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Development of a Social-justice Mindset Through Discovery Learning from the Conflict Between Safety and Welfare in Engineering Ethics

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Abstract

The National Society of Professional Engineer's Code of Ethics states that engineers shall, "Hold paramount the safety, health and welfare of the public." Previous studies have shown that when engineering solutions to problems, welfare may trade off with safety, if the financial expense of safety negatively impacts a client's financial welfare. Thus, there is the potential for conflict if engineers seek to hold both safety and welfare to be paramount. Research has shown that undergraduate engineering students favor safety over welfare independent of a client's ability to pay.

This paper completes a review of published research on student responses to safety and welfare in design supplemented with additional analyses. Based on these results, the authors developed a classroom module, which we present in this paper. In the module, students are presented with a task in which they must design an engineering solution for clients of different socio-economic backgrounds. The task calls upon universal engineering skillsets such that it can be completed by engineering students from any discipline. By highlighting the conflict between safety and welfare in the engineering code of ethics, students may organically arrive at definitions and ideas of social justice such as equity and fair distribution of wealth through a discovery learning process.

Introduction

A trade-off exists between safety and welfare in the National Society of Professional Engineer's (NSPE) Code of Ethics. This trade-off is especially evident and problematic when we consider cases where the client is poor. Previous research indicates that students do not recognize this tension and typically ignore welfare in favor of safety [2]. However, social justice in engineering design includes an equitable distribution of resources [3],[4]. We propose that by using discovery-based learning and highlighting the tension between safety and welfare in the NSPE code of ethics, students will learn to recognize this element of social justice in engineering design.

Background

The NSPE states that engineers shall, "Hold paramount the safety, health and welfare of the public." Nearly every professional engineering and architecture society, has similar or identical language as the first canon to their code of ethics. To hold something paramount means it should be the *most* important or the *highest* priority. While it seems true that the health, safety, and welfare of the public should be high priorities for engineers, there are certain situations where it

may not be possible to hold both safety and welfare paramount at the same time. As it is worded, the code of ethics provides no guidance as to which should be given final priority in such cases.

The concepts of health, safety, and welfare have been central to engineering ethics since 1935 when a Society Code of Ethics was first suggested for consideration in the May issue of The American Engineer [14]. The suggested language, in this document, included health, safety, and welfare as the second of a series of engineering ethical principles, stating, "B. (1) Relationships with the Public-The engineer shall at all times and under all conditions seek to promote the public welfare by safeguarding life, health and property." While it is unknown whether any action was taken on this original proposal, it is clear that many of the same ideas were incorporated into the first approved Cannons of Ethics in 1946 [15]. At this point, welfare was mentioned in the document preamble, "It is his duty to interest himself in public welfare, and to be ready to apply his special knowledge for the benefit of mankind." While safety and health are addressed in Section 4 of the document under the heading Relations with the Public: "He will have due regard for the safety of life and health of public and employees who may be affected by the work for which he is responsible." The current emphasis on health, safety, and welfare as the first of the Fundamental Cannons dates to 1981 when the Board approved a new format for the Code of Ethics [14]. Between 1946 and 1981, the Code of Ethics underwent numerous amendments that impacted – to varying degrees – the format and content of the Code of Ethics [16]. In spite of regular revisions, health, safety, and welfare have consistently been addressed as important ethical principles.

From this history, we see that it is a relatively recent addition that three constructs, safety health and welfare, are all held paramount. The authors propose that safety, health and welfare may conflict so it is important to arrive at clear definitions. Safety is a concept that applies to risk in engineering—where risk concerns the potential occurrence of something harmful or unwanted. While all actions involve risk, safe actions or objects bring risk to an acceptable level for a reasonable person. An object is safe, or a person's safety is preserved when the engineered object presents a de minimis or acceptable level of risk. Health has been more broadly defined by the medical community such as the World Health Organization, [17] "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

"Welfare" is a nebulous term, so it is simpler to focus in on "economic welfare"—also known as the "material view" of welfare [13]—those material conditions necessary for one's life to go well. While there may be disagreement on what those precise conditions are, some basic material needs can surely be agreed upon by all, including food, shelter, clean water, clothes, and healthcare. In the United States, all these material needs cost money. Hence, to have low economic welfare is to be unable to afford the basic material goods that are necessary to have one's life go well.

With this understanding of welfare, it is now possible to see how holding safety paramount can conflict with holding welfare paramount. To hold safety paramount can come at a substantial cost. If the cost of an engineering project that holds safety paramount is so high that it affects the client's economic welfare, then it is indeed not possible to hold both safety and welfare paramount.

A previous study [1] has been completed that illustrates engineering students either do not recognize this tradeoff, or if they do, generally favor safety over welfare. This tradeoff, and potential tension, inherent in the first canon of the NSPE code of ethics can be used by engineering educators to teach concepts of social justice. In this paper a learning module is presented using the accepted practice of discovery learning.

The instructional goal of the discovery-based learning module is to have engineering students use an equitable distribution of resources in their designs. The authors propose that we can elicit elements of social justice in engineering designs by highlighting the tradeoff between safety and welfare in the NSPE engineering code of ethics' first canon.

Social Justice in Engineering

Many definitions exist of social justice in engineering. As defined by Lucena [3] social justice is approached through "practices, including those by engineers, that should attempt to an equal distribution of rights, opportunities, and resources to enhance human capabilities and reduce the risk and harms among the citizens of society." Other definitions exist but most describe an attempt toward and equitable distribution of opportunities and resources to enhance human life while reducing risks [4]. To have equitable distribution of opportunities and resources, engineers must be able to navigate the tradeoff between safety and welfare in design.

For example, imagine two potential clients: one quite rich the other quite poor. Each client has the same engineering needs and, in both cases, to hold safety paramount will make the cost of the project be $5000. The wealthy client will not have to forego meals, miss utility bill payments or housing payments, or skip visiting the doctor when sick to afford this price. Hence the $5000 price of safety in no way affects the economic welfare of the rich client. The poor client is different. The cost of the project will absolutely affect the economic welfare of the client, forcing this client to forego meals, miss utility bill payments or housing payments, and skip visiting the doctor when sick. Hence in the context of an impoverished client, there will be tradeoffs between safety and economic welfare such that it is not possible for the engineer to hold both paramount.

Public Versus the Individual

The discovery-based learning module proposed in this paper uses an individual, or family, as a potential engineering client. Recently, there has been a significant amount of effort in health-related research defining the difference between population health and individual health. In

healthcare, it is recognized that individual health is studied and practiced at the clinician level while population health is studied as a collective [1]. However as described by Arah [2], individual and population health is very context dependent. You cannot understand the health of an individual without understanding the socioeconomic circumstances of their environment [2]. We contend that this insight from health-related research applies in engineering contexts as well. An engineer cannot hold the health, welfare and safety of their client paramount without understanding the socioeconomic environment of that individual or family.

Previous Survey and Attitudes Toward Design

A previous survey has been conducted to understand how students respond to the first canon in the NSPE code of ethics. In this survey, six subsets of engineering students, a total of 83 students, were asked to provide a simple engineering design for two clients. One client had obvious wealth, and the other client was poor. The wealthy client was asking students to design a pool foundation while the poor client was asking for a home foundation repair. The results of that study indicated that students chose a costlier design for the poor client as opposed to the wealthy client. The more expensive solution was chosen despite having a classroom discussion before the design exercise on how the cost of solution would have a negative impact on the client's welfare.

To further analyze why students made these design choices, a modified Attitude on the Subject of Chemistry Inventory (ASCI) [5] was given to the students to understand their attitudes towards the first canon of the NSPE code of ethics and their designs for the wealthy and poor clients. Students were asked to comment on how the first canon, design for the wealthy client, and design for the poor client made them feel on a scale from 1 – 7 and used the form shown in Figure 1. The modified ASCI measures intellectual accessibility and emotional satisfaction. Intellectual accessibility is assessed with questions 1, 3, 6 and 8 while emotional satisfaction is assessed with questions 2, 4, 5 and 7. Intellectual accessibility describes an individual's feelings or emotions of a topic in the affective domain while emotional satisfaction describes an individual's belief or knowledge of a topic in the cognitive domain.

The results of the modified ASCE survey are shown in Table 1. Students generally had neutral attitudes (a score near 4 on a 7-point scale) in terms of intellectual accessibility and emotional satisfaction when queried with the first canon. Response results were slightly lower when asked to describe their attitudes when designing for a wealthy and poor client. Both averages for intellectual accessibility and emotional satisfaction are slightly higher when students were asked about their attitudes towards designing for a poor client as opposed to a wealthy client. Despite this slight difference in attitude, students did not create less costly designs for the poor client.

1	easy	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	hard
2	chaotic	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	organized
3	confusing	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	clear
4	comfortable	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	uncomfortable
5	satisfying	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	frustrating
6	challenging	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	not challenging
7	pleasant	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	unpleasant
8	complicated	| 1 | 2 | 3 | 4 | 5 | 6 | 7 |	simple

Figure 1 – Modified ASCI survey used to measure student attitudes towards the first canon of the engineering code of ethics and engineering designs for a wealthy and poor client

Table 1. Previously unpublished attitude survey of student's response to the first canon of the code of ethics and engineering designs for a wealthy and poor client (4-point scale)

Intellectual Accessibility		Emotional Satisfaction	
1st Canon	3.91	1st Canon	3.91
Wealthy Client	3.69	Wealthy Client	3.73
Poor Client	3.80	Poor Client	3.90

Discovery-Based Learning

The module proposed in this paper uses discovery-based learning to nudge students to use elements of social justice in their engineering designs when designing for clients of different socio-economic status. Discovery learning has been used by other engineering instructors to help students develop advanced problem-solving skills when traditional methods of lecture delivery may be inadequate [6], [8], [9]. The method encourages students to discover principles for themselves as opposed to being led through a technique or method by an instructor [7]. As defined by Prince and Felder [10], discovery-based learning most often includes students discovering material themselves, is self-directed, and active. Like other types of learning and teaching such as problem-based, case-based or guided inquiry, discovery learning is different than traditional lecture-based instruction because it is inductive as opposed to deductive [10]. Many have shown the educational benefits of inductive learning. Shymansky et al. [11] analyzed 81 separate experimental studies and showed explicitly that inductive based teaching methods produced large gains in academic achievement. With some guidance of the instructor, fully discovery-based learning may be categorized as guided inquiry [10]. Depending on instructor

preference, the discovery-based module proposed here may be considered guided inquiry if the instructor determines that prior knowledge of the students is insufficient to meet learning goals.

Module Iterations and Development

The authors propose that we can elicit elements of social justice in engineering designs by highlighting the tradeoff between safety and welfare in the first canon of the NSPE engineering code of ethics. At the completion of module, students should understand the role of welfare and social justice when designing for clients of different socio-economic status. To accomplish this, we provide students with the same design challenge, but have clients of different socio-economic status. Assessment of student responses to the engineering design should show that students create different designs for the two clients.

A previous study [1] illustrated that students chose safety over economic welfare of a client in an engineering design. A total of 83 students were surveyed in that study. These students were from three separate classes (a first, second- and third-year civil engineering course). The module developed in this paper was the result of reviewing this research and providing two additional draft modules to students in a professional ethics course open to all majors at a university. The goal was to create a module where students recognized the socio-economic status of the clients and proposed engineering designs that took this into account. The two additional draft modules are described below.

Table 2. Two draft modules prepared prior to the proposed module presented in this paper

Draft Module 1	Draft Module 2
No description of client provided	Descriptions of clients provided
Two engineering designs to repair a home foundation	Client 1 – Doctor with secondary home Client 2 – Wal Mart greeter
Home 1 – 5,000 ft^2 large backyard pool	Home 1 – 5,000 ft^2 large backyard pool
Home 2 – 950 ft^2	Home 2* – 950 ft^2
	* Home to be placed on stilts to reduce flood risk in the Lower Ninth Ward, New Orleans, LA

These presented drafts influenced the design of the final module presented in this paper. For the first presented draft module, students were not given information about the client. The results indicated that students recognized the more negative impact on cost for the smaller home. For the second draft module, students were presented with detailed information about the clients that highlighted changes in socio-economic status. However, when presenting this module to students, the engineering design for the smaller home indicated that it was necessary to place the home on piers to prevent flooding. The larger home repair was for a rear porch. This caused a few students to ignore socio-economic status in their design with the justification that there was a higher safety risk for the home on piers as opposed to the porch repair.

These preliminary results changed how the authors prepared the following module for implementation in classes. Retained was a description of the client's socio-economic status but removed was any indication of implicit safety of design. Both designs were for home repair.

The Module

The authors propose that at the end of this module, students will be able to understand the role of welfare and social justice when designing for clients of different socio-economic status.

The results of previous research [1] indicated that students do not consider welfare of a client in engineering designs. The following changes to the module have been made to meet our proposed student outcome:

- Use two homes for design, as opposed to a home and a pool. Feedback from the previous module indicated that bias may be introduced when the design is of two different structures.
- It was shown in the previous study that a discussion of the tradeoffs between safety and welfare did not change student designs. In lieu of a discussion on the tradeoffs between safety, health and welfare in the NSPE code of ethics, students are asked to define these three constructs in their design (discovery-based learning).
- Unpublished data analyzed from a previous study [1] shows that students have better attitudes towards designing for poor as opposed to wealthy clients. Emphasis was placed on defining the *clients* in the new module to elicit a response to designing for welfare as well as safety.

Two separate engineering designs are proposed to students. At the same time these two designs are proposed, students are asked to design following the principles in the NSPE first canon, to hold paramount the safety, health and welfare of the public. The module was designed to be given to students as a single page and is provided here for reference.

One-page Module

The National Society of Professional Engineer's Code of Ethics states that engineers shall, "Hold paramount the **safety**, **health** and **welfare** of the public. We request two simple engineering designs below. Two structures for different clients will be supported on helical piles.

	

Design 1	Design 2
Client – Dr. James Pence	Client – Sam the Walmart Greeter
Structure – 5,000 ft^2 residential home, secondary residence	Structure – Rehabilitation of 950 ft^2 in the Lower Ninth Ward, New Orleans, LA
Problem – Excessive settlement of rear porch structure.	Problem – Excessive settlement predicted
Weight – 100,000 lbs	Weight – 100,000 lbs

Choose the number or helical piles for each client. Each pile costs $6,000.00. Use a factor of safety for each design that holds paramount the safety, health and welfare of the client. Dr. Pence's home is their secondary residence located in Florida. Sam the Walmart Greeter's residence is their only home in the Lower Ninth Ward, New Orleans, LA.

Client 1 Number of Piles =	Client 2 Number of Piles =

For each client, use single words or phrases to describe how you held safety, health and welfare paramount in your design.

Client 1	Client 2
Safety -	Safety -
Health -	Health -
Welfare -	Welfare -

Conclusions

A previous study [1] indicated that students favor safety over welfare when completing simple engineering designs. Welfare, particularly economic welfare as defined in this paper, is an important concept when completing engineered designs following concepts of social justice. This same study indicated that students continue to favor safety at the expense of welfare when traditional lecture delivery methods are used. A survey of student attitudes towards design indicated a more positive response when students designed for clients of lower socio-economic status compared to higher socio-economic status. The module presented here was created using accepted practices of discovery learning. The intention is that by combining discovery learning, with the proposed tension in the NSPE Code of Ethics first canon between safety and welfare, students will organically arrive at engineered designs that incorporate social justice as defined in this paper. This module will be delivered to students in a first-year engineering program and the results will be assessed to see if students are able to understand the role of welfare and social justice when designing for clients of different socio-economic status.

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