Using a Museum Exhibit as a Pedagogical Tool for Developing Reflective Engineers

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Abstract

Engineering educators are currently interested in the use of informal learning settings for developing reflective skills in engineers. The present study examined the effects of exposing engineering and non-engineering undergraduates to an exhibit at a university museum that focused on recycling. One goal was to test whether exposure to creative uses of recycled materials in everyday contexts made participants more sensitive to variables associated with reflective thinking in those contexts, like their sense of the utility of the recycled materials, the societal value of the recycled materials, and an appreciation for the process of recycling. A second goal was to test whether participants' interpretation of the exhibit depended on how the experimenter framed recycling issues prior to participants' interactions with the exhibit. The two forms of framing that were applied were a Government-Economy frame and a Community-Environment frame. The results of this study showed that participants' dispositions towards recycling changed after interacting with the exhibit. There was also a clear framing effect on participants' beliefs about recycling. This research study provides one example of the ways in which engineering instructors can use out-of-classroom resources, like museum exhibits, in order to develop more reflective engineers.

Introduction

Engineering educators have recognized a need to transform engineering education to allow "more opportunity for a broader liberal education on the part of undergraduates" in order to develop creative, competitive, informed, and innovative engineers [1]. One way to accomplish this is to incorporate courses from the liberal arts into the undergraduate engineering education. Another way is by complementing classroom instruction with the resources available in informal learning settings, like museums. The National Research Council's Committee on Learning Science in Informal Environments [2] concluded that museums can support reliable learning through inquiry, sense-making, and reflection on one's experiences. The present study examined that possibility by exposing undergraduates to a Green Revolution exhibit which was available at our university museum. Green Revolution is a traveling exhibit that focuses on recycling (http://www.sites.si.edu/greenRevolution/). The exhibit is made available to museums around the country through the Smithsonian Institution.

The development of reflective skills is increasingly recognized as an important part of engineering training. Socha et al. [3] state the following:

> *One of the most effective tools for lifelong learning is the ability to reflect and learn from past experience. Reflection helps to clarify our understanding of the world and to create new distinctions and possibilities for the future. It is a way of creating intention. By putting our attention on the perception of what has happened and what we want to achieve, solutions to problems emerge more easily. We also believe reflective skills are among the main characteristics that distinguish excellent engineers from merely good ones. This makes these skills important to teach.*

Clearly there are many different learning contexts through which reflective skills could be

developed, and the scope of instruction can vary. The present study used a museum exhibit as the vehicle for a brief, reflective exercise. Students were given an opportunity to study and interact with displays in the exhibit and were guided in their reflections about the displays. Using a pretest-posttest methodology, we were able to assess whether students' experiences with the displays clarified students' understanding and revealed new distinctions and possibilities to them, as suggested in Socha et al. [3].

Engineering instruction is based on facts, constants, principles, and formulas. However, when confronted with any problem, there is a *framing effect*. Framing here refers to the cognitive representations that individuals form in order to understand situations. The way in which one frames a problem determines how the problem is perceived and processed [4, 5]. Framing effects apply as much to classroom settings as they do to professional and everyday settings. Therefore, the museum experience in the present study is susceptible to framing effects. The issue of framing and our understanding of how it works is important to engineering training and professional practice. This is because the ways in which engineers frame situations has a significant impact on people, communities, and resources.

Research has shown that mental representations are malleable through framing. For instance, Gross and D'Ambrosio [6] conducted an experiment in which participants read a newspaper story about the 1992 Los Angeles riots. One version of the article was framed to emphasize the social context in Los Angeles at the time. The other article was framed to emphasize the rioters' criminality. The authors showed that participants' responses to these articles were influenced by the way the story was framed. In order to test the impact of framing in the present study, one half of the participants received prior written information that framed the Green Revolution exhibit in terms of Government-Economy issues; the other half of the participants received information that framed the exhibit in terms of Community-Environment issues.

Because we were interested in the utility of informal learning settings to develop reflective skills in engineers, we recruited engineering undergraduates as volunteer participants for this study. A question that has not been examined in the research literature concerns whether engineering students respond differently to informal learning settings compared to non-engineering students. Therefore, we recruited a sample of non-engineering undergraduates as a comparison group.

Research Questions

1. Can a museum exhibit, like the Green Revolution exhibit, change participants' views on recycling?
2. Will participants react differently to the Green Revolution exhibit due to their academic major – i.e., engineering or non-engineering?
3. Will participants react differently to the exhibit due to the way in which the exhibit is framed prior to their experience – i.e., Government-Economy frame or Community-Environment frame?
4. Will participants show evidence of changes in analytical thinking after experiencing and reflecting on the Green Revolution exhibit?

Methods

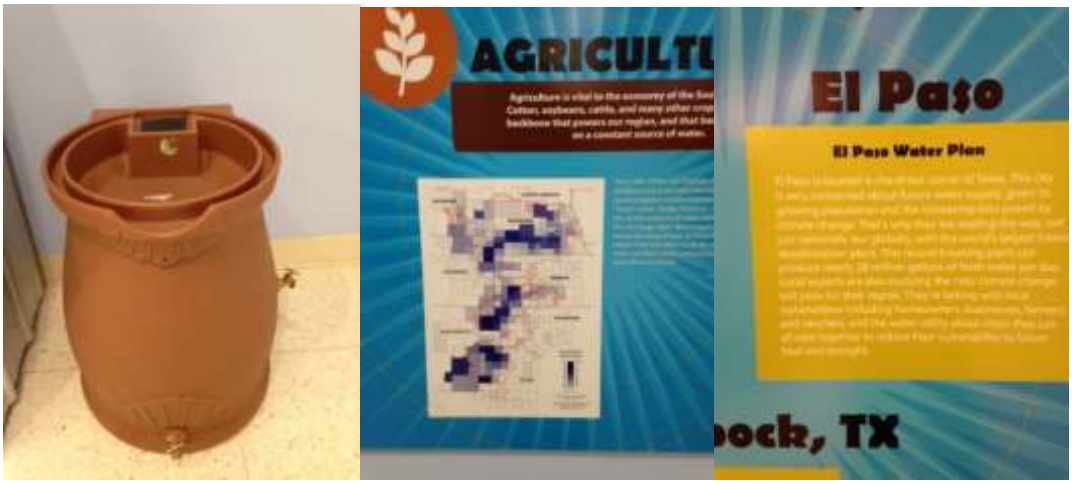
Participants. The participants were ten volunteer engineering and ten volunteer non-engineering undergraduates. The engineering undergraduates were either Civil Engineering (*n*=5) or Environmental Engineering (*n*=5) majors. The non-engineering undergraduates represented nine majors outside of science and engineering (e.g., Philosophy, Business). There were six juniors and four seniors in each group. Students participated for extra credit in the courses from which they were recruited.

Materials. The Green Revolution exhibit was installed by the university museum according to the specifications provided by the Smithsonian Institution. Prior to the present study, the researchers identified five themes that were clearly represented among the displays in the museum exhibit: Climate Change, Recycling Trash, Water Use, Green Jobs, and Electricity Use. These themes were used to direct participants through the exhibit using a printed "gallery guide" constructed by the researchers and to evoke reflective thought from the participants at each theme. The "gallery guide" for Water Use is shown in Figure 1. Seven questions about recycling using a Likert scale of 0 (Low) to 9 (High) were used in order to assess participants' views regarding recycling. The seven questions are shown in Table 2. Study materials for the five themes were used to bias participants to favor either government control or community control of resources. The summary bullets from the study materials (see Table 3) were used in a post-test to assess whether participants experienced the Green Revolution exhibit differently, depending on how it was initially framed through the study materials. Paper and pencils were provided to participants for all written responses.

Figure 1. The Gallery Guide Used for the Water Use Theme

WATER USE (15 minutes) – Find and read each of the displays shown below. Then find a place to sit and respond to the short answer questions below. Answer directly on these pages.

1. Rain Barrels
2. Ogallala Aquifer
3. El Paso



Question 1: Briefly summarize the information in the displays.
Question 2: Briefly summarize your reaction to the information in the displays.

Procedure. The study was conducted in meeting room and in the Green Revolution exhibit at the university museum. Upon arrival to the museum in small groups, participants were introduced to the Green Revolution exhibit and were given a brief overview of their activities. All participants received a packet of identical written materials, with the exception of brief study materials, as follows. Half of the participants received descriptions of the five themes that was consistent with a Government-Economy framing bias, and the other half received descriptions that was consistent with a Community-Environment framing bias. Participants then completed the steps outlined in Table 1. Step 4 in the procedure prompted students to gather information about each theme and then to reflect on each theme. For Steps 5-7, participants were instructed to answer the questions in the way they thought and felt about the issues, based on the observations that they made in the Green Revolution exhibit.

Table 1. Summary of Procedure

1. Completed pre-exhibit survey questions (see Table 2).
2. Wrote 200-500 word essays to each of the following prompts: 1) Express your views on recycling; 2) In some detail, describe a way to recycle trash.
3. Studied their framing materials for 15 minutes. Half studied the Government-Economy materials and half studied the Community-Environment materials.
4. Visited each theme in the Green Revolution exhibit for 15 minutes, using the "gallery guides" to direct them to specific parts of the exhibit. For each theme, participants responded briefly in writing to the same two prompts: 1. Briefly summarize the information in the displays. 2. Briefly summarize your reaction to the information in the displays.
5. Completed the post-exhibit survey (see Table 2).
6. Wrote 200-500 word essays to each of the following prompts: 1) Express your views on recycling; 2) In some detail, describe a way to recycle trash. 3) In some detail, describe a way to recycle electronic equipment.
7. Rated the Government-Economy and Community-Environment summary statements from the study materials (see Table 3).

Results

The analyses below applied repeated-measure analysis of variance (ANOVA) to pre-exhibit and post-exhibit dependent measures. The independent variables were Major (Engineering, Non-Engineering) and Framing (Government-Economy bias, Community-Environment bias).

Changes in Views Concerning Recycling. In order to address the first research question, participants' responses to the survey questions before experiencing the exhibit were compared to their responses after experiencing the exhibit. The research question concerned the changes in reasoning, beliefs, and practices about recycling after experiencing the Green Revolution exhibit. There were no significant effects for Major or Framing. There was a significant effect for Pre-exhibit vs Post-exhibit ratings [$F(1,16)=5.37$, $p=.034$]. An effect size = .34 was small to moderate, and significant. Mean responses to each question and the overall means are shown in Table 2. These results showed that participants showed significant gains in their dispositions towards recycling. The results suggest that even a brief museum experience, like the Green Revolution, can evoke significant change in individuals.

Table 2. Mean Pre-Exhibit and Post-Exhibit Ratings by Question (Rated on 0-9 scale)

Survey Questions	Pre-Exhibit Mean Rating	Post-Exhibit Mean Rating
How familiar are you with the topic of recycling?	6.35	7.60
How often do you currently recycle?	4.00	4.10
Please indicate your interest in recycling. How interested are you in recycling?	5.75	6.55
Please rate the utility of recycling. How important do you think it is to recycle?	7.80	8.20
Please estimate the probability that you will recycle objects in your environment (e.g., plastic, glass, tin, newspaper) in the future.	6.70	6.80
Please estimate the probability that you will encourage others to recycle in the future.	6.10	6.45
Please estimate the probability that you could discover a creative way to recycle discarded objects.	4.95	5.20
OVERALL MEAN	**5.95**	**6.41**

Effects of Framing on Reactions to the Green Revolution. During the study period (Step 3 in Table 1), participants studied either Government-Economy descriptions or Community-Environment descriptions, including the summary statements shown in Table 3. After experiencing the Green Revolution exhibit, participants rated the statements they had studied earlier, as well as those that they had not studied. These ratings were on a 10-point scale from 0-Totally Disagree to 9-Totally Agree. In order to assess whether framing the five themes by administering a brief study period affected participants' experience, participants' ratings of the Government-Economy summary statements were compared to ratings Community-Environment summary statements (see Table 3).

Table 3. Summary Statements for Green Revolution Themes by Framing Bias

Overall Summary	
Government-Economy Bias	**Because individuals find it difficult to agree, it's important for governments to solve problems for the common good.**
Community-Environment Bias	**Because individuals can find ways to agree, it's important for people to come together for the common good.**
Water Use Theme	
Government-Economy Bias	**Water use must be regulated to protect the rights of individual property owners.**
Community-Environment Bias	**Water use must be regulated to protect the common good.**
Recycling Trash Theme	
Government-Economy Bias	**It is very costly to recycle styrofoam into building materials.**
Community-Environment Bias	**It is ecological to recycle styrofoam into building materials.**
Electricity Use Theme	
Government-	**It is costly to use energy to convert aluminum and glass into electricity.**

Economy Bias	
Community-Environment Bias	**It is ecologically smart to use energy to convert aluminum and glass into electricity.**
Green Job Theme	
Government-Economy Bias	**Green jobs could negatively affect the labor force and opportunities.**
Community-Environment Bias	**Green jobs could positively affect the labor force and opportunities.**
Climate Change Theme	
Government-Economy Bias	**Pragmatically speaking, an overly aggressive reaction to a carbon footprint will put people out of work and cause economic distress.**
Community-Environment Bias	**Scientifically speaking, a large carbon footprint is dangerous to the environment.**

ANOVA analyses showed a significant difference in ratings for the two statement types [$F(1,16)=21.53$, $p < .001$], a significant difference due to Framing Condition [$F(1,16)=8.71$, $p=.009$], and a significant interaction between the two factors [$F(1,16)=8.95$, $p=.009$]. Table 4 shows that all participants generally rated Community-Environment statements (Mean = 7.46) more favorably than Government-Economy statements (Mean = 5.30). The effect of framing shows up in the significant interaction effect. Specifically, participants who were in the Community-Environment framing condition rated Government-Economy statements unfavorably (Mean = 4.17). In other words, the framing condition made these participants especially negative towards government-oriented positions. Conversely, participants in the Government-Economy framing condition had a more favorable attitude towards Government-Economy statements (Mean = 6.43). Participants in both framing conditions favored community-oriented positions. Overall, these results suggest that the manner in which a museum experience is framed prior to individuals' experience of the exhibit has an effect on their subsequent cognitions related to the themes of the exhibit.

Table 4. Mean Summary Statement Ratings by Framing Condition and Statement Type (Ratings on a 0-9 scale)

Framing Condition	Summary-Statement Type		Overall Mean
	Government-Economy Bias	Community-Environment Bias	
Government-Economy	6.43	7.20	6.82
Community-Environment	4.17	7.72	5.95
Overall Mean	5.30	7.46	6.39

Analysis of Essays for Changes in Analytical Thinking. The essays were analyzed using the Linguistic Inquiry and Word Count (LIWC) software [7]. Each essay was analyzed by LIWC for Analytical Thinking. LIWC provided a percentile score for each essay, based on a comparison to LIWC's extensive corpus of documents exemplifying analytical thinking. Higher numbers for Analytical Thinking indicated formal, logical, and hierarchical thinking; lower numbers indicate more informal, personal, here-and-now, and narrative thinking [7].

An analysis of changes in Analytical Thinking in Essays 1 and 3 (*Express your views on recycling***)** showed a significant effect for the two-way interaction, Pre-Experience-vs-Post-Experience by Major [$F(1,16)=8.02$, $p=.012$], and a marginally significant effect for the three-way interaction Pre-Experience-vs-Post-Experience by Major by Framing Condition [$F(1,16)=3.44$, $p=.082$]. Table 5 shows that the greatest gains from pre-experience to post-experience in Analytical Thinking were for engineering students, as indicated by the significant two-way interaction. A closer examination shows that engineering students gained the most in the Government-Economy framing condition (Mean 43.70 to 73.06), as indicated by the three-way interaction. Overall, these results suggest that engineering students were significantly less analytical in their essay responses than non-engineering students. Framing the issue from a Government-Economy perspective, but not a Community-Environment perspective, was able to evoke significant gains in analytical thought in the engineering students.

Table 5. LIWC Analytical-Thinking Percentile Scores for Pre vs Post Green Revolution Experience by Framing Condition and Major: Essay ***Express your views on recycling.***

Framing Condition	Engineering Undergraduates		Non-Engineering Undergraduates	
	Pre-Experience	Post-Experience	Pre-Experience	Post-Experience
Government-Economy	43.70	73.06	72.48	62.54
Community-Environment	47.05	50.60	64.46	59.82
Overall Mean	45.38	61.83	68.47	61.18

Here is an example of how the analytical thinking of an engineering student in the Government-Economy framing condition changed after he experienced the Green Revolution exhibit. These are the pre- and post-experience essays from the student in response to the prompt ***Express your views on recycling.*** This student showed large gains in Analytical Thinking, based on LIWC.

> (Pre-Experience) *Recycling is very important to keep our environment clean. Paper, plastics, glass, etc. can be reused. Not making new items with new materials. It will save the materials and reduce trash. These days, I have seen news about the air pollution and water pollution. If you recycle trash that problem won't get worse, it will be better. Some people think we don't need to recycle because they can just burn the trash, however, that causes air pollution. This is why recycling is very important and it should be mandatory.*
>
> (Post-Experience) *Recycling can be proceed in many different ways. Also, it helps a lot to the environment. By looking at the exhibit in the museum, there are many ways to recycle and by recycling, you can create energy. Many wastes are hard to dump in the landfill because it is very expensive to dig the landfill and it takes a long time to decompose. Also, I have read how the wastes and daily use affects air pollution that we breathe in. Factories, forests, gasoline, etc. affect a lot of the air pollution. It was very impressive that Styrofoam can be recycled to make Styrofoam bricks that can be used to build new buildings.*

An analysis of changes in Analytical Thinking in Essays 2 and 4 (*In some detail, describe a way to recycle trash*) showed a marginally significant effect for the three-way interaction Pre-Experience-vs-Post-Experience by Major by Framing Condition [$F(1,16)=3.67$, $p=.073$]. A close look at Table 6 shows that the greatest gains came for non-engineering students in the Government-Economy framing condition, as suggested by the three-way interaction. This result suggests that the Government-Economy perspective was the most provocative in stimulating analytical thought in non-engineering students when the topic was more technical and involved considering actual methods of recycling.

Table 6. LIWC Analytical-Thinking Percentile Scores for Pre vs Post Green Revolution Experience by Framing Condition and Major: Essay ***In some detail, describe a way to recycle trash.***

	Engineering Undergraduates		Non-Engineering Undergraduates	
Framing Condition	Pre-Experience	Post-Experience	Pre-Experience	Post-Experience
Government-Economy	72.53	73.37	58.67	80.09
Community-Environment	68.57	75.13	73.19	64.94
Overall Mean	70.55	74.25	65.93	72.52

Here is an example of how the thinking of a non-engineering student in the Government-Economy framing condition changed after experiencing the Green Revolution exhibit. These are the pre- and post-experience essays from the student in response to the prompt ***In some detail, describe a way to recycle trash.*** This student showed gains in Analytical Thinking based on LIWC.

> (Pre-Experience) *The easiest way I can think to recycle is, to have a normal waste basket and a recycling waste basket in your home. That way all the recyclable trash that accumulates in your home is, thus able to be recycled. If every home did this, there would be no need for some innovative recycling method. Additionally this could be applied to businesses and schools. This would allow for most of the trash that was able to be recycled to be recycled.*
>
> (Post-Experience) *A way to recycle trash is for cities to have recycling bins need to the trash bins on the sidewalk. When people go to throw something away they are likely to throw recyclables in the recyclable trash. This is an efficient way to recycle trash that wouldn't require in more effort from people then just throwing away trash if most major cities did this, there would be a ton of recycled waste. This waste could then be used to remake item or be turned into electricity. Shipping companies can also recycle Styrofoam. This Styrofoam can be heated and turned into building material. Or just shrunk down so it doesn't take up as much space in landfill.*

The combined results summarized in Tables 5 and 6 suggest that framing has different effects on different groups depending on the topic. When asked to reflect on recycling, engineering students showed the greatest gains from pre to post experience, especially engineering students in the Government-Economy framing condition. When asked to describe ways to recycle, non-

engineering students showed the largest gains, especially those in the Government-Economy framing condition.

Overall, these results show that framing affects students' reactions to museum experiences, framing affects students differently depending on their major, and, finally, framing affects students differently depending on the topic or concept at hand. The overall results also suggest that students came to the Green Revolution with preconceptions that favored a Community-Environment perspective. The Government-Economy framework served to prompt changes in thinking more so than the Community-Environment perspective.

Discussion

The overall results in the present study showed that an out-of-classroom experience, like a museum visit, can change students' knowledge, reasoning, and attitudes towards environmental issues. This suggests that these unconventional non-classroom settings may provide students with important opportunities to develop reflective skills [3]. Personal outcomes associated with reflective practice include learning from a situation or experience, deeper understanding of one's own beliefs, attitudes, and dispositions, gains in knowledge and understanding, and changes in intentions for future behavior. The questionnaire data and student essays provided indirect evidence for these outcomes. In the future it would be important to obtain more direct evidence of cognitive processing associated with reflective practice in non-classroom settings like a museum exhibit.

Further, the manner in which the experience is framed changes the ways in which the experience is represented. Finally, museum exhibits can be experienced differently by engineering and non-engineering students. In general, these results indicate the utility of participation in informal-learning educational contexts, like museums. These informal contexts can be used to provide engineering students with more opportunities for reflective thinking regarding social, community, and resource issues involving engineering. They also afford the instructor, or docent, an opportunity to frame the experience for students in accord with particular instructional goals or teaching mission.

The framing effects here are similar to those in Gross and D'Ambrosio [6]. From a pedagogical perspective, the significant framing effects here are important because they show the influence that the instructor can have on how students process an interactive experience. In contrast to some of the demonstrations of framing for typical classroom problems [4, 5], the findings here show how framing can affect students' cognitions on environmental topics in informal settings.

Engineering education focuses on the transmission of technical knowledge from authoritative sources. Engineering curricula do not provide students with many opportunities for the application of knowledge, and these often occur towards the end of undergraduate training [8]. The transition to engineering practice is difficult for many students [9]. Informal learning contexts, like museums, may afford students with opportunities to begin reflecting on engineering practice earlier in their training.

There is a growing recognition of the social and environmental responsibilities of engineers in

current society. According to the U.S. Board on Engineering Education [10]:

> *There is a widening recognition of the responsibility of engineers to consider the social and environmental impact of their work. In sharp contrast to the attitudes and practices that prevailed at mid-century and before, engineers today are required to design sustainable systems that consider as crucial inputs the environmental impact of their manufacture and use, their accessibility to people of diverse ethnicity and physical abilities, their safety, and their recyclability.* (p. 14)

Engineering students, in general, are confident in transferring the engineering design knowledge and skills they have acquired in their educational program to real-world settings; however, they are apprehensive about their capacity to apply creativity, critical thinking, and innovative skills required in the workplace [11, 12]. Museums, and other informal learning contexts, may provide students with a new range of contexts in which to apply and practice creativity and critical thinking. Extending the range of situations where engineering may make a difference could aid in the transition from student to reflective engineering practitioner.

The present study is subject to several limitations, and the results here need to be extended in several ways. In this study, we limited our analysis of student essays to the Analytical variable in the LIWC software. The Analytical variable is associated with cognitive processing that is consistent with reflective practice and therefore relevant to the assessment of reflective thinking in the present context. In other words, we view changes in analytical thinking as a plausible outcome of reflection. However, future analyses will consider other variables, like changes in emotional valence, sensitivity to social issues, ethical issues, environment, resources, and sustainability. Another limitation is sample size. A larger sample could strengthen and somewhat modulate some of the results here. Finally, participants in this study engaged the museum exhibit in a structured manner that demanded reflection through participants' summaries of reactions at each theme and through essay writing. It would be informative to compare participants' responses to the museum exhibit when participants had more ability to self-direct their museum experience and/or more time to reflect upon it. Such comparisons would provide some indication of the extent to which structuring the museum experience is important, especially for students for whom reflection may not be a regular practice.

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