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Sustainable Green Design and Life Cycle Assessment for Engineering Education

Prof. Tzu-Liang Bill Tseng, University of Texas at El Paso

Dr. Bill Tseng is a Professor and Chair of Department of Industrial, Manufacturing and Systems Engineering at the UTEP. He is also a Director of Research Institute for Manufacturing & Engineering Systems, the host institute of Texas Manufacturing Assistance Center at UTEP. He received his two MSIE degrees (MFG & DS/OR) from the University of Wisconsin at Madison and Ph.D. in Industrial Engineering from the University of Iowa. Dr. Tseng is also a Certified Manufacturing Engineer from Society of Manufacturing Engineers. Dr. Tseng's research area cover emergency management, systems engineering, computational intelligence/data analytics and cyber engineering technology. Over the years, he has served more than 10 million dollars as principle investigators sponsored by NSF, NIST, USDT, DoEd, KSEF and industry like LMCO, GM and Tyco Inc. Dr. Tseng delivered research results to many refereed journals such as IEEE Transactions, IIE Transactions, International Journal of Production Research, Journal of Manufacturing Systems, Expert Systems with Applications and other conferences (over 260 refereed publications). He is currently serving as an editor of Journal of Computer Standards & Interfaces (CSI) and editor boards of International Journal of Data Mining, Modeling and Management (JDMMM) and American Journal of Industrial and Business Management (AJIBM). He is currently a Senior Member of Institute of Industrial Engineers, Society of Manufacturing Engineers and the Division Chair of Manufacturing Division of American Society of Engineering Education (ASEE). He is also actively involved in several consortia activities.

Mr. Md Fashiar Rahman, The University of Texas at El Paso

Md Fashiar Rahman is currently a doctoral student at the University of Texas at El Paso in Computational Science Program (CPS). He earned a Master of Science in computational science at The University of Texas at El Paso (UTEP) in 2018. He has worked on a number of projects in the field of image data mining, machine learning and deep learning for industrial inspection & quality control. His research interests are in big data analytics, application of machine learning and deep learning for both complex system analysis and healthcare. Email: mrahman13@miners.utep.edu

Dr. Richard Chiou, Drexel University

Dr. Richard Chiou is Associate Professor within the Engineering Technology Department at Drexel University, Philadelphia, USA. He received his Ph.D. degree in the G.W. Woodruff School of Mechanical Engineering at Georgia Institute of Technology. His educational background is in manufacturing with an emphasis on mechatronics. In addition to his many years of industrial experience, he has taught many different engineering and technology courses at undergraduate and graduate levels. His tremendous research experience in manufacturing includes environmentally conscious manufacturing, Internet based robotics, and Web based quality. In the past years, he has been involved in sustainable manufacturing for maximizing energy and material recovery while minimizing environmental impact.

Prof. Johnny C. Ho, Columbus State University

Johnny C. Ho is a Professor of Production and Operations Management at Columbus State University. He received his Ph.D. in the Scheller College of Business at Georgia Institute of Technology. He has published over 55 articles in such journals as Naval Research Logistics, European Journal of Operational Research, Annals of Operations Research, International Journal of Production Economics, International Journal of Production Research, Computers & Operations Research, and Mathematical and Computer Modelling. Professor Ho received the Columbus State University Faculty Research and Scholarship Award in 1997, 2004, and 2008. He is a Certified Quality Auditor and Certified Quality Engineer through the American Society for Quality for more than 20 years. Previously, he was a faculty member at the University of Texas at El Paso and Truman State University.

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ABSTRACT

Green design and product life cycle assessments (LCA) help us to quantify and understand the actual impact on nature, society, and the economy. Recognizing the importance of sustainability analysis, many manufacturing industries are working to build an environment for practicing the concept of green design and LCA in product development and commercialization. To further strengthen the emerging interest, this paper describes the development of class project modules in the Industrial, Manufacturing, and Systems Engineering (IMSE) department at The University of Texas at El Paso. The primary focus of these modules is to introduce the student to the concept of green design and LCA in the evaluation of the environmental impact of the manufacturing process. This enables a high interdisciplinary platform for research and class modules suitable to be used in the academic environment for hands-on student training. The modules are developed by thoroughly analyzing the skillsets required by the industrial needs. The module includes: 1) Introduction and theory of sustainable design; 2) Product design and development using CAD software; 3) sustainability analysis of the 3-D soft product model; 4) introduction and theory of life cycle assessment; and 5) life cycle assessment using GaBi software. SolidWorks sustainability tool and GaBi software are incorporated as the working platform of the aforementioned four modules. The effectiveness of the project modules is investigated by integrating them as special topics in the summer, 2020 course and measuring the student outcome using a rigorous pre- and post-student survey.

Keywords: Sustainability Analysis, Life Cycle Assessment, SolidWorks Sustainability Tool, and GaBi

INTRODUCTION

Engineering design is inherently tied to society and human needs. It evolves over time and reflects societal needs and concerns. In the 1980s, societies across the globe started to push for a high-quality product with optimal cost. This introduced the various concepts of product design and manufacturing such as Design of Manufacturing (DFM), Lean Manufacturing, and Concurrent engineering [1]. Similarly, the concept of six sigma was introduced and adopted to improve product quality [2]. However, all of the above-mentioned concepts were focused on designing and manufacturing the product with higher efficiency and lower cost. Later, societies across the globe began to push for environmental awareness and concerns [3]. This introduced the "green" movement in product designing, which was termed as Design for Sustainability (DFS) [4]. The concept of sustainable design extends the broader concept behind DFM, concurrent engineering, and six-sigma.

Sustainable design adapts the engineering design process and its activities to address the environmental, social, and economic impacts of creating any products and services throughout their lifecycle [5]. Designers shape the development of the products and services which directly impact society and the environment. The potential impacts occur at the manufacturing and at the end-of-life stage. The application of sustainable design can play a critical role here by reducing these impacts [6]. Thus, the impacts are embedded in the product by the designers, at the design and decision-making stage. The design and the product development teams are responsible for taking various decisions regarding product designing, prototyping, and eventually producing the real product. The design phase is the right time for finding unique and creative ways to reduce the environmental and social impacts by adapting the concept of sustainable design. For example, while designing a product, the designer can decide on the type of materials, production process, manufacturing region, use region, and the way of transportation, etc [7]. However, deciding on the abovementioned issues is not trivial. Lots of complex parameters such as product properties, customer needs, manufacturing limitations, geographical constraints, etc. are involved in the design process. Given the constraints, the designer performs experiments and analysis to find out the required parameters from the concept of sustainable design.

While sustainable design focuses on the early stage of product development, Life Cycle Assessment (LCA) is a technique for assessing the environmental aspects associated with a product over its entire life cycle [8]. It is a method to assess quantitatively the environmental impacts of goods and processes from cradle to grave. LCA models cause-effect relationships in the environment and thus helps to understand the environmental consequence of human actions [9]. The field of LCA has become matured greatly in the past two decades. It supports decision-making processes and identified the alternatives with low environmental impacts. The holistic approach of LCA decreases the risk of shifting activities that have large environmental impacts at different stages of the product life cycle [10]. There are two LCA standards created by the International organization for Standardization (ISO) –ISO 14040 and ISO 14044 [11]. According to the ISO standards on LCA, it can assist in decision making in industry, government, or non-government organizations e.g., strategic planning, priority setting, product, and process design or redesign. LCA is also important for the selection of relevant indicators of environmental performance and even in marketing from the perspective of the eco-labeling scheme or environmental product declarations.

Clearly, the field of sustainability analysis and LCA plays a critical role in identifying the opportunities to improve the environmental aspects of products and services at various points of their life cycles. Many industries, governmental and non-governmental organizations are embracing the sustainability analysis and LCA to improve the service and capture the market by society's demand from the perspective of the green movement. This indicates the great demand and necessity of green engineering. Engineering education always serves the purpose to meet the skillsets required by the industries. Consequently, engineering education is dynamic and integrates different concepts into the education system to fill the gap of skillsets. In literature, we found that several authors have been designed and reported the necessity and effectiveness of different course modules in engineering education [12-14].

Realizing the importance of sustainability analysis and LCA, this paper begins by analyzing two separate case studies on sustainable design and analysis, and LCA using GaBi software. Then, based on these case studies, we proposed to develop a training plan which consists of five-course modules such as 1) Introduction and theory of sustainable design; 2) Product design and development using CAD software; 3) sustainability analysis of the 3-D soft product model; 4) introduction and theory of life cycle assessment; and 5) life cycle assessment using GaBi software. The course modules are designed to cover in 10 weeks, which allow the participants to increase their skillsets in sustainability analysis and product life cycle assessment.

GREEN DESIGN

Engineers usually focus on product design based on strength requirements and in-service performance requirements. Sometimes, the aesthetic needs are focused to prioritize the consumers' feelings about the products. Nowadays, the thinking has been changed and designer moved from the traditional design to sustainable design concept [6]. From the point of view of sustainable design, an engineer must consider the environmental requirements and the strategies of handling products after their end-of-life. Any products consume electricity, fuel, or gasoline during their useful life. Due to the scarcity of natural resources, a product should be evaluated in terms of energy consumption and pollution.

A product must meet the environmental and energy constraints to minimize the pollution and greenhouse effects as much as possible. The pollution can be measured in terms of carbon dioxide emission, water pollution, and air pollution [15]. The energy consumptions can be minimized by designing and making the products as efficient as possible. Designing and producing sustainable products involves three basic steps namely sustainable design, sustainable manufacturing, and sustainable waste management. Sustainable design deals with the concern of sustainable waste i.e., fewer emissions and less pollution of the environment. Whereas, sustainable manufacturing is controlled by materials used and the manufacturing processes. In practice, the common sustainability factor is energy use in manufacturing and transporting products. It also includes the energy used by the products while in service. Besides the service life, the after-life consideration is equally important in sustainable design. The product should be designed in such a way that the component of discarded products can be easily dissembled, recycled, and disposed of. In some cases, the product should be designed to make it suitable for refurbishing, especially for the electronic and automotive industry. Nowadays, a lot of products such as electronic devices, automotive parts are being refurbished which helps to minimize resource consumption and environmental pollution even after their service life [16].

Case study for sustainable design:

This course module includes designing a gear-box assembly from the concept of sustainability. The gear-box assembly and its components are shown in Figure 1. The gear-box consists of 14 components namely bearing needle, snap ring (the circular clip for shafts), curved spring lock washer, gear drive, gear housing, drive shaft key, pan head cross screw, large plain washer, radial ball bearing, bearing retainer, motor mount screw, driveshaft, pulley shaft, and v-belt pulley. The purpose of this module is to perform sustainability analysis on each of the individual parts and the total assembly units. The advantages of performing this sustainability analysis are three-fold (1) identifying the critical components in the gear-box assembly; (2) performing the sustainability analysis on the critical components; and (3) generating the sustainability analysis report.

Figure 1. Gear-box assembly for sustainability analysis

Methods and tools:

For the abovementioned case, the sustainable design approach includes three basic guidelines such as (1) using safe materials; (2) using an efficient manufacturing process; and (3) reducing the carbon footprint. It needs extensive analysis of sustainability at each stage of the design phase. For example, the materials for the different components of the gearbox are carefully chosen that have a low impact on the environment during the processing or after discarding it. Again, the manufacturing process which is fast to complete and consumes less energy is preferred. Choosing the correct manufacturing process results in minimum pollution and other adverse environmental impacts. Finally, the carbon footprint of a product is defined as the total set of greenhouse gas (GHG) emissions caused by the gearbox. The GHG includes methane, carbon monoxide, and other greenhouse gases. The generation of carbon footprint can be reduced by selecting safe material, better process, and better transportation system. Clearly, the materials, processes, and systems are the key elements that affect sustainable design. For example, materials are the decisive and driving element in sustainable design as they directly control the choices of processes and systems. Sustainable design needs a systematic and logical manner to identify the correct materials, processes, and systems. The design process used in the gear-box design is illustrated in Figure 2.

According to the approach shown in Figure 2, we can see that the materials, manufacturing process, manufacturing region, use region, and transportation are the key input of the sustainable design process. These input parameters are set as the baseline of the design process. Based on this baseline, we calculate the impact factors i.e., carbon footprint, energy consumption, air acidification, water eutrophication. We use the baseline to compare the selection of different materials and other parameters. Thus, we compare the impact with other new materials and processes. If the calculated impact factors for the new materials are not satisfactory, the design is modified. The modified design is evaluated with similar materials and with other input factors until a satisfactory sustainable design is achieved.

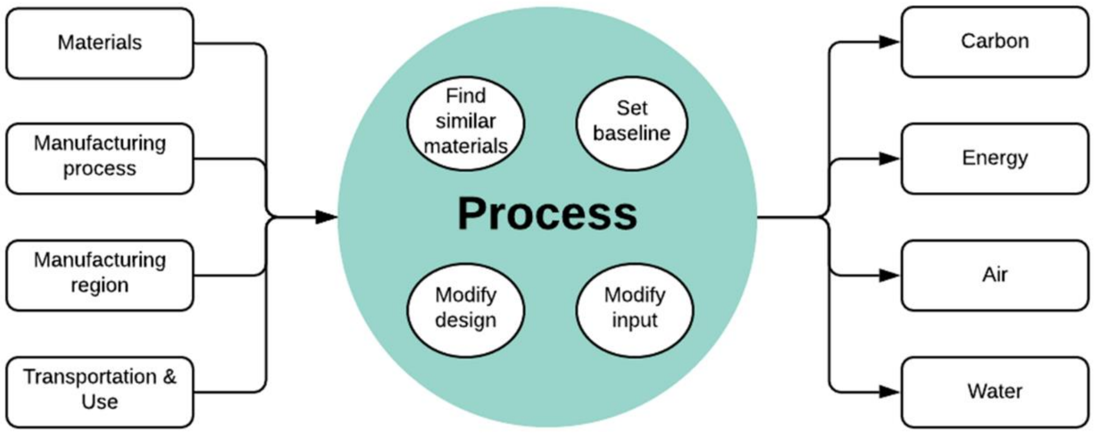

Figure 2. The systematic approach of sustainable design for gearbox

In this design process, the SolidWorks design software is used to create the 3D models of the different components of the gearbox. Once, the components are created, we used the SolidWorks assembly tool to assemble the gear-box. Then the sustainability analysis is performed using the SolidWorks Sustainability tool is used. The advantage of this tool is that it provides an interactive analysis platform that is easy to use and understand. The tool can also generate various design alternatives effectively through reports and graphic display. Moreover, the SolidWorks Sustainability tool is available to every SolidWorks user at no cost. The sustainability analysis for the gearbox using the SolidWorks Sustainability tool is displayed in Figure 3.

(a) (b) (c)

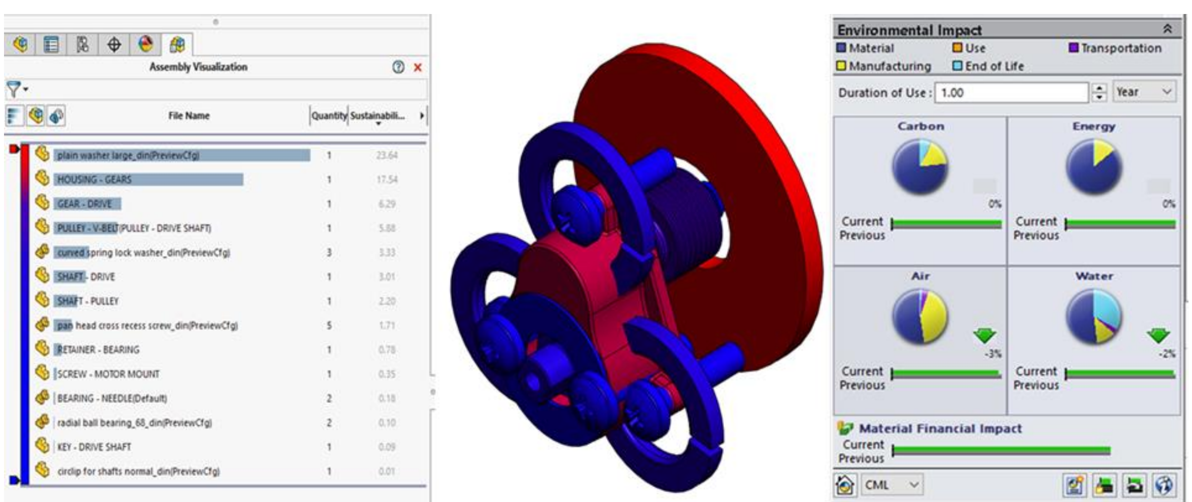

Figure 3. Sustainability analysis of gear-box (a) sustainability factor of individual components of the gear-box(b) color map representation according to the sustainability factors, and (c) Environmental impacts for the gear-box assembly

LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) of products is an important step for assessing the environmental impact of products and services from cradle to grave. One major difference between the above-mentioned sustainable design and LCA is that sustainable design mainly focuses on the early phase of the product development, whereas the LCA focuses on the entire life cycle of the products. The primary motivation of LCA is to get a full picture of the impacts of a product or service to find the best solutions for their improvement. Nowadays, LCA has become an essential part of many fields such as environmental management, product development, and engineering. Realizing the importance of the LCA, this section describes a case study of performing the LCA of a steel door hanger. The purpose of conducting this case study is to systematically analyze the four basic pillars of LCA analysis i.e., the goal and scope definition, inventory analysis, impact assessment, and interpretation.

LCA case study:

This case study conducts the life cycle assessment for a steel door hanger manufacturer who is concerned about global warming potential in regards to their manufacturing unit. The analysis is performed based on the life cycle stages as shown in Figure 4. To assess the impact of manufacturing of steel hanger, the primary focus is related to the raw material acquisition, material processing, product use phase, end of life, and disposal. The parameters such as the energy required for manufacturing are also considered for the analysis. The facility recovers scarp and raw materials for reuse at the end-of-life cycle and the disposal phase. The transportation, packaging, and maintenance are considered beyond the scope of this analysis.

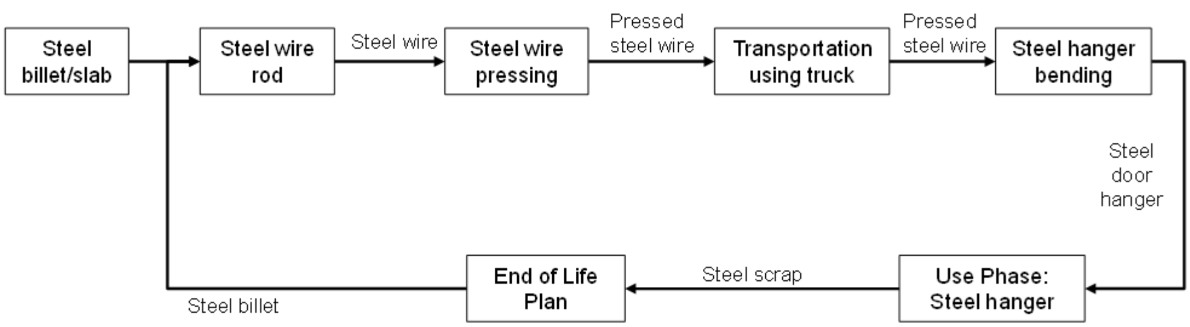

Figure 4. The holistic view of the steel door hanger

The relevant data required to perform the life cycle assessment for one single steel door hanger are identified and reported in Table 1.

Table 1. Data analysis for a single steel hanger

Process/Phases	Flow	Material	Amount/Units
Steel wire pressing process	Input	Steel wire	0.045 kg
	Input	Electricity (power)	0.02 MJ
	Output	Pressed steel wire	0.045 kg

Steel hanger bending process	Input	Pressed steel wire	0.045 kg
	Input	Electricity (power)	0.03 MJ
	Output	Steel door hanger	0.045 kg
Use phase	Input	Steel door hanger	0.045 kg
	Output	Steel scrap	0.045 kg

It is considered that, at the end-of-life and disposal phase, the steel door hangers are sorted out from the municipal waste using a magnetic separator and will be recycled. Due to the limitation of having the proper measurement of the amount of material loss at the disposal phase, we consider the same amount of steel scraps are recycled as steel billet at the end-of-life plan. Regarding transportation, a truck is used to transport the pressed steel wire from the steel wire pressing plant to the steel hanger bending plant. The distance between these two plants is 100 miles. For simplicity and ease to understand, other transportation and carrying issues are neglected in this case study.

Method and tools:

In this work, the GaBi software is used. GaBi combines the world's leading LCA modeling and reporting software, content databases with intuitive data collection and reporting tools. GaBi software guides product sustainability at every step of the product life. It offers the most user-friendly and flexible experience to develop an LCA plan. It provides a very interactive interface that helps to observe the environmental impact at the different stages of the product life cycle. Moreover, the software allows the users to analyze the effect of different parameters and compare the result with the baseline model through scenario modeling.

To perform the LCA for the above-mentioned case study, we first break down and set the sequence and flow of the processes in the product life cycle. This helps to understand the flows, creating the plan, and adding processes. GaBi provides a wide variety of processes to add to the life cycle assessment plan. Hence, we connect and active the GaBi database to add different process parameters into the plan for the steel door hanger. However, the database provides some standardized processes, meaning that it may not have some customized processes. For example, in our case study, the steel hanger bending is a customized process that needs to be created to add to the plan. Given, the input-output and materials amount, it is very convenient to create a new process using GaBi. Notice that, while adding and creating the processes in GaBi, we need to adjust the values of the input-output and material amount (given in Table 1) for each of the processes. Once the processes are created, the flows are added among the processes. Here, again some flows may not be available to the database and need to create them. In our cases, two new flows namely the pressed steel wire and steel door hanger are created as the new flows. Thus, we complete the plan for the LCA analysis as shown in Figure 5.

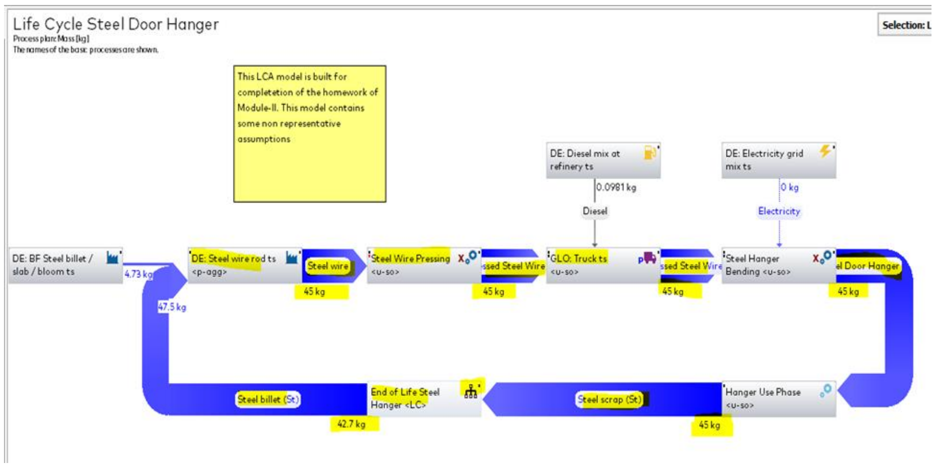

Figure 5. The LCA plan created for the steel door hanger using GaBi

After finalizing the LCA plan, we create the GaBi balance to analyze the environmental impacts of the steel door hanger. The GaBi balance is an interactive dashboard containing all the calculated results for the modeled system and includes all the life cycle inventory (LCI) results as well as the life cycle impact assessment (LCIA) results. The dashboard allows choosing the different views of LCI and LCIA results. It also provides a view of the life cycle costing and life cycle working environmental analysis. The good thing is that the balance can be saved to the GaBi database. Later the saved balance can be retrieved from the database for modification and analysis. From the balance dashboard, we can easily access the different impacts such as global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), and ozone depletion potential (ODP). In this dashboard, the total impact, as well as the individual process impacts, are reported graphically using a bar chart. However, it also facilitates drilling down any particular result by clicking on a bar to view the next level of the model. The balance dashboard showing the environmental impact of the steel door hanger is displayed in Figure 6. It is found that, considering the 2 years of a life cycle, the steel door hanger has a total GWP impact of 35.2 kg CO_2 equivalent and the EP impact of approximately 6.4×10^{-3} kg of nitrogen (N) equivalent. The impact of ozone depletion impact is very negligible in this case.

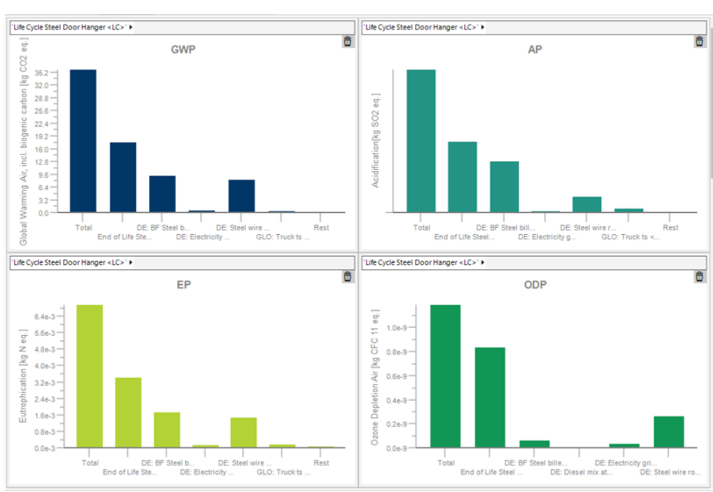

Figure 6. GaBi balance showing the environmental impact for a steel door hanger

COURSE PROGRAM OUTLINE AND OUTCOME

Based on the aforementioned works, a suitable interdisciplinary course can be developed with a proposed class schedule for a course in Green Engineering as shown in Table 2. The proposed course schedule consists of five modules which are designed to cover in 10 weeks: 1) Introduction and theory of sustainable design; 2) Product design and development using CAD software; 3) sustainability analysis of the 3-D soft product model; 4) introduction and theory of life cycle assessment; and 5) life cycle assessment using GaBi software. The ultimate purpose of this proposed course module is to enhance the skillsets among the engineering students by making them familiar with the theoretical fundamentals and hands-on experience for the sustainable design and life cycle assessment. The course modules are suitable both for undergraduate and graduate students across interdisciplinary departments such as manufacturing engineering, mechanical engineering, and environmental science. The detailed details course schedule is demonstrated in Table 2.

Table 2. Proposed modules and schedule for the course in green engineering in sustainability design and life cycle assessment

Weeks	Course Module	Module details	Lecture/Laboratory
Week 01 Week 02	M-01: Introduction and theory of sustainable design	▪ Introduction to sustainability and sustainable design ▪ Guideline to sustainable design ▪ The industrial process for sustainable design	▪ Class lecture using PowerPoint presentation ▪ Demonstration of the concept of sustainable design using case studies
Week 03 Week 04	M-02: Product design and development using CAD software	▪ Introduction to CAD design ▪ Hand-on-training on designing and developing the 3-D model	▪ Lab to introduce the different toolbar of the SolidWorks ▪ Lab for designing and creating different parts and products
Week 05 Week 06	M-03: Sustainability analysis	▪ Discuss the various parameters and their effect on sustainability analysis ▪ Introduction to SolidWorks Sustainability tool	▪ Lab for providing hands-on-training for sustainability analysis using SolidWorks ▪ Lab to create a sustainability report
Week 07 Week 08	M-04: Introduction and theory of Life Cycle Assessment	▪ Introduction to LCA ▪ A systematic approach to conducting LCA	▪ Class lecture using PowerPoint presentation
Week 09 Week 10	M-05: Life Cycle Assessment using GaBi	▪ Introducing to GaBi software ▪ Work with various functions and GaBi database to perform the LCA analysis	▪ Class lecture using PowerPoint presentation ▪ Lab to conduct the LCA analysis using an industrial case study

The proposed course was offered in Summer 2020 as a special topic at the University of Texas at El Paso. 17 students were enrolled in this course; among them, 9 students were from the Industrial, Manufacturing, and Systems Engineering (IMSE) department and 8 students were Mechanical Engineering department. To evaluate the course contents and students' learning outcomes, we conduct a pre-survey at the beginning of the course and a post-survey at the end of the course as shown in Appendix A and Appendix B. The survey includes both qualitative and quantitative measurements. For quantitative analysis, we used a questionary with 5 categories of level of knowledge such as excellent, good, basic, and weak. The questions were set with the aim to understand students' interest, quality of the course contents, students' knowledge improvement on the subject matters, skillsets development, and students' self-assessment about the course work. Students' self-assessment is evaluated based on the four categories such as knowledge and understanding (KU), application skills (AS), analysis skills (AnS), and expert (E). The purpose of students' self-assessment analysis is to understand the learning pedagogy i.e., how well the students can analyze and apply the subject matter knowledge. The basic survey results are reported in Table *3*.

Table 3. Survey results of student assessment based on the pre- and post-survey

Students' knowledge assessment	Pre-Survey				Post-Survey			
	Weak	**Basic**	**Good**	**Excellent**	**Weak**	**Basic**	**Good**	**Excellent**
	% of students				**% of students**			
GEE subject matter knowledge	64.15	20.71	15.14	0	0	33.65	44.92	21.43
SolidWorks Sustainability tool	55.70	28.41	19.89	0	0	28.6	45.55	25.85
GaBi Software (LCA)	74.20	25.75	0	0	0	33.65	48.88	15.39
Students' Self-assessment	**KU**	**AS**	**AnS**	**E**	**KU**	**AS**	**AnS**	**E**
Knowledge in GEE	78.57	14.29	7.14	0	40	35	11.67	13.33
Sustainability analysis	57.14	23.81	14.29	4.76	22.23	33.33	39.89	5.56
Life cycle analysis	71.43	21.43	7.14	0	31.58	36.84	26.32	5.26

The results are depicted graphically in Figure *7*. Here, Figure *7*(a) demonstrates the result of students' subject matter knowledge on green energy engineering. Similarly, Figure *7*(b) shows the result of student pre-and post-knowledge of SolidWorks sustainability tool, whereas, Figure *7*(c) illustrates the knowledge shift on GaBi life cycles analysis software. Clearly, Figure *7* shows a significant improvement of students' skillset on both sustainability analysis and life cycle assessment using GaBi. Clearly, most students were able to shift their skills from weak to an excellent, good, and basic level. This skill improvement consists of both theoretical knowledge on the subject matter and hand-on-experience of 3-D model development, sustainability analysis using SolidWorks sustainability tool, and LCA analysis using GaBi software.

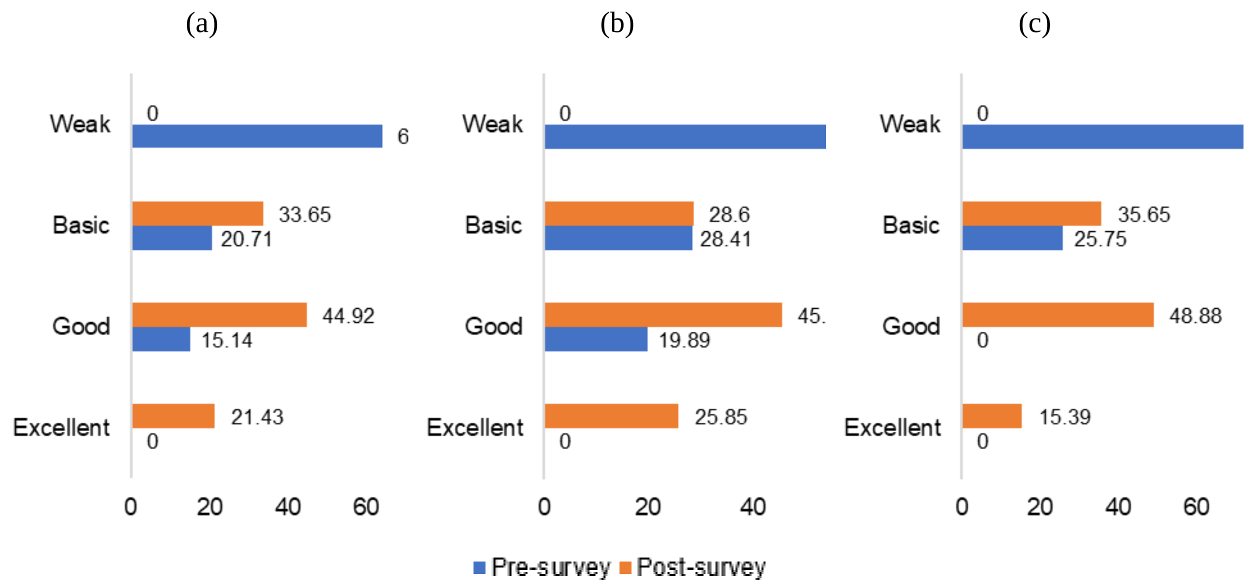

Figure 7. Survey results on the improvement of students' subject matter knowledge

The students' self-assessment results are depicted in Figure *8*. Here, Figure *8*(a) demonstrates the result of students' assessment survey of knowledge on green energy engineering. Similarly, Figure *8*(b) shows the result of the students' knowledge on sustainability analysis, whereas, Figure *8*(c) illustrates the knowledge shift on product life cycle analysis. Figure *8* clearly testifies that after completing the course modules, students were able to shift their basic knowledge to analysis and applications level. This implies that these course modules make the student more confident to use their knowledge in applied cases. It is also observed that some students were able to transfer their knowledge at the expert level. Hence, it can be concluded that the course modules can fulfill their intended objectives by developing the students' skill-sets and make them prepared to meet the industrial demands and applications.

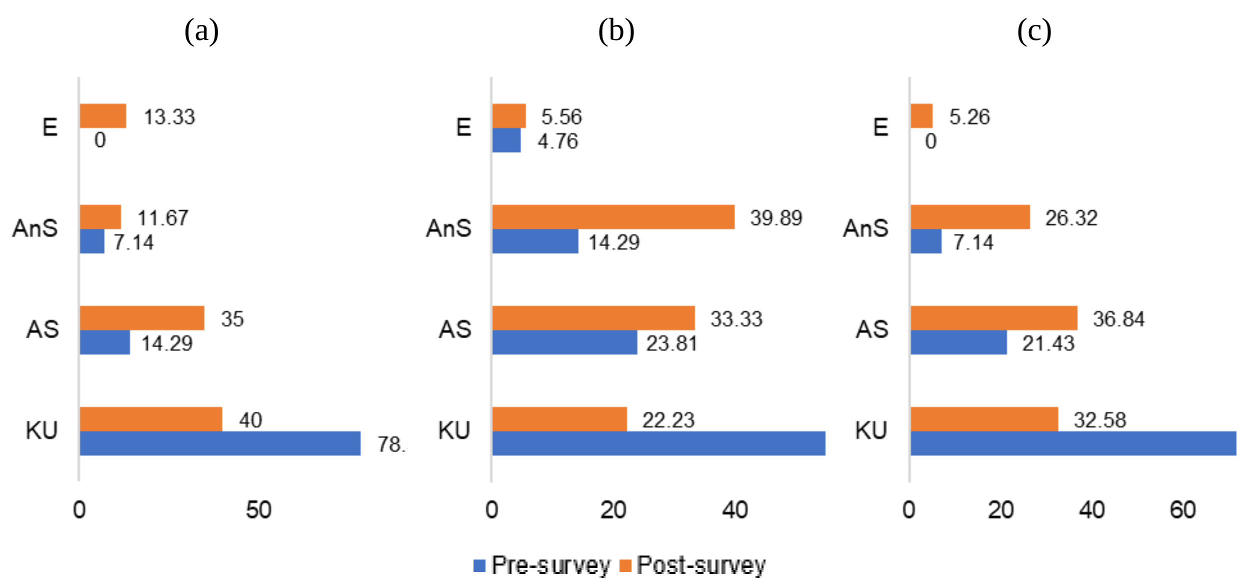

Figure 8. Survey result on students' self-assessment

CONCLUSION

This paper portrays a proposed training plan based on sustainability analysis and product life cycle assessment. The training plan includes five modules, which focus on the theoretical and hand-on-experience of 3-D design, sustainability analysis, and LCA analysis. One major advantage of adapting the proposed course modules is that it does not require any expensive or intensive set up. The modules only require the SolidWorks and GaBi LCA software. Integrating the course modules will help to understand and improve the skillsets among engineering students. The concept of sustainability analysis and LCA analysis is widely adapted to various private and government organizations. It implies that companies will be looking for engineers with interdisciplinary skills and knowledge required for sustainability design and analysis. The proposed course is well designed for students to learn different aspects of skills and knowledge throughout one semester giving graduates a valuable advantage in an increasingly competitive job market.

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Appendix A: Pre-Survey of Green Energy Engineering Summer Course

First Name: ____

Last Name: ____

Email Address: ____

What's your major?
1. IE Undergraduate
2. ME Undergraduate
3. ME Graduate
4. Others ____

Gender:
1. Male
2. Female

Why did you enroll in this course?
1. To fill requirement
2. Fulfill elective credit
3. I wanted to learn Manufacturing can be used in the future

Did you have any experience with Green Energy before this course?
1. No
2. Yes
3. If yes, please provide details ______________________________________

Do you feel that high-quality learning can take place without having face-to-face interaction?
1. No
2. Yes
3. Explain ____

Are you comfortable with learning technical information over the Internet, for instance, using YouTube to learn a skill or process?
1. Strongly Affirmative
2. Affirmative
3. Neutral
4. Negative
5. Strongly Negative
6. Explain ____

Do you think you can learn as much or more using multimedia (i.e., using many content forms including audio, still images, animation, video, and interactive content) instruction when compared to traditional instruction with a live instructor?
1. Strongly Affirmative
2. Affirmative
3. Neutral
4. Negative
5. Strongly Negative
6. Explain ____

Rate the level of your knowledge in SolidWorks Software:

1. Excellent
2. Good
3. Basic
4. Weak
5. Other, explain: ____

Rate the level of your knowledge in GaBi Software:

1. Excellent
2. Good
3. Basic
4. Weak
5. Other, explain: ____

Rate the level of your knowledge in Life Cycle Assessment:

1. Excellent
2. Good
3. Basic
4. Weak
5. Other, explain: ____

Rate the level of your knowledge in Green Energy Technology:

1. Excellent
2. Good
3. Basic
4. Weak
5. Other, explain: ____

Rate the level of your knowledge in Green Materials/Storage Devices:

1. Excellent
2. Good
3. Basic
4. Weak
5. Other, explain: ____

Rate the level of your experience in web-based training. For instance, have you taken an online course?

1. Excellent
2. Good
3. Basic
4. Weak
5. Other, explain: ____

Do you think that the lack of an instructor's presence can be overcome by incorporating new technologies in courses (using something like an intelligent tutoring system)?

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

6. Explain: ____

Please provide a self-assessment of your knowledge in SolidWorks Software before taking this class.

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Explain: ____

Please provide a self-assessment of your knowledge in GaBi Software before taking this class:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Explain: ____

Please provide a self-assessment of your knowledge in Life Cycle Assessment before taking this class:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Explain: ____

Please provide a self-assessment of your knowledge in Green Energy Technology before taking this class:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Explain: ____

Please provide a self-assessment of your knowledge in Green Materials/Storage Devices before taking this class:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Explain: ____

Appendix B: Post-Survey for Green Energy Engineering Summer Course

First Name: ____

Last Name: ____

Email Address: ____

What's your major?
1. IE Undergraduate
2. ME Undergraduate
3. ME Graduate
4. Others ____

Gender:
1. Male
2. Female

In which of the following areas do you believe the multimedia approach serves education better when compared to that of the conventional face-to-face teaching approach? (you can circle more than one answer)
1. The multimedia class materials could be available and seen when a student misses classes.
2. The multimedia class materials could be used as an aid for the course. The course slides or any related information could be online so that students would be able to review the materials at any time.
3. The multimedia class materials would be available anytime compared to the limited availability of the instructor

Do you have any experience with SolidWorks Software after you complete this course?
1. No
2. Yes. If so, please provide details ______________________________

Do you have any experience with GaBi Software after you complete this course?
1. No
2. Yes. If so, please provide details ______________________________

Do you have any experience with Life Cycle Assessment after you complete this course?
1. No
2. Yes. If so, please provide details ______________________________

Do you have any experience with Green Energy Technology after you complete this course?
1. No
2. Yes. If so, please provide details ______________________________

Do you have any experience with Green Materials/Storage Devices after you complete this course?
1. No
2. Yes. If so, please provide details ______________________________

Do you feel that high-quality learning can take place without having face-to-face interaction?
1. Yes
2. No

3. Explain ____

Do you think you can learn as much or more using multimedia (i.e., using many content forms including audio, still images, animation, video, and interactive content) instruction when compared to traditional instruction with a live instructor?

1. Strongly Affirmative
2. Affirmative
3. Neutral
4. Negative
5. Strongly Negative
6. Other, explain ____

Rate the level of your knowledge in Green Energy (GE) after completing course:

1. Excellent
2. Good
3. Basic
4. Weak
5. Other ____

Please provide a self-assessment of your knowledge in class as a whole after you complete course:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Other, explain: ____

Please provide a self-assessment of your knowledge in SolidWorks Software after you complete course:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Other, explain: ____

Please provide a self-assessment of your knowledge in GaBi Software after you complete course:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Other, explain: ____

Please provide a self-assessment of your knowledge in Life Cycle Assessment after you complete course:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Other, explain: ____

Please provide a self-assessment of your knowledge in Green Energy Technology after you *complete course:*

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Other, explain: ____

Please provide a self-assessment of your knowledge in Green Materials/Storage after you complete course:

1. Knowledge and understanding
2. Application skills
3. Analysis skills
4. Expert
5. Other, explain: ____

In your opinion, what are the strengths and weaknesses in the classroom?

____
____
____