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Web-Based Engineering Design Activity in Biology: An Assessment on the Demonstration of Higher-Order Thinking Skills

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Abstract: Senior High School (SHS) STEM curriculum in the Philippines is on its infancy stages which lacks technology-related and engineering-oriented courses. Along with the challenges in education sector brought by the COVID-19 pandemic and ineffective teaching of 21st century higher-order thinking skills in a Philippine setting, this study aims to utilize an engineering design activity to introduce engineering principles using technological tools and assess the presence or absence of higher-order thinking skills in the design solutions using an engineering design rubric. A design activity was developed by the researcher. The average and total scores of each group as evaluated by the subject teacher, students and researcher using the engineering design rubric to measure the demonstration of higher-order thinking skills in the outputs were analyzed. Based on the components assessed, problem-solving skills and critical thinking were demonstrated on the design solutions at competent and sophisticated level of performance. This shows that incorporating collaborative engineering design activities in an online setting allow the students to exhibit higher-order thinking skills.

Keywords: engineering design, assessment, higher-order thinking skills, senior high school

1. Introduction

Science, Technology Engineering and Mathematics (STEM) is one of the strands/tracks students can pursue in senior high school under the K-12 curriculum in the Philippines that was implemented in 2016 to become globally at par and ensure enhancement of skills. However, based on the subjects and competencies in the Philippine Senior High School (SHS) STEM curriculum set by the Department of Education (DepEd), it lacks the integration of technology-related or engineering-oriented courses and competencies (Arnilla 2018).

Problem-solving, innovation and design are the themes that are evident in the technology and engineering portion of STEM education (Hernandez et al. 2013). Engineering Design Process (EDP) is an efficient tool that teachers can use to introduce engineering principles to students, as well as develop higher-order thinking skills such as problem solving and critical thinking (Mangold et al. 2013; Ure 2012). Despite the many subjects in the basic education curriculum, higher order thinking skills such as critical thinking is not effectively taught in the Philippine setting (Marquez 2017). It is also supported by the Program for International Student Assessment (PISA) results reported in 2018--in which the examination uses the application of 21st century skills such as problem-solving, critical thinking and logical solutions, thus, incorporation of EDP in the curriculum could be a step on harnessing these higher-order thinking skills.

Along with changes on the educational settings brought by the COVID-19 pandemic which caused shifts from the traditional face-to-face class to online learning, utilizing EDP in an online setting where students have to make prototypes, could be a challenge. Nonetheless, studies show that through online support, students were able to familiarize the process of engineering design for analyzing open-ended design problems.

The aim of the study is to assess the demonstration of critical thinking and problem-solving skills through creating design solutions following the modified eight-steps of EDP which includes the iteration process of analyzing, selecting, creating, evaluating, and redesigning their solutions after

identifying objectives and constraints as well as researching about their problem and communicating their final designs.

2. Methodology

Mixed method was utilized to analyze and gather data. For the of quantitative component, descriptive statistics was conducted through identifying the mean scores of the students on each criterion set in the engineering design rubrics, while observations from the students group interaction comprise the qualitative portion.

Engineering design activity in biology was developed by the researcher on the topic on energy transformation specifically ATP-ADP cycle, photosynthesis, and cellular respiration. 29 SHS STEM participants from a private school in Manila, Philippines were purposively selected, grouped and tasked to collaborate as a team and create an energy sustainable building design using the simulation software, Energy 3D following the modified eight-steps of EDP adapted from Mangold and Robinson (2013). Demonstration of higher-order thinking skills were evaluated by the subject teacher, students and researcher using the engineering design rubric under research and design, communication, and teamwork components using three-point rubric scale ranging from (3) sophisticated (2) competent and (1) not yet competent. The engineering design rubric was adapted from the project design rubric by the University of Pittsburgh. Each group's prototype design, written output as well as presentation were assessed. Due to the constraints of online set-up, teamwork component was evaluated through students' recorded discussions in creating their design outputs. Groups who did not conduct synchronous meetings submitted screenshots of their conversations in a messaging app.

3. Results

Based on the components assessed using the engineering design rubric through the mean scores, higher order thinking skills such as problem-solving skills and critical thinking were demonstrated on the design solutions at competent and sophisticated level of performance. Figure 1 shows a sample energy sustainable building design inspired by biological processes created by one group of students using the software Energy 3D.

The observations on the students' recordings and screenshots as they communicate with their teams show that similar routines were evident in all groups that contributed in the success of their design solutions. There was at least one member who led and initiates in the contribution of ideas, mostly males. It is then followed by the assignment of specific tasks, since not all of the members have computers/laptops in creating 3D designs, there is one member in the group who was assigned in creating the 3D design using the software Energy 3D. It was also observed in most groups that as a member propose a design idea it is followed by a confirmation from other members that they all agreed. Should the students find the proposed design solution lacking, members ask questions for clarifications and share improvements on the ideas. Members of some groups also search for design inspirations that were later modified based on their set goals and further evaluate the given suggestions. Some members also think about the possible limitations of the designs and apply their prior knowledge in creating solutions.

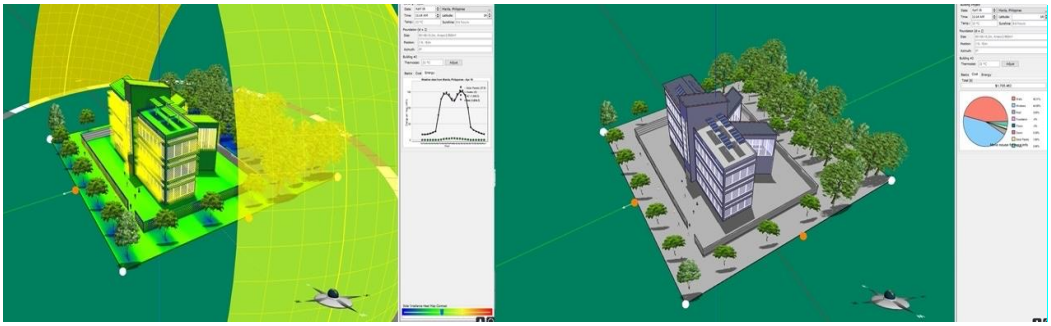

Figure 1. Sample Design by One Group using the Software Energy 3D.

4. Conclusion

Based on the components assessed using the engineering design rubric, it indicates that higher-order thinking skills such as problem-solving skills and critical thinking were demonstrated on the design solutions. Moreover, it shows that utilizing web-based engineering design activities in science concepts is one of the useful ways to introduce engineering and technology concepts to high school students.

It is recommended to impose true integrated STEM education in the Philippines by incorporating engineering and technology-based competencies on the science and mathematics courses. Through these, students will understand the relevance and connections of these fields as well as further improve necessary thinking skills.

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