Exploring Electrical Engineering through Movement: Going with the Flow and Programming Puzzles

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***Abstract*— The Exploring Electrical Engineering program will electrify your understanding of engineering! Developed as part of a larger K-6 engineering education research initiative, this workshop paper details two activities for exploring electrical and computer engineering concepts for grade 3-5 students through the use of cross-disciplinary concepts in physical education and movement. Activity 1: Going with the Flow uses human electrons and circuit components to demonstrate electron behaviour in parallel and series circuits. Activity 2: Programming Puzzles introduces code design through life-size maze creation and completion. These creative activities have been tested as part of on-going research work in several classrooms, with over 350 elementary school students participating, and have resulted in an increased interest in electrical engineering as a future career.**

Keywords—cross-disciplinary; K-12; electrical engineering; physical education; exploratory learning

I. Introduction

The Exploring Electrical Engineering program was created in 2013 as part of a K-12 engineering education initiative at the University of Calgary. Since its creation, the program has been expanded to include several different grade levels and cross-disciplinary activities. The original concept testing and implementation of the Exploring Electrical Engineering program has been published in [1]. This paper focuses on the expansion of the first program activity, Going with the Flow, and the creation of a new activity for computer science literacy, Programming Puzzles. This work-in-progress paper complements the scheduled workshop.

Literature shows that by upper elementary or junior high school grades, students- female students in particular- have already decided against pursuing the science, mathematics, engineering and technology (STEM) domains [2-3]. Students also demonstrate inaccurate perceptions about engineering [1,3-4], associating engineers with repair and installation rather than design and innovation. This paper will discuss two activities targeting grade 4, 5, and 6 students that use cross-disciplinary techniques to engage student interest while conveying technical STEM knowledge. These particular activities use physical education concepts, as our past work has revealed athletics to be a popular hobby and career interest among young students, regardless of gender [1].

With the growing demand for computer literacy, these activities aim to incorporate the importance of electricity, electronics and programing within daily life, and emphasize the roles and responsibilities of engineers within these areas. Our research has shown that elementary students have little understanding about engineering as a career, and that teachers themselves may not be familiar with engineering [6], or may have a negative bias towards STEM subject areas [7]. Students will learn what an engineer does, especially within electrical and computer engineering fields, the engineering design process, teamwork, and the importance of testing engineering inventions. These activities emphasize the role of engineering innovation in solving problems within society.

II. Methodology

The activities themselves have also been designed using the CDIO (Conceive-Design-Implement-Operate) engineering design process, and incorporate aspects of the CDIO engineering education design syllabus [8]. The incorporated curriculum concepts have been designed to integrate engineering along with science, technology, and physical education standards, allowing educators to combine multiple subject concepts in a cross-disciplinary learning environment. Cross-disciplinary engineering education is particularly important when attracting or retaining students, particularly female students, who may have already begun to lose interest in science and mathematics.

All of the activities within the Exploring Electrical Engineering program are specifically designed to improve learning outcomes through the use of cross-disciplinary curriculum connections. Each module design first identifies the primary scientific objectives for the relevant grade and combines these objectives with content from the rest of the curricula using a three-step pattern: concept learning, application, and creative design.

Both Going with the Flow (2016 revision) and Programming Puzzles use cross-disciplinary learning outcomes from physical education to integrate technical STEM understanding. The inclusion of physical movement provides opportunities for students to engage and involve themselves in life-sized scale models of otherwise abstract concepts, such as the movement of an electron. It also allows the students a chance to get away from their desk and exhaust energy without

taking away from their classroom learning. Both activities incoporate SHAPE PE standards, especially Standard 2: Knowledge of concepts, principles, strategies, and tactics related to movement [9].

III. Activities

A. Activity #1: Going with the Flow

In this project, students learn about basic circuit terminology, electron movement, switches, and the differences between parallel and series circuits. Students demonstrate their learning using physical activity, observation, and follow-up written questions. When first introduced to electricity and circuits, students often have difficulty visualizing electrons and how they work. To better demonstrate the concepts, this activity was designed to use the students' own bodies as a life-sized representation of electrons.

Electrons and their movement patterns are introduced in a game format. Most students are already able to identify basic circuits intuitively when asked about the world around them, including their own experiences with lights and batteries. Students start by imagining themselves as giant electrons. While the majority of the class gathers at the front of the room in an imaginary "battery zone", a few students are selected to act as "switches" and "circuit load". The circuit load may be represented in many ways, but the best tool tested so far is an inexpensive plastic pinwheel.

As the "electrons" travel around a pre-determined path and back to the battery area, they are asked to transfer a "burst of energy" to the pinwheel as they pass by. The use of a pinwheel allows students to see that a single electron cannot keep a light on; a continuous "current" is required for the pinwheel to remain spinning. The "switches" allow students to explore parallel and series circuit behavior. The difficulty level may vary by class, but students are quick to learn as they enjoy the individual and team challenge. Each student must decide which path they will take, and if a path is broken by an open "switch", then their "electron" must freeze in place. This creates a game atmosphere and engagement through fun.

This activity was designed to incorporate teamwork and individual responsibility, and students must make individual decisions to contribute to the overall team goal of creating a life-sized circuit. At the end of the activity, students demonstrate their understanding of the concepts by answering a few related questions in the accompanying handout, which was designed as part of this work to reinforce their learning and provide the teachers with a form of possible assessment.

Going with the Flow addresses NGSS standards relating to electricity and the flow of matter, specifically NGSS 3-PS2-3: Relationships of electric interactions, NGSS 4-PS3: Energy, NGSS 5-PS3-1: Energy and Matter, NGSS 5-PS1-1: Model to describe small particles [10].

B. Activity #2: Programming Puzzles

This activity extends the students' understanding of electricity and how it is used in their everyday lives through its application to computers. They explore the uses of computers in society and basic algorithm design principles. The instructional component begins with a quick discussion about computers: who uses computers, where are they used, and what their uses may be, and the differences between software and hardware. Students are asked to "program" themselves to complete a maze as designed by other participants. Students will work in pairs to create and navigate a maze of squares using colours and basic word instructions: forward, backwards, left, right, clap. Students will learn about ambiguity in programming, and how to identify program "bugs".

Laminated squares of paper are placed on the floor to create a maze. Each sequence must begin with a green square and end with a red square. The interior squares can be white (normal) or blue, which signifies that the participant must clap their hands. The clap action represents a more complex computer program or task being executed. Once a team has decided on their maze, they must write down the instructions in a step-by-step format. Teams then switch their instructions with another group, and attempt to follow the new set of instructions to re-create the other team's original maze. The team cannot deviate from those instructions, and if they notice a mistake (i.e., falling off the maze) they must restart and determine possible program "bugs". Once they believe their maze "programming' is correct, the original creation team will verify the accuracy of the algorithm execution.

This activity can be tied back into real-life applications. For example, a rover on Mars needs to follow the specific instructions from NASA to explore the planet. Consider other connections with curricula from other subjects that students have already worked on. Programming Puzzles addresses many points in the CSTA Computer Science Standards [11], including 1:3.CT-4: Recognize that software is created to control computer operations, 1:3.CPP-4: Construct a set of statements to be acted out to accomplish a simple task, and 1:3.CPP-5: Identify jobs that use computing and technology. By having students design their mazes and then test them it connects with the engineering design process and ITEA standard 11: collect information, visualize a solution, test and evaluate solutions, improve a design [12].

IV. Impact

Going with the Flow (2016 revision) and Programming Puzzles are currently being tested in local schools. Previous iterations and similar cross-disciplinary activities have been successful in improving perceptions of engineering and interest in engineering as a possible future career [5].

Cross-disciplinary STEM activities combine engineering and design concepts with mandated curriculum concepts to increase the level of interest of students in STEM areas and decrease the disconnect between student perceptions of engineering and reality. These cross-disciplinary modules are designed to teach STEM concepts as part of the regular curriculum activities, allowing teachers to educate their students about engineering principles in the context of English, social studies, fine arts and physical education curricula. By combining STEM material with other subject areas, we propose to (A) increase the appeal of STEM to children who have expressed interest in other subjects, and (B) provide new

methods of learning for children who may struggle with the technicality and lack of creativity found in more traditional STEM education. Our modules have been tested by over 400 Calgary students and teachers, and have demonstrated improvement in student perceptions regarding STEM subjects, careers, and gender issues within these fields [5].

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