AC 2009-442: STUDENTS' ATTITUDES AND CONCEPTS ABOUT ENGINEERING AS AN ENVIRONMENTAL CAREER: A SURVEY

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Students' Attitudes and Concepts Towards Engineering as an Environmental Career – A Survey

Keywords: Environmental knowledge; engineering; first year; resistance to change

Abstract

The overall purpose of the research is to determine students' attitudes towards environmental and ecological issues in the context of choosing engineering as a career. We report the results of a survey of 1700 first-year engineering students at Purdue University, West Lafayette campus. The survey tested student knowledge of environmental issues, their prioritization of sustainable development in various contexts, and also explored student attitude toward change. The results of this survey are combined with high school academic performance data and demographic data to determine how formal curricula and other factors such as personal experience influence a student's environmental knowledge. We observed positive correlations between the high school science courses or high school environmental education, and the average environmental knowledge scores. There is no difference in average knowledge scores when comparing male and female students, or when comparing students from the United States (U.S.) with non-U.S. students. We observed a negative correlation between the number of high school math courses and the average knowledge score. In addition, the authors investigated how the students' tolerance to change affected their prioritization of environmental issues and environmental knowledge. High resistance to change scores indicate low perceived importance of environmental engineering and low levels of understanding of environmental engineering issues, with the exception of issues related to policy/legislature where the relationship is positively correlated. To translate the findings into practice, this research recommends to focus on students' transformations in attitude towards and knowledge of: (a) the natural environment (as something to be concerned about) and (b) engineering (as a profession which has a large impact on the natural environment) as well as their overall 'resistance to change'.

Introduction

Environmental protection strategies will improve and evolve only with the participation and perspectives of all engineering disciplines. In fact, there is increasing awareness in most fields of engineering that environmental constraints are embedded in almost every societal challenge. For example, the Accreditation Board for Engineering and Technology's ABET-EC 2005-2006 accreditation rules requires all engineering disciplines to include environmental and sustainability issues as constraints in design (criterion three)[1]. Similarly, the Institutions of Engineering, Australia's Code of Ethics and National Competency Standard 2000 mandate sustainability design and development for all undergraduate engineering students[2].

From a workforce standpoint, it is equally an opportune time to train engineers with a broader understanding of environmental impacts. According to the U.S. Bureau of Labor Statistics, employment for environmental engineers (EE) will increase "much faster than average" through 2014[3]. The National Science Board anticipates a 27% growth in EE jobs through 2010 [4]. And, while workforce estimates vary somewhat, the estimated current number of environmental engineers in the United States varies between 45,000 – 110,000 (11), and the total domestic engineering workforce is about 1.5 million people [3].

The value and importance of environmental education has been endorsed both in the United States and internationally (e.g. United Nations Educational, Scientific and Cultural Organization, 1975, 1978; North American Association for Environmental Education, 1999). Based on available data, reports like "Environmental Literacy in America: What 10 Years of NEETF/Roper Research and Related Studies Say About Environmental Literacy in the U.S" (NEETF, 2005) show however mixed results. On the one hand, the report shows a "confused public that performs poorly on basic environmental literacy questionnaires", and on the other hand "95% of this public supports environmental education in our schools" [5].

In order to innovate the engineering curriculum, it is necessary to understand how engineering students view the many dimensions (technical and non-technical) of human impacts on the environment. One method of capturing student viewpoints is by administering a survey instrument. Although there are several national and international surveys of environmental knowledge (administered either to students or to a broader audience), none of the surveys is focused specifically on engineering students, nor exist any surveys that focus on beginning (first-year) engineering students. Thus, these survey results are important for several reasons. First, the results will be utilized to develop curricula and pedagogical methods for all engineering students at Purdue University that highlight the importance of engineering activities in protecting and enhancing the environment. Second, the survey results addresses a knowledge gap in understanding how students choose their majors and ultimately their careers. There are very few published studies that investigate why engineering students choose (or do not choose) environmentally related careers.

Literature review, theoretical framework and foundations

National surveys such as the College Student Survey conducted by the Higher Education Research Institute (HERI) are designed to capture student attitudes about academic and non-academic goals, and include questions about the "environment" in a much broader context than curriculum or professional goals[9]. Surveys of college-level engineering students in the United

States[8] focus on specific majors (e.g., students who already have an interest in the environment) or students of various class-levels. Earlier work on environmental literacy in the field of engineering showed a similar pattern than the national NEETF report: In a worldwide survey of engineering students, Azapagic et al. (2005) found (a) unsatisfactory knowledge, and at the same time (b) a general belief that environmental issues are very important.

Although reports exist in the engineering education literature, especially on individual lesson design[6] and curricula design[7], there is a gap in the literature and a general lack of more detailed research into the conceptions and attitudes of students towards environmental and ecological issues, especially how both relate to engineering careers.

'Resistance to change' – theoretical framework

Research results in environmental education are particularly puzzling: (1) The gap between the consensus that environmental issues are very important and (2) the reality of little to no knowledge or change of behavior is so tremendously high, that factors besides knowledge and 'attitudes towards environment' need to be considered to explain this discrepancy. Theoretical concepts from other disciplines such as organizational behavior might provide insight, particularly the construct of 'resistance of change'. Developed by Oreg[11], the construct can be described as an "individual's tendency to resist or avoid making changes, to devalue change generally, and to find change aversive across diverse contexts and types of change" (p.680). The particular construct and its instrument focus particularly on resistance to change as a "multidimensional disposition that comprises behavioral, cognitive, and affective components" (p.680). Emerging subscales are Routine Seeking (e.g., "I prefer having a stable routine to experiencing changes in my life"), Emotional Reaction to Imposed Change (e.g., "When things don't go according to plans it stresses me out,"), Cognitive Rigidity (e.g., "I don't change my mind easily"), and Short-Term Focus (e.g., "When someone pressures me to change something, I tend to resist it even if I think the change may ultimately benefit me").

For this particular study, the research team is interested in the interrelations of high levels of resistance to change with knowledge on environmental issues, legislature and policies, environmental processes and tools, and matters of sustainability.

Additional foundations for research

Based on the discrepancy between a low level of environmental literacy of the general public and a large call for better education (see previously mentioned NEETF report and the study by Azapagic et al.), the research team was particularly interested in the level of environmental education in secondary school to further verify, if the large gap between desire and reality exists in the student population at Purdue University. In addition, the team was interested, which types of environmental issues were students more aware and knowledgeable about? The knowledge of environmental issues was grouped into four categories: 1) Environmental concerns, 2) Legislature and Policy, 3) Environmental Tools, Technologies and Approaches, and 4) Sustainable Development.

These baseline data on (a) environmental education in secondary school and (b) knowledge on environmental issues can additionally provide insight into two correlated issues: (1) The transfer and incorporation of general environmental education in high school into environmental engineering knowledge and (2) The correlation between science classes and the performance on environmental engineering knowledge can function as an indirect measure of environmental education in high school.

Previous statistics provide documentation that some engineering disciplines attract greater numbers of women than others. Overall, 19.5% of engineering bachelor's degrees were awarded to women during the 2004-2005 academic year. Engineering disciplines reporting 35% or more female graduates include Chemical (CHME; 37.2%), Biomedical (BME; 42.4%) and Environmental Engineering (EE; 42.9%) that same year[12]. In fact, these high percentages persist through graduate education. For instance, 41% of EE MS degrees were awarded to women (22.7% overall) and 28% of EE doctoral recipients were women (18% overall). Similarly, one could speculate, if the country of origin might have an impact on the environmental knowledge of students, particularly countries in which drastically environmental problems are very severe. For the research team it was from particular interest if the data reveal differences based on gender and country of origin.

Of similar interest is the role of income level on students' view on environmental issues: This direction aims at the assumption that the prioritization of environmental issues may depend on a student's family income levels.

Purpose

The overall purpose of the research is to determine students' attitudes and conceptual understanding towards environmental and ecological issues in the context of choosing engineering as a career. We report the results of a survey of 1700 first-year engineering students at the Purdue University, West Lafayette campus.

Research Questions

Five questions were generated from the literature review and the theoretical framework to investigate the interrelations between demographic information, knowledge on environmental issues and 'resistance to change'.

1) How does students' initial understanding of environmental knowledge impact their attitudes to environmental issues?

- 1.1) How many of them received environmental education in high school?
- 1.2) Which types of environmental issues were students aware and knowledgeable about?
- 1.3) How does high school environmental education correlate with knowledge of environmental engineering issues?

2) How does students' education in science or math in high school impact their understanding of environmental issues?

3) How do the differences in gender and country of origin impact students' attitudes towards engineering as an environmental career?

4) How do the differences in students' social economical background impact their attitudes towards environmental issues?

5) How do students' level of resistance to change impacts their view to the importance of environmental issues?

Methods: Data Collection and Analysis
During the first week of fall semester 2008, the research team administered a survey to all first-year students through their required introductory class (return rate: 1437). The survey was administered via a web-based survey tool, which created a unique key for each student. Students were asked to demonstrate attendance for their first day of class by completion of the survey.

The survey questions (survey instrument available in Appendix A) tested student knowledge of environmental issues, such as acid rain, photochemical smog, and climate change. In addition, students were asked to rate the importance of sustainable development in various contexts (for themselves, for their profession, for their country, etc) and also explored student attitude toward change. The survey was constructed using and adapting existing survey instruments: For the environmental issues portion, the research team adapted the environmental engineering instrument[10]; for the tolerance of change portion we utilized the well-documented and validated 'resistance to change' instrument[11].

The survey was combined with academic data obtained from the University's Admissions Offices (for example, the number of science based courses completed in high school, and environmental education in high school), as well as demographic data (for example, average household income in the student's permanent residence zip code, geographic region in the United States). Students' permanent zip code data were utilized to determine zip-code specific demographic information about the students, such as poverty level. Zip-code relevant demographic data was obtained from the U.S. Census bureau from the latest U.S.-wide survey of 2000. The data were analyzed using frequency analysis and Pearson R correlation tests, which is designed to convey the magnitude and direction of the association between two variables. The analysis was carried out via excel and SPSS, a specific social science statistical software package.

Results and discussion
To research question 1:

The discrepancy between a low level of environmental literacy of the general public and a large call for better education makes it valuable to investigate the relationship between students' environment-related education received at high schools and their understanding of environmental issues. Based on the preliminary analysis (see Figure 1), nearly two-third (65.5%) of the first-year students reported that their high school experience did not include any environmental education.

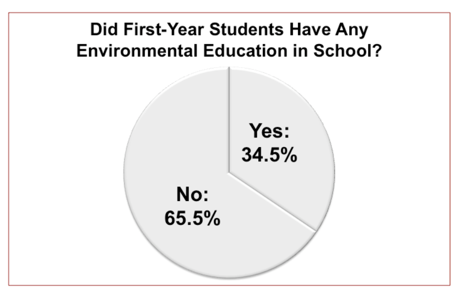

Figure 1: Environmental Education in Secondary Education

During the evaluation of their initial knowledge of environmental issues (Figure 2), they demonstrated a much higher knowledge level in the category of "effects on environment", which

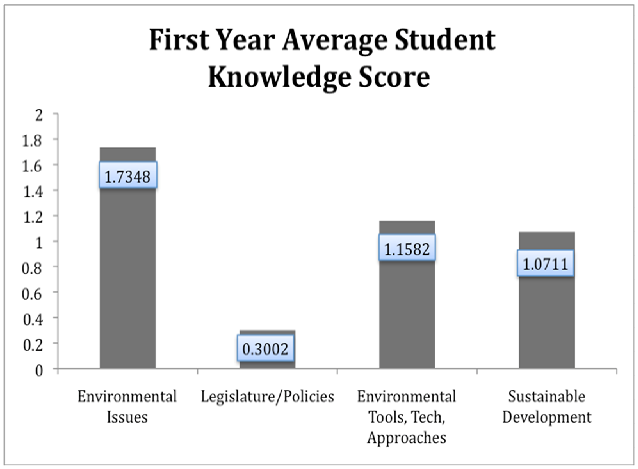

Figure 2: Knowledge on Environmental Issues

included acid rain, water pollution, air pollution and global warming. The survey indicated however, that their knowledge level was less in environmental tools, sustainable development and legislature and policies. Items in "effects on environment" were frequently in the media or were items that did not need much specialized information to understand such as 'water pollution.' It could be argued that the less common-sense the terminology and the more specialized prior knowledge was required to understand the concepts, the least likely students were aware or knew about the particular environmental issue. In other words: students' awareness of environmental challenges was much higher than knowledge on how to take up these challenges.

The relationship between students' high school environmental education and their knowledge level of environmental issues was investigated using Person correlation coefficient. The result (Table 1) indicated there was a positive relationship between the two variables.

Table 1
The Correlation Between High School Environmental Education and Student Knowledge of Environmental Engineering Issues (N=1360)

	1	2	3	4	5
1. Prior Environmental Education	--				
2. Environmental Issues	.272**	--			
3. Legislative Policy	.196**	.466**	--		
4. Environmental Tools, Technologies, Approaches	.096**	.601**	.471**	--	
5. Sustainable Development	.161**	.595**	.497**	.715**	--

**. Correlation is significant at the 0.01 level (2-tailed).

Students who declared to have received environmental education in high school did indeed demonstrate statistically significant higher scores in all knowledge categories.

<u>To research question 2:</u>
In order to investigate how students' education in science or math in high school impacted their understanding of environmental issues, Pearson correlation (two-tailed) was calculated for the number of semesters of high school math/science and average scores in each of the four categories of environmental knowledge. Data analysis disclosed that the range of cumulative semester hours of high school math was 0 – 16 with an average of 7 and that the range of cumulative semester hours of high school science was 0-19, with an average of 9.

The correlations listed in Table 2 revealed that the number cumulative semester hours of high school math was not positively correlated with student scores in any category of environmental knowledge. However, the number of semesters of high school science was positively correlated with student scores in all categories of environmental knowledge. A cautious interpretation would indicate that typical high school science courses including chemistry, biology, and physics could possibly include case studies or examples related to the environment, which potentially enhanced students' understanding of environmental issues.

Table 2
The Correlation Between High School Math and Science Education and Student Knowledge of Environmental Engineering Issues (N=1360)

	Semesters of High School Math Taken	Semesters of High School Science Taken	1	2	3	4
Semesters of High School Math Taken	--					
Semesters of High School Science Taken	.268**	--				
1. Effect of Environment	-.101**	.180**	--			
2. Legislative Policy	-.069*	.123**	.466**	--		
3. Environmental Tools, Technologies, Approaches	-.028	.103**	.601**	.471**	--	
4. Sustainable Development	-.070**	.155**	.595**	.497**	.715**	--

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

To research question 3:

In addition to formal education (high school curriculum), many other factors may shape a student's attitude and knowledge of the environment. In the engineering disciplines, there has been much discussion about various dimensions of diversity, including gender and multi-cultural perspectives.

Given the greater participation of women in environmental engineering degree programs (as mentioned earlier in this paper), the researchers explored gender as a factor that may impact environmental knowledge scores.

Hypotheses:

H0: There is no difference in the knowledge scores between male and female students.

HA: There is a difference in the knowledge scores between male and female students.

The data were subject to Levene's Test for Equality of Variances. In all cases, we fail to reject the null hypothesis. There is no significant difference in the knowledge scores of male and female students.

Although there have been several surveys that includes students from multiple countries, to our knowledge, differences between students from different countries were not explored. Thus, we also explored the impact of U.S. versus non-U.S. perspectives on student knowledge.

<u>Hypotheses:</u>
H0: There is no difference in the knowledge scores between U.S. and foreign students

HA: There is a difference in the knowledge scores between U.S. and foreign students

The data were subject to Levene's Test for Equality of Variances. The project team failed to reject the null hypotheses for all categories of environmental knowledge; there is no difference in knowledge scores between U.S. and foreign students. It appears that first-year engineering students at Purdue University have similar perspectives on the environment, regardless of differences in previous personal experiences that may result from gender differences or cultural differences.

<u>To question 4:</u>
Students' social economical background was another element assumed to interfere with their ratings of the importance of sustainable development. Their household income was examined as a core variable. Students' permanent zip code was mapped to U.S. Census 2000 data on average household income within the zip code. Income levels were further classified based on participant groups as follows:

- Group 5 (Affluent): Income greater than $500,000 per year
- Group 4 (Upper Middle Class): Income between $100,000 - $499,999 per year
- Group 3 (Middle Class): Income between $75,000 and $99,999 per year
- Group 2 (Lower Middle Class): Income between $35,000 and $74,999 per year
- Group 1 (Working Class): Income between $16,000 and $34,999 per year

Since our data did not capture the income level of international students and not all zip codes were available for domestic students, this research question operates only with an n=1177.

The means and standard deviations were presented in Table 3. A one-way between-groups analysis of variance was conducted to explore how students from different income levels viewed the importance of environmental issues. There was a statistically significant difference at the $p < .05$ level for the four income groups: $F(3, 1173) = 5.193$, $p=.001$. Despite reaching statistical significance, the actual difference in the mean scores was quite small. The effect size, calculated using eta squared, was .01. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for Group 2 was statistically different from Group 3 and Group 4.

Table 3

How students from different income levels viewed the importance of environmental issues (N=1177)

	Group 4	Group 3	Group 2	Group 1
M	2.02	1.92	1.71	1.69
SD	0.7	0.91	0.89	0.93

To question 5:

As a strong factor to provide insight why the perception of importance of environmental issues is so high and the actual knowledge is so low, the 'resistance to change scale' was utilized to examine the relationship between resistance to change and importance of environmental issues. Data analysis showed that there was a negative correlation between the two variables (Table 4). High 'resistance to change' scores are associated with low importance of environmental issues scores.

Table 4

The Correlation Between Student Average Score for Resistance to Change and How They Rate The Importance of Environmental Issues (N=1360)

Average Score for Resistance to Change	--
Importance of Environmental Issues	-.115**

**. Correlation is significant at the 0.01 level (2-tailed).

As for individual area of environmental issues including environmental issues, legislative/policy, environmental tools, technologies, and sustainable development, data analysis showed statistically significant results, with different directions (Table 5):

Table 5

The Correlation Between Student Score on Resistance to Change and Their Knowledge of Environmental Issues (N=1360)

Resistance to Change	--
Environmental Issues	-.071**
Legislative Policy	.006
Environmental Tools, Technologies, and Approaches	-.078**
Sustainable Development	-.079**

**. Correlation is significant at the 0.01 level (2-tailed).

- Environmental Issues: There was a negative correlation between the two variables. High resistance to change scores was associated with lower levels of knowledge about environmental issues.

- Legislative/Policy: The two variables were positively correlated, yet not statistically significant. High resistance to change scores was associated with higher levels of knowledge about legislative and policy issues
- Environmental Tools, Technologies, and Approaches: There was a negative correlation between the two variables. High resistance to change scores was associated with lower levels of knowledge about environmental tools, technologies, and approaches.
- Sustainable Development: There was a negative correlation between the two variables. High resistance to change scores was associated with lower levels of knowledge about sustainable development.

A cautious interpretation of the correlations would indicate a stronger politicized than knowledgeable population of students.

Summary and Conclusion

This study reveals trends across a large body of first-year engineering students at a large R1 university: Students across the board are aware of environmental issues, yet when it comes to specific legislature, environmental engineering tools/approaches and sustainable development strategies, students' awareness and knowledge are considerable lower.

While two-thirds of the students reported to not have received an explicit environmental education in high school, the number of semester hours of science in high school showed positive statistically significant correlation to the students' understanding of environmental issues. Not surprisingly, the same holds in the correlation between prior environmental education and knowledge of environmental issues. The amount of math courses however showed a significant negative correlation, which yet needs explanation.

The research also reveals statistically significant correlation between the resistance to change instrument and the importance of environmental issues and knowledge level. High resistance scores indicate low perceived importance of environmental engineering and low levels of understanding of environmental engineering issues (with the exception of policy/legislature where the relationship is positively correlated).

No differences were found, when looking at gender or country of origin.

Further research is necessary to (1) scale the research to other institutions for better generalizations and (2) to provide more explanations on why these correlations exist.

For teaching purposes, our research, particularly the components on resistance of change, would indicate that it is equally important to teach environmental engineering skills and knowledge as it is to address issues in regards to resistance to change.

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Appendix A: Survey Instrument

1. How do you rate your knowledge of the following topics

	Not heard of	Heard of but could not explain	Have some knowledge	Know a lot
Acid rain				
Air pollution				
Biodiversity				
Climate change				
Deforestation				
Depletion of natural resources				
Desertification				
Ecosystems				
Global warming				
Ozone depletion				
Photochemical smog				
Salinity				
Solid waste				
Water pollution				
	Not heard of	Heard of but could not explain	Have some knowledge	Know a lot
EU EMAS				
The Florence Convention				
Intergovernmental Panel on Climate Change (IPCC)				
ISO 14001				
Kyoto Protocol				
Montreal Protocol on CFCs				
Rio Declaration				
	Not heard of	Heard of but could not explain	Have some knowledge	Know a lot
Clean technology				
Clean-up technology				
Design for the environment				
Eco-labelling				
Fuel cells				
Industrial ecology				
Life cycle assessment				
Product stewardship				
Renewable energy technologies				
Responsible care				
Tradable permits				
Waste minimization				
	Not heard of	Heard of but could not explain	Have some knowledge	Know a lot
Sustainable development—definition and the concept				
Components of sustainable development				

Approaches to sustainable development				
Precautionary principle				
Population growth				
Inter- and intra-generational equity				
Stakeholders' participation				
Connection between poverty, population, consumption				
and the degradation of the environment				
Earth's carrying capacity				
Social responsibility				
Engineering community's response to sustainable development				
Actions that can be taken by companies and engineers to promote sustainable development				

e) How would you rate the importance of sustainable development for

	Not important	Possibly important	Important	Very important
You personally				
You as an engineer				
Your country				
The society world-wide				
Population growth				
Future generations				

2. Did you have any environmental education in school? YES NO
(If yes) Describe what environmental education you had? [Free-text]
(For both) Describe what environmental education you would have liked to get? [Free. text]

3. Resistance to Change

Statement	Strongly disagree	Disagree	Inclined to disagree	Inclined to agree	Agree	Strongly agree
1. I generally consider changes to be a negative thing.	1	2	3	4	5	6
2. I'll take a routine day over a day full of unexpected events any time.	1	2	3	4	5	6
3. I like to do the same old things rather than try new and different ones.	1	2	3	4	5	6
4. Whenever my life forms a stable routine, I look for ways to change it.	1	2	3	4	5	6
5. I'd rather be bored than surprised.	1	2	3	4	5	6

Statement	Strongly disagree	Disagree	Inclined to disagree	Inclined to agree	Agree	Strongly agree
6. If I were to be informed that there was going to be a significant change regarding the way things were done at school/work, I would probably feel stressed.	1	2	3	4	5	6
7. When I am informed of a change of plans, I tense up a bit.	1	2	3	4	5	6
8. When things don't go according to plans, it causes me great stress.	1	2	3	4	5	6
9. If one of my professors/bosses changed the grading criteria, it would probably make me feel uncomfortable even if I thought I'd do just as well without having to do any extra work.	1	2	3	4	5	6
10. Changing plans seems like a real hassle to me.	1	2	3	4	5	6
11. Often, I feel a bit uncomfortable even about changes that may potentially improve my life.	1	2	3	4	5	6
12. When someone pressures me to change something, I tend to resist it even if I think the change may ultimately benefit me.	1	2	3	4	5	6
13. I sometimes find myself avoiding changes that I know will be good for me.	1	2	3	4	5	6
14. I often change my mind.	1	2	3	4	5	6
15. I don’t change my mind easily.	1	2	3	4	5	6
16. Once I’ve come to a conclusion, I’m not likely to change my mind.	1	2	3	4	5	6
17. My views are very consistent over time.	1	2	3	4	5	6