information, so this portion of the activity will probably be eliminated in the future.

Activity

Participants were placed into teams of 3 to 4 students. Each team was assigned one of five different waters: Boulder tap water (surface water source), Boulder tap water plus home treatment by a commercial pitcher filter, Castle Rock tap water (ground water source), a bottled natural spring water, or a bottled purified water. The students were given an ~5 minute lecture on each of the topics listed in Table 5 and then asked to discuss a related question with their team and fill in an evaluation form on their assigned water. The student teams were given information sheets to support their discussions. These included 3 pages of background information on water. A summary of the key points on the information forms are listed in Table 4.

Table 4. Summary of the facts listed on the drinking water information sheet

Type of Information	Example information	References
Life cycle information on bottled water	Energy cost 1.5 MJ 600-mL bottled water vs 4 MJ to drive 1 km vs 0.2 mJ for 600-mL tap water 2.7 M tonnes plastic for water bottles worldwide 1.5 M barrels crude oil for plastic water bottles in US air pollution from making 1 kg of PET for bottle = 40 g hydrocarbons, 25 g SOx, 18 g CO, 20 g NOx, 2.3 kg CO_2 bottled water ~90-1000x more negative environmental impact than tap water	2, 3, 4, 5
Contaminants found in bottled water	In 1986, an EPA survey of 25 bottlers showed that none of them had ever had a complete analysis of their water; 8% of the water tested showed evidence of some bacteria Arsenic, cadmium, mercury, and other metals in some samples of bottled water sold in Alabama were found to exceed USEPA standards for drinking water	6, 7, 8, 9, 10
Chemicals that leach from plastic bottles	Antimony, formaldehyde, and acetaldehyde from polyethylene terephthalate (PET) bottles Polyphenol, phthalic esters, bisphenol A, and other endocrine disrupting compounds from plastics	11, 12 13, 14, 15
Information on the specific bottled water, from the manufacturer	Source of the water Treatment processes used Standards met for quality (rarely available)	Company URLs
Information on home point-of-use water treatment	components of the pitcher filters energy consumption and air pollution from production if not replaced frequently, can add contaminants to the water including previously removed toxins and bacteria	16, 17

The groups assigned to evaluate the tap waters were also given the relevant Consumer Confidence Report (CCR) that municipalities generate for the public. The U.S. Environmental Protection Agency requires that all public water supplies create a CCR (http://www.epa.gov/safewater/ccr/index.html). These are the same CCRs that were located for most of the student participants' home water sources, and the URLs for these were provided on a separate handout to the students. By observing the students during the activity, it became apparent that the information sheets provided too much reading material given the short time for the activity. The groups did not really have enough time to read the important information, discuss it, and then decide on the answers to the questions as a team.

The questions that the student teams were asked to answer are listed in Table 5. The first day of the activity, only 25 of the 35 prepared slides were presented due to time constraints, so life cycle analysis was not covered. The teams only got to answer up to question 4. Because there was not enough time to get all the way through the activity in 50-minutes during the first day, the form was revised for the second day of the activity and the lecture slides revised to 25 slides. On day 2, the student results from the pre-survey were not included in the slides. The activity ended up about the right length with the fewer slides and shorter form. Three of the five teams completed all of the evaluation questions.

Table 5. Questions that the student teams answered to evaluate their assigned water

Question	Day 1 comments	Day 2 comments
1. List the source(s) of this water	OK	OK
2. List contaminants that are likely to be present in the source water	5 items listed	3 items listed
3. State the treatment used for the water	OK	OK
4. Which of these [treatment] methods are likely to remove the contaminants listed above	5 items; only 2 gps answered	3 items listed
5. State how the water is distributed	Not answered	OK
6. List any additional contaminants you think might enter the water during distribution; which of these are not removed or killed prior to water consumption	Not answered	2 items listed
Rate the following factors related to your water [scale 1=bad to 5 = excellent] 1. Overall quality and safety for human health 2. Taste 3. Cost 4. Convenience 5. Environmental burden	Not answered	OK All 3-5 All 3-5 2 bottled – 5 tap All 3-5 Bottled waters 1,2 vs 3-5 for tap
Given your team rating of the importance of each of the 5 factors above in selecting a drinking water, which of the 5 possible waters would you prefer to drink?	Not answered	3 of 5 teams answered tap water; 2 teams did not answer

Overall, the biggest negative of the activity seemed to be that there were not a lot of direct "hands on" tasks for the students. The students spent about half of their time listening, and the other half discussing and reading with their group. The concept of drinking water and the new information that they learned seemed generally interesting to them, but the material could perhaps be presented in a more exciting way.

Re-designed Drinking Water Activity for 2008

The drinking water activity will be re-designed as a water treatment competition in 2008. The goal of each group is to produce the "best" water. The entire group of students will weight the importance of the factors that determine the best water. These factors are similar to those from the 2007 pre survey. However, some will be hard to evaluate within the constraints of the activity, and there are benefits to keeping it simple. Therefore, the survey will be modified to include only three factors: clean/safe water, cost, and overall environmental impacts. All teams will start with the same water quality. We will use water samples that they collect from Boulder Creek during the morning field activity. Because the drinking water activity will follow the field activity at the creek, the students are more likely to have an accurate idea of what contaminants might be present in the water.

The students will be allowed to self-aggregate into teams. After the field activity they might be somewhat "acquainted" and more comfortable picking their own groups. Each team will be optimally composed of 3 students, to maximize the chances that all students will actively participate. Each team will have a mentor. These mentors will be undergraduate college students participating in the Environmental Engineering Research Experience for Undergraduates (REU) program. There are normally 9 to 10 undergraduate students participating in the EVEN REU program in the summer. The REU students will read the background information in advance, and be the resource to answer questions for their team of high school students.

Resources needed during the competition activity that were not needed in 2007 are the undergraduate environmental engineering laboratory and computers to allow the students to make simple calculations of costs and benefits. Students will select various simple methods to treat the water. Each treatment method will have an associated monetary cost, environmental impacts, and efficacy in removing contaminants from the water. Due to the short 50-minute length available for the activity, some of the water quality analyses may be done by the REU mentors after the activity. The results will be presented at the end of the day, and the winning team will be awarded prizes. In 2007, all students were given a reusable plastic water bottle with the University of Colorado logo.

Summary

Activities conducted in the HSHI have the potential to encourage students to pursue degrees in engineering, and specific engineering disciplines. On surveys to evaluate the overall HSHI program in 2007, 70% of the 247 students indicated that their interest in pursuing a career in science or engineering was reinforced. One female student in the first year EVEN course at the University of Colorado wrote: "Ever since 'discovering' this major during High School Honors

Institute, I've been thinking about how this education could be essential to doing something great for the earth and mankind." Enrollment in EVEN at the University of Colorado at Boulder was fairly stagnant from 2001 to 2004, but has been increasing recently with 7, 14, and 22 new freshmen in 2005, 2006, and 2007. Of the 19 rising seniors who participated in the EVEN HSHI activity in summer 2007, two applied to the EVEN program at the University of Colorado. Numbers for previous years and if the students applied to a different major are not available. All people should be interested in drinking water, so the activity will be beneficial even if the students choose not to major in EVEN.

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