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Developing a cross-disciplinary curriculum for the integration of engineering and design in elementary education

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Abstract

Several studies show that students have lost interest in the domains of science, mathematics, engineering and technology (STEM) before reaching high school and believe that these areas are not innovative or creative. Using the CDIO educational framework, cross-disciplinary modules were developed to teach engineering design concepts as part of regular curriculum activities, such as English, social studies, fine arts and physical education. By combining engineering design with other subjects, this study proposes to increase the appeal of STEM to children who have expressed interest in other areas and provide new methods of creative learning.

Problem Statement

The decline of student enrollment in post-secondary STEM education has become a problem for many first world nations, such as the USA, Canada, Australia and New Zealand. These countries are not producing enough STEM graduates to fulfill their needs[1]. The lack of student enrollment in engineering at the post-secondary level can be traced back to the education that students receive earlier in their lives[1]. Studies show that by upper elementary or junior high school grades, many students, particularly girls, have already decided that STEM domains do not interest them[2,3]. Additional reports[4,5] indicate that children do not have an accurate perception about engineering. For example, when surveyed, children believed that engineers are responsible for repairing and installing technical items, but are not as involved in innovation and design[4,5]. To make matters worse, past studies from the USA showed that many elementary teachers felt that they were not well qualified to teach science disciplines and only 18% felt very well qualified to teach subjects related to physical science. In comparison, 76% of teachers reported that they felt very qualified to teach reading and language arts[6]. In other reports[7], more than half of the surveyed elementary teachers in Alberta, Canada had no university education in mathematics and science, and 88.9% had never taken any university courses in applied sciences.

Proposed Methodology

This work proposes to apply engineering and design concepts to subject areas where elementary teachers have indicated strength, i.e. arts and social sciences. A cross-disciplinary series of modules has been designed to increase the appeal of STEM material to children who have expressed interest in other subjects, provide new methods of learning for both teachers and children who may struggle with the technicality and lack of creativity of the traditional STEM education, and increase the visibility of engineering during elementary education. To create the cross-disciplinary series, the main concepts of a grade 5-level curriculum were examined to find possible connections between subjects. The primary concepts were organized into a modular system that allows each lesson to build on the concepts learned in the previous material. Each module follows the international CDIO (Conceiving – Designing – Implementing – Operating) Standard 3- Integrated Curriculum educational initiative[8] to encourage the investigatory and multidisciplinary mindset that is important to cultivate future engineers. All of the modules are concerned with teaching electricity. The first module in the series focuses on concept learning, while the second module explores applications of these concepts through hands on experience.

The third module consists of a final creative design project where students will demonstrate their understanding through the creation of "circuit art". Each module includes an observational lab book, as well as additional questions to reinforce the lesson concepts. All of the projects are designed for a standard 40 minute class period, but could be expanded with additional material.

Description of Module Projects

Module #1 – Project #1: Going with the Flow: Students will learn about electron movement, continuous current, switches, and energy transformation through physical activity. Working as a team, students will gather in one area designated as the "battery". One student will hold an open/closed sign as the "switch" and one student will hold a pinwheel as the "light bulb" while each of the remaining students represent a single electron, a basic switch, or a load on the circuit. Under direction, the "electrons" will run around the circuit perimeter according to the position of the "switch". Each "electron" will transfer their energy to the circuit "light bulb" by spinning the pinwheel. Students will see that a single electron is not enough to power the light- they will need to provide a continuous flow of electrons in order for their circuit to function properly. **Concepts:** Students will learn about… **Physical Education**- teamwork, coordinating efforts, movement adaptation, achieving group goals. **Science**- flow of current, transfer of energy, basic switches, common types of electrical devices/circuits loads.

Module #1 – Project #2: Dripping with Potential: Students will explore electrical potential and current using water flow analogy. Working in small groups, students will be given a variety of plastic tubes, wheels and funnels to design a water circuit. Students will use a "single electron" (marble) to test the initial performance of their circuit, and then they will observe how their circuit performs when varying amounts of water are used to represent continuous current. They will be asked to combine their ideas into a short, oral presentation for the rest of the class. **Concepts:** Students will learn about… **English**- representing knowledge as a group, representing knowledge in oral/written text, using of previous knowledge, making connections. **Science**- electric potential, the uses of switches, power sources, resistors, circuit elements.

Module #1 – Project #3: Constructing Conductivity: Students will learn about voltage and conductivity through a hands-on exploration of household items and natural materials. Working in small groups, student will rotate through two different stations. At the first station, they will be given a simple circuit consisting of two AA batteries, an LED, wires, and a piece each of copper and zinc. The groups will place the copper and zinc pieces in a variety of liquids, such as distilled water and lemon juice, and will record their observations in a chart. At the second station, students will insert similar copper and zinc pieces into common fruits and vegetables, and use a multimeter to measure the amount of voltage produced. Finally, students will be asked to design and sketch a lightning shelter using the most insulating liquid, and a flashlight powered by one of the fruits or vegetables. **Concepts:** Students will learn about… **English**- creating original text, effectively presenting information, summarization, expressing ideas. **Science**- conductors, insulators, electrical resistance, designing/constructing circuits, design solutions.

Module #2 – Project #1: Circuits through Time: Students will be assigned a period of electrical history, or important electrical inventions to research and document in their lab book. They will then create a timeline that shows how electricity evolved in North America. Finally, students will re-create Edison's historic light bulb experiments by testing and observing how different types of

wires glow when connected to a 6 volt battery. **Concepts:** Students will learn about… **Social Studies**- the impact of historical events/discoveries, collecting and evaluating a variety of information, applying skills towards written and visual literacy. **Technology**- the effects of technology on society, safe Internet/technology use to obtain research information. **Science**- electrical conduction through materials, design of an electrical system.

Module #2 – Project #2: Speaking with Computers: Students will be introduced to circuits in computer hardware, and learn about the basic binary language that enables computers to "speak" to one another. Following a brief lesson about the base-2 number system and binary patterns, they will be asked to solve binary puzzles and use their math skills to predict binary patterns. Puzzles will include basic binary codes for numbers and letters. Finally, students will create a binary calendar and represent their birthday date using two different colours of thumbtacks (for 1s and 0s) on foam board. **Concepts:** Students will learn about… **Technology-** techniques and limitations in communicating information. **Mathematics**- using patterns to solve problems, determining pattern rules, making predictions using patterns. **Science**- digital circuitry.

Module #3 – Project #1: The Electrifying Exhibition: Students will combine all of their learned concepts into a final art and design exhibition. Each student will be asked to design their own individual artwork or circuit using material such as conductive paint, LEDs, motors, etc. Each student will also be given both conductive and nonconductive playdough, as well as a variety of batteries, LEDs, and wires. Students will be asked to write and then present a description that explains about their artwork and how it works. Their final work will be displayed in an open exhibition, allowing students to appreciate each other's creations. **Concepts:** Students will learn about… **Art**- utilizing different mediums, transforming and distorting forms, comparing function/form/shape, using varied mediums to create a final project, designing and constructing individual artwork to express ideas. **English**- making use of previous knowledge, making connections, creating original text, effectively presenting information, summarization, expressing ideas. **Science**- experimental design using learned concepts, designing and constructing circuits to operate lights/motors/other electrical devices.

Bibliography

1. Smaill, C. R. (2010). The implementation and evaluation of a university-based outreach laboratory program in electrical engineering. *IEEE Transactions on Education*, 53(1), 12-17.
2. Arnot, M., Gray, J., James, M., Rudduck, J., & Duveen, G. (1998). Recent research on gender and educational performance. London: OFSTED.
3. Bussière, P., Cartwright, F., & Knighton, T. (2004). The performance of Canada's youth in Mathematics, Reading, Science and problem solving: 2003 first findings for Canadians aged 15. Ottawa: Human Resources and Skills Development Canada, Council of Ministers of Education, Canada and Statistics Canada.
4. Capobianco, B. M., Diefes-Dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *JEE, 100*(2), 304-328.
5. Cunningham, C. M., Lachapelle, C. P., & Lindgren-Streicher, A. (2005). Assessing elementary school students' conceptions of engineering and technology. *ASEE Annual Conference and Exposition*. Portland, OR.
6. Wilson, J., Krakowsky, A., & Herget, C. (2010). Starting early: increasing elementary (K-8) student science achievement with retired scientists and engineers. *IEEE Trans. on Education,* 53(1), 26-31.
7. Rowell, P. M., & Ebbers, M. (2004). Elementary science education in Alberta schools. *Centre for Mathematics, Science and Technology Education.* University of Alberta, Edmonton, Alberta, Canada.
8. Crawley, E., Malmqvist, J., Östlund, S., & Brodeur, D. (2007). *Rethinking engineering education, the CDIO approach*. Springer US.