Article

Incorporating Sustainability into Engineering Education Using e-Learning

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Abstract: The purpose of this study was to develop e-learning activities that integrated sustainability concepts and practices in process engineering education. Two blended courses were developed with two activities evaluated quantitatively and qualitatively to measure student engagement, quality of responses, and incorporation of sustainability in their arguments. Social network analysis and lexical analysis were used to assess students' participation in discussions and peer reviews. In the online discussion, 97 comments were made averaging 120 words per comment. The participants averaged 3.88 comments, with the majority of comments exhibiting simple and complex argumentation, a deep reflection, and widespread use of terms associated with sustainability such as recycling, pollution, waste, and environment. Furthermore, evaluation of peer reviews revealed that the participants demonstrated they could identify errors and positives in an argument. Therefore, this study demonstrated that e-learning, particularly peer review and online discussion could help chemistry and engineering students understand sustainability.

Keywords: sustainability; Green Engineering; curriculum development; chemical education; engineering education

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1. Introduction

Demonstration of an understanding of sustainability and societal and environmental is considered a key engineering competency by several engineering societies.[1] Hence, engineering education could play a critical role in ensuring the SDGs are met by 2030. Industrialization and urbanization are often credited for improving the standard of living and the life expectancy of people worldwide. However, in the past century, industrialization and urbanization contributed to significant deterioration of various environmental compartments, such as soil, water and the atmosphere.[2–5] For that reason, in 2016, the UNDP set seventeen sustainable development goals (SDGs) focusing on eradication of poverty without compromising the environment or the future. The National Research Council defined sustainability as "a path forward that allows humanity to meet current environmental and human health, economic, and societal needs without compromising the progress and success of future generations."[6] Many African nations have agriculture- and mining-based economies that rely heavily on fossil fuels. Hence, a lack of sustainability directly affects their national economies.

Applied chemistry graduates from local universities in developing nations are often employed in the process industry. Hence, such curriculum often includes several process engineering courses to improve their employability. The curriculum are often designed to ensure that upon completion of studies, the students would demonstrate personal effectiveness, academic, workplace, and industry-wide technical competencies (Figure 1).[1] Process engineering courses focus on industry-wide technical competencies, that is foundations of engineering, design, manufacturing and construction, engineering economics, operations and maintenance, and safety. Although sustainability and environmental impact is a core engineering competency, applied chemistry curriculum does not often include classes on sustainable development. Sustainability could be incorporated through creation of new elective courses. In the past 25 years, Green Engineering classes

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were successfully developed in many universities in North America.[6,7] Since curriculum development is often expensive and time consuming, introduction of new Green Engineering courses has been lacking in many African nations. However, professors often have autonomy over course content, hence they can incorporate sustainability as term papers, assignments, quizzes or class discussions.

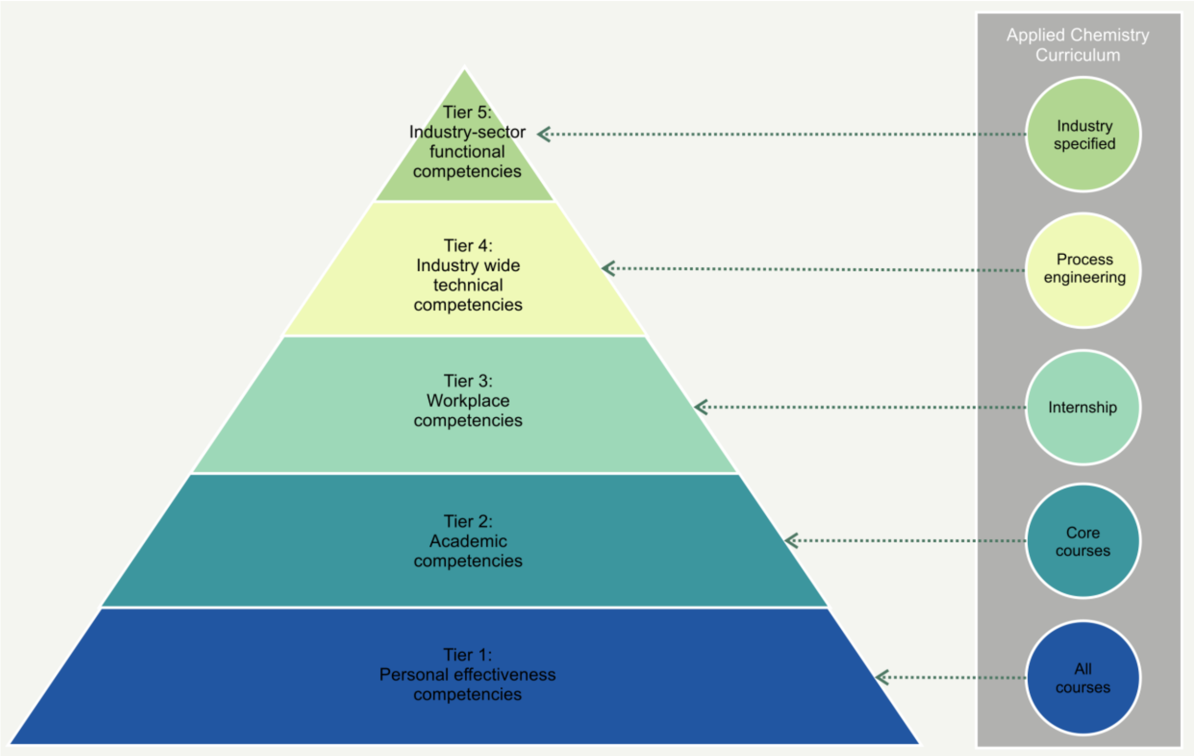

Figure 1. Engineering competencies addressed in the undergraduate applied chemistry curriculum at a public university in Zimbabwe.

Blended learning can offer a unique opportunity of incorporating key sustainability concepts and practices within the applied chemistry and engineering curricula.[7] The recent developments in technology, such as e-learning offer an opportunity for substantial growth in engineering education. However, they are several challenges with implementing e-learning in Africa, and these include poor internet access or connectivity, lack of locally developed learning material and lack of technical know-how.[8,9] Furthermore, online learning can be hindered by technological difficulties and lack of community resulting in decrease of learner motivation.[8] However, by combining face-to-face and online learning, blended learning has been shown to be an effective alternative.[10–12]

It was hypothesized that student engagement and appreciation of sustainability in developing nations could be improved through e-learning. Incorporating sustainability requires development of content that address local issues.[13] Hence, the goal of this project was to develop e-learning course materials that emphasize the role of sustainability in process engineering. Furthermore, lexical analysis was used to assess students' participation in discussions and peer reviews.

2. Methodology

2.1. Participants

The participants in the study were 25 students from a public university in Zimbabwe. All the students were in their final year at college. The students had varying experiences in online learning. However, none of the students had previously enrolled in a blended learning class as part of their curriculum. Course materials for the two courses were prepared on Canvas, a learning management system. The participants accessed Canvas on their phones or using a computer.

2.2. Measures

The types of activities, assessed questions, and the corresponding learning objectives are listed in Table 1.

Table 1. Activities used in the incorporation of sustainability in process engineering.

Activities		Learning objectives	Source
Type	Question		
Online discussion	According to Milorad P. Dudukovic, "The key challenge for chemical reaction engineering is the development of new more efficient and profitable technologies. This is to be accomplished via an improved science-based scale-up methodology for transfer of molecular discoveries to sustainable nonpolluting processes that can meet the future energy, environmental, food, and materials needs of the world." Discuss how chemical reaction engineering can be used to meet the Millennium Development Goals in Zimbabwe, particularly goal 7 on environmental sustainability.	• Apply the fundamentals of reaction engineering in answering sustainability problems. • Develop an understanding of the MDGs and SDGs	Research article[14]
Design report	Your local hospital received a report from the Environmental Monitoring Agency that stated that the effluent from the hospital is contaminating a local river. As a design engineer, you are tasked with proposing and designing a wastewater treatment plant for the local hospital. Write a design report for a cost-effective and innovative wastewater treatment plant for the hospital. Discuss how your design is sustainable and helps the nation to meet the MDG 7.	• Apply the fundamentals of reaction engineering in answering sustainability problems. • Evaluate the reliability, effectiveness, and limitations of available tools, equipment or technology for solving engineering problems. • Develop a solution that best meets system requirements and specifications.	Report[15]

MDG 7 was used in the activities as it offers a concise reference to the SDGs relevant to process engineering; namely, SDG 6, 7, 9, 13, 14, and 15.

Participant engagement during the online discussion and peer review was measured using the quality of comments submitted. The first activity, online discussion was open for about 6 weeks during the semester. The second activity involved preparing a design report for a rural wastewater treatment plant. After submitting the design report, anonymously evaluated and scored other participants' reports. Each submission was peer reviewed by three participants. Lexical analytics were used to establish the impact of social engagement in the online discussion and peer reviews. Participant posts from the online discussion (N = 97) were collected from the two courses and subsequently weighted for their quality in five key aspects; namely, Argumentation, Responsiveness, Elicitation, Reflection on Individual Process, and Reflection on Group Process (Table 2).[16,17] The peer reviews were analyzed for their quality as well.

Table 2. Weighting scheme for quality of participant contribution.

Dimensions	Key aspects	Weight			
		0	1	2	3

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Content	Argumentation	None	Unsupported	Simple	Complex
Discursiveness	Responsiveness	None	Acknowledge	Respond to single idea	Respond to multiple ideas
	Elicitation	None	Unclear question	Question one person	Question whole group
Reflectivity	Reflection in the question or submission	None	Shallow: reflection on own posts with no explanation	Deep: explain how the learning process shape one's idea	
	Reflection on group discussion	None	Shallow: reflection on group posts with no explanation	Deep: explain how the learning process was shaped by group's idea	

Adapted from Chen et al., 2018.

3. Results

3.1. Online Discussion

The online discussion was available between January 21, 2017 and February 28, 2017. All the participants took part in the activity generating. The participants averaged 120 words per comment. Furthermore, the participants averaged 3.88 posts in the online discussion (Figure 2). Of the 25 participants, 5 where highly active as they contributed at least 6 comments each. Ten participants contributed 2 or less comments, and the remainder made 3 or 4 comments. The participants shared 11 high quality web pages from universities, government departments, international organizations and research papers (data not shown).

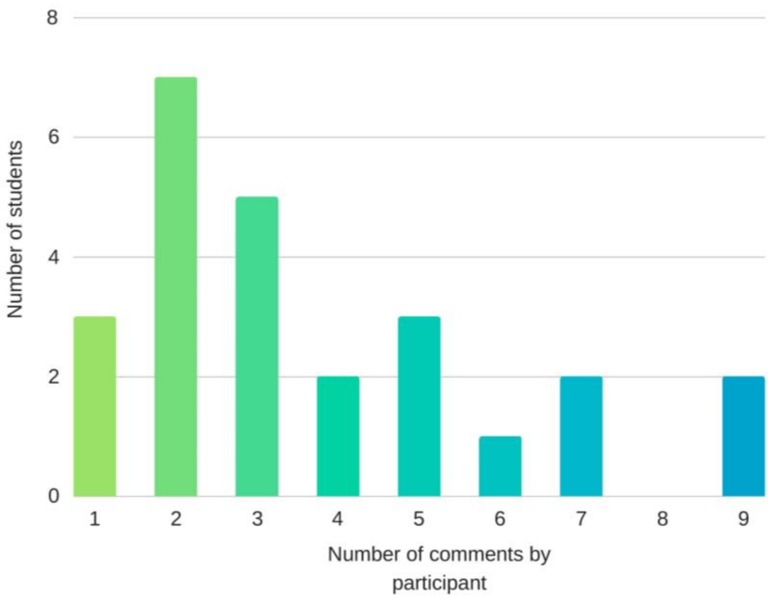

Figure 2. The level of participant engagement in an online discussion.

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To determine if the participants incorporated sustainability concepts and practices in the online discussion, a word cloud was generated from the forum posts (Figure 3). The participants used words associated with sustainability such recycling, waste, environment, catalysts, carbon, and pollution.

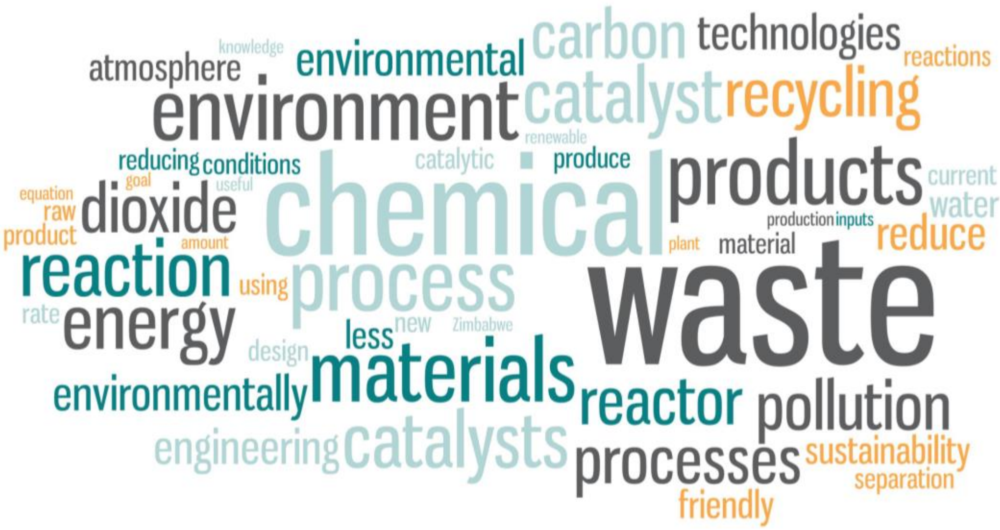

Figure 3. The visualized the most frequent words used in the online discussion.

The participants contributed 15 questions that demonstrated the participants reflected on sustainability. Examples of the engaging questions posted on the forum are shown in Table 3. However, it should be noted that two of the questions contributed were for technical assistance.

Table 3. Elicitations in online discussions.

Examples of engaging questions*
1. How does your final year project incorporate with the Millennial Development Goal 7?
2. Are there any solvents currently used in Zimbabwe that are persistent in the environment?
3. How exactly does chemical reaction engineering play a role in sustaining a modern Zimbabwean lifestyle?
4. How does chemical reaction engineering affect the environment?
5. Are you implying that most industrial operations in Zimbabwe are using the wrong catalysts? if so, do you have examples to justify that?
6. Considering the research paper was published in 2009, is it possible that basing claims on this text may fail to accommodate some recent developments in reaction engineering?

*Questions have been edited for clarity.

The argumentation and responsiveness in the comments where slightly above moderate at 2.25 and 2.16, respectively (Table 4). However, the level of elicitation was low at 0.39. They were only 15 questions out of the 97 comments. The reflection in the post and group ideas was slightly above average at 1.24 and 1.14, respectively.

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Table 4. The total count and means of weighted conceptual engagement in online discussion.

Key aspects	Weight				Mean
	0	1	2	3	
Argumentation	6	8	39	44	2.25
Responsiveness	6	16	31	44	2.16
Elicitation	79	4	8	6	0.39
Reflection in the question or submission	16	42	39		1.24
Reflection on group discussion	21	41	35		1.14

3.2. Design Report

Out of 25 participants, 22 submitted their design report and were double-blind reviewed by three peers. About 51.5 % of the comments were poor with participants failing to identify the positive or negative aspects of the paper they reviewed. However, 24.2 % peer reviews identified at least one positive attribute of a submission. Furthermore, another 24.2 % peer reviews identified at least one error in the submission reviewed. The participants, identified the errors using expressions such as, “lacked,” “did not,” “neglected,” “more research,” and “did not include.”

4. Discussion and Conclusions

The study sought to establish e-learning could be used as a tool for incorporating sustainability in chemical and engineering education in developing nations. The results suggested that e-learning activities such as online discussion and peer review of assignments encouraged student engagement. Similar results were obtained in a study on blended learning among health students at Makerere University. Although, the study focused on international collaborations among participants from low-income and high-income countries, the results similarly demonstrated blended learning offered an engaging platform and a ‘personalized learning experiences.’[8]

The quality of the comments in online discussion and peer review were high suggesting the students offered well-argued responses that offered at least a single supported idea and deep reflection. Social interaction among participants probably encouraged students to participate more. The learning management system used in the study had tools for ‘liking’ a comment and this probably incentivized posting more thoughtful and well-argued comments.[16] The quality of the responses in this study were probably due to the fact that the question the participant addressed was local and relevant. A previous study found student engagement was mainly influenced by course design and student perception.[11] Furthermore, the study found when a student considered the online activity to be highly important they became cognitive and emotional engaged to the task.[11] Therefore, to enhance student engagement, the instructor should probably demonstrate the importance of the activity.

The participants managed to incorporate sustainability concepts and practices in their arguments. As illustrated by the word cloud (Figure 3), the responses in online discussion demonstrated Tier 4 engineering competencies. For example, the following words were widely used reaction, process, raw materials, inputs, conditions, pollution, which are associated with engineering competencies of foundations of engineering, design, manufacturing and construction, engineering economics, operations and maintenance, and safety, respectively.[1] Thus, online learning offered a platform for students to actively learn about sustainability. This study provides instructors with techniques on how to incorporate sustainability in chemical and engineering education. Furthermore, in this study we used and demonstrated techniques for assessing the quality of student responses.

Conflicts of Interest: The authors declare no conflict of interest.

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