Board 73: The Impact of "Green" Requirements in Engineering Students' Design Projects on Engineering Students' Green Mindset

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Abstract

With modern industrial development, carbon dioxide emission has become a big problem for the whole world. Global warming is having irreversible damage to the world. "Carbon Emission Reduction" has become one of the most important goals of the entire world. It is the major issue discussed at the recent G20 Summit 2021 in Rome [1]. Each nation promised a specific goal of carbon emission reduction. To reach those promised goals, besides replacing fossil energy with green energy such as solar, wind, water, or nuclear, the design of those green energy power plants and the design of green energy using machines, buildings, vehicles, and other energy-consuming equipment become critical in reaching those goals. Green energy education is becoming important for the current and future engineers who will be responsible for those designs.

The design mindset of engineers will have a great impact on society because of their direct or indirect responsibility in designing buildings, machines, vehicles, infrastructures, power plants, petroleum refinery processes, etc. The finished design would have long-lasting impact to the environment. Whether the engineers have "go green" in their minds could affect the overall environment of this world, and it will determine if the nation can reach its emission reduction goal. To help the engineering students to develop the "go green" mindset and put this term into action, one direct method is to put this "green" requirement into engineering students' design classes and make it a required element in their design projects.

An overall "green" requirement was applied the junior design class. At out institution, students are required to find the best "green" choice for their specific design projects. A survey was done at the end of the semester to check the change in students' energy usage design mindsets. The survey results show that only 62% of the students thought about using green energy in their design before this class; 95% of the students would like to use green energy in their design after this class because of the green energy requirements. Among these 95%, 100% of those who worked on projects directly related to green energy decide to use green energy whenever possible in their future design. On the other hand, 82.5% of those students whose projects were not directly related to green energy application will also consider using green energy in their future designs. The results clearly show that the "go green" requirements in their design class greatly influenced their energy usage decision in their design. It demonstrates the importance of the "go green" requirement in engineering education.

Key Words: Sustainability, Green Requirement, Design Projects, Design Mindset

Introduction

Global warming, forest fire, wild animal distinction, virus, white trash, smog, etc. are great concerns which are causing the whole world anxious for the sustainability of our planet earth. Most of those problems are directly or indirectly caused by pollution from excessive use of fossil fuel. The global community is

working hard to find solutions to solve the current pollution problems to make the environment more sustainable. US as the most developed countries promised to achieve a 50-52 percent reduction from the 2005 levels in economy-wide net greenhouse gas pollution by 2030 [1]. To reach the goals of greenhouse gas pollution reduction, and to keep the world sustainable, design engineers should be equipped with the knowledge, skills, and the sustainability so called "green" mindset to design and implement sustainable or green solutions. Their "green" mindset is the key in their designs as engineers design and develop the products and systems that directly impact the environment. Therefore, engineering education becomes important to implement this "go green" requirement to engineering students who are the future engineers, the important agents to foster practical changing of the world through their sustainable "green" design. High education institutions become important in finding ways to educate the engineering students to be "green" minded. Higher education becomes instrumental for developing the skills needed for engineering graduates to become changing agents for sustainable development [3]

Higher education institutions are critical in the education of future leaders that will contribute to the successful United Nations Sustainable Development Goals (SDGs) implementation. As a transformational agent, the higher education institutions have tremendous impacts on students' thinking and mindset and contribution to a sustainable society. To establish the required change in education, sustainability principles need to be at the heart of higher institutions strategy and should be the key to be incorporated in the organizational culture. [5]

The United Nations declared the period from 2005-2014 as the Decade of Education for Sustainable Development to emphasize the importance of education to increase world sustainability [9]. The overall objective was "*to integrate the principles, values and practices of sustainable development into all aspects of education and learning*,"[2] and create "*a more sustainable future in terms of environmental integrity, economic viability and just society for present and future generations*"[1].

Engineering programs are subject to well-established accreditation programs such as EUR-ACE in Europe and ABET in North America. Both EUR-ACE and ABET include requirements for engineers to contribute to sustainable or green development.

ABET student outcomes 1 and 2 below are directly related to the sustainability education requirement: [7]

1. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
2. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

EUR-ACE (ENAEE) requires engineering students "[demonstrate] awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice" [6].

Therefore, incorporating "sustainability" or "green" into engineering education is not only required but also essential. This study is to demonstrate the effects of implementation the "green" requirement in engineering students' design projects.

Methodology

Higher education institutions implemented education for sustainability in different categories, such as:

1) Teaching and research focus to improve sustainability by project development and incorporation sustainable principles.
2) the practice carried out by different educators to influence broader opinions.
3) developing an institutional culture of sustainability to increase awareness among university communities.
4) by implementing sustainable campus-wide practices to become practical examples (e.g., reducing greenhouse emissions, promoting biodiversity, efficient use of energy and reducing the ecological footprint).

There are three required design classes in our current institution: freshmen design introduces freshmen engineering students to the concept of engineering design through simple entry-level design projects; junior Design helps students to learn to do engineering design documentation through working on a design project, and senior capstone design. Freshmen students don't have enough engineering knowledge to do "green" design, they were informed by learning different types of energy sources and their comparison. They were not required to apply them due to the lack of essential engineering knowledge at the first semester of their freshmen year. The freshmen energy education falls into category 2) mentioned above which does not require students to implement it to their practice. Junior engineering students have learned enough engineering knowledge which equips the students to study and find the strategies to "go green" in their design projects. After practicing "green" requirements in engineering design, they will automatically implement this strategy in their senior capstone design projects and, hopefully, will carry on this "green" mindset in their future engineering designs.

In order to help the students to develop this mindset, students were required to choose to work on projects with "green" design. Here, we define "green" design as the design considering the following factors: 1) generating more energy such as improving the current solar system or wind energy catching system efficiency; 2) using clean energy, such as wind and solar energy, as energy input, 2) enhancing systems' energy usage efficiency, 3) selecting the recyclable, reusable, or decomposable materials in their design, 4) reusing components from previous projects, and 5) using design to reduce energy consumption. These requirements in junior design class fall into categories 1), 2), and 3). Below is a list of six examples of the twelve junior design projects:

A. *Aerodynamic design of bicycles*: This project requires students to design a bicycle which allows passengers to sit in a position and generates the least drag force to increase the speed of the bicycle. The faster speed will encourage people to choose zero emission bicycle as their transportation tool.
B. *Nitinol heat engine design*: This project is to use the unique properties of nitinol alloy to convert heat into mechanical energy. This design will allow people to recycle heat energy such as the heat from cooling water to power mechanical system.
C. *Solar powered car*: This project is to design a car covered with solar panels which will be used to charge the car battery to power the car.
D. *Sunlight following panels*: This team design a control system which powers the solar panels to turn to the direction of the sunshine to generate the most possible power.
E. *A design of a portable wind turbine* which can be installed on bicycle, scooter, or outside the window. The power generated can be used to charge cell phones, flashlights, or any other portable small appliances.
F. *A "green" house* was designed to use whatever green energy approachable such as wind or solar in southern California and water turbine by the big river or ocean to power the house.

A survey was done to these junior engineering students at the beginning of the semester before they were required to "go green" in their design to check the percentage of the students holding "green" concepts in their mind. The same survey would be done again to the same group of students at the end of the semester after they their "green" design projects finished.

The survey questions to assess the students' green mindset and environmental awareness. The responses were analyzed and compared to check if the "green" requirement is effective in developing students' "green" mindset.

Results and discussion

The survey results show that only 62% of the students thought about using green energy in their design before the green requirement implemented in this class; in contrast, 95% of the students would like to use green energy in their design at the end of this class. There is a 33% increase due to the influence of the green requirements. Among these 95%, 100% of those who worked on projects directly related to green energy intend to use green energy whenever possible in their future design. On the other hand, 82.5% of those students whose projects were not directly related to green energy application agreed to use green energy whenever possible.

Table 1. Survey questions

Questions	Answer (yes)	Answer (no)
Before this class, did you think you would try to use green energy in your engineering design if not required		
Will you consider using green energy in your current/future design if possible?		
If you want to promote green energy, what will you do to promote it?		
If your project is related to green energy, what do you learn from it about green energy? If your project is not related to it, but related to save energy or using alternate energy, what do you learn from it?		

The results clearly show that the "green" requirements in their design class greatly influenced their energy usage decision in their design. It demonstrates the importance of the "green" requirement in engineering education. The survey results indicate that incorporating green requirements in their engineering design can significantly increase engineering students' green mindset development, environmental awareness, and consideration of using sustainable practices in their future professional career. All of the students said that not only they themselves choose to use clean energy whenever possible, but also they would like to promote using green energy among their peers and to their clients, or to keep energy efficiency in their mind for their future engineering designs.

Higher education institutions have a remarkable impact on shaping students' mindset. According to Bowen [10], the impact of high education in adult life lasts an average of fifty to sixty years after graduation. It means the "green" mindset developed through this junior design class will influence the future engineers for their entire career life. If all the current engineering students are educated by different "sustainability" programs, the future engineering design will be "greener" comparing with the designs made by the current engineers not educated by this type of requirements. Therefore, the investment in high education in the development of programs to emphasize sustainability is crucial in helping the whole world develop in a sustainable way.

Conclusion and future research

This study illustrates that incorporating green requirements into engineering students' design projects significantly increase students' level of "green" awareness and hence helped them developing their "green" mindset to influence their future engineering career. This information is meaningful for higher education institutions who plan to implement sustainability in their curriculum. This finding also provided a practical direction to governments who want to find a sustainable way to reach their goals of greenhouse gas reduction, to invest in "green" education and to develop students' "green" mindsets, which will in turn to increase future engineers and general civilians' sustainability awareness and practices to keep the world more sustainable.

Our future research will focus on developing more open-ended questions in our survey to gain more understanding of students' mindset on "green", before and after junior design and senior capstone design classes, conducting survey in serval years after these students' graduation. This will help use to understand the impact of the "green" education to their future professional career.

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