Investigating Assessment Methods for Informal Environmental Engineering Education Modules for K-12 Students, Specifically Focusing on Sustainability (Extended Abstract: Hands-on Environmental Engineering Panel)

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Rebecca Citrin is a senior Civil and Environmental Engineering student at Lafayette College with a strong interest in K – 12 Engineering Education. She is currently working with Lafayette College and North Carolina State University faculty members on an NSF funded education project. Rebecca has conducted research on various informal K – 12 engineering education projects and has worked on developing assessment methods for these projects. Rebecca has organized various student events such as the Lafayette College Engineering Brain Bowl and the Lafayette College STEM Camp, to both promote engineering and science education for K – 12 students, as well as assess the learning outcomes of these programs.

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Arthur D. Kney received his doctorate of philosophy (Ph.D.) in Environmental Engineering from Lehigh University in 1999 and his professional engineering license in 2007. He is currently serving as an Associate Professor and Department Head in the Department of Civil and Environmental Engineering at Lafayette College.

Throughout Kney's career he has been active in the community, at the local, state and national level. He has served as chair of the Pennsylvania Water Environment Association (PWEA) research committee, chair of the Bethlehem Environmental Advisory Committee, vice president of Lehigh Valley Section of the American Society of Civil Engineers (ASCE), secretary of ASCE/Environmental and Water Resources Institute (EWRI) Water Supply Engineering Committee and been a member of the AWWA/ASCE WTP Design 4th Edition Steering Committee. He currently serves on the states PWEA Research Committee and Water Works Operators' Association of Pennsylvania (WWOAP) scholarship committee, and locally on the Bethlehem Backyards for Wildlife committee, the Bushkill Stream Conservancy board, the Wildlands Conservancy's Education Advisory Team as well as a number of Lafayette College committees. Recognition for his work have been provided through a number of awards; most recently the PA Water Environmental Association (PWEA) 2010 Professional Research Award, 2010 Delta Upsilon Distinguished Mentoring and Teaching Award; 2010 Aaron O. Hoff Award,. and the 2010 Spring Cove School District Red Sneaker Award.

Kney's areas of interests include water/wastewater treatment (including industrial wastewater treatment), issues of PPCPs in water and wastewater and sustainable engineering focusing on urban sprawl and its environmental effects on watersheds. Most recently he has begun to explore methods to integrate undergraduate and K-12 education in innovative ways.

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Introduction

The goal of informal environmental engineering education practices, specifically focusing on sustainability, is to expose K-12 students to critical environmental issues which will ultimately impact society's future economic, social-cultural and ecological dimensions. By exposing students to the concept of sustainability, which is not formally taught in standard school curricula, students will be more knowledgeable of one of the most pressing concerns facing our planet's future: how to sustainably use our resources now, in order to ensure that future generations will have access to these same resources. Sustainability themed environmental engineering modules were developed to go beyond what is taught in a typical classroom setting and build off of standardized curricula. Students should be able to take the core science concepts communicated in school, and apply these concepts to the ideas presented in the sustainability focused activities. The framework used to develop informal sustainability modules was based on creating interactive, hands-on experiences, which allowed students to better grasp and connect to the topics presented.

In order to assess the sustainability modules, and prove that students were grasping the intended learning outcomes, assessment tools were established. Assessment strategies have undergone numerous revisions, based on data collected from various sustainability based programs held on the Lafayette College Campus, such as the Lafayette College S.T.E.M. (Science, Technology, Engineering and Mathematics) Camp, to develop the most effective model for measuring student learning outcomes, opinions, and intended behaviors regarding sustainability. Assessment methods included multiple choice and open ended questions, as well as Personal Meaning Maps[1]. The goal of the modules was not only to teach specific facts or definitions relating to the concept of sustainability, but to also introduce students to the broader concept of sustainability through more focused examples. While the development of sustainability themed modules was an important component of educating K-12 students on this important issue, the establishment of assessment methods was a critical element in ensuring that students were grasping the intended

learning outcomes, developing favorable attitudes towards sustainability, and were intended to cause behavioral changes to promote sustainability within their personal lives.

Theoretical Framework

In order to substantiate the importance and effectiveness of informal sustainability themed education, a practical educational model was established, combined with the development of corresponding assessment methods to validate that intended learning outcomes were reached. The Lafayette College S.T.E.M. Camp demonstrated the effectiveness of teaching informal sustainability themed education to middle school students. Middle school students were chosen as the focus for this case study because the neurological development of children between 10 and 12 years of age demonstrate a transition from concrete to abstract learning. This transitional period in brain development, and ability to process and connect information, provides a beneficial platform for learning science through hands-on, experiential activities. Intended learner outcomes included an increased cognizance of the environment and sustainability, identification of how an individual can change their behavior to live more sustainably, as well as the identification of how society can change present behaviors to help maintain the planet's limited supply of resources for future generations.

The theme of the camp, which took place over the course of three days in July 2013, was *Our Planet. Our Future.* The program focused on sustainability, with a specific emphasis on how to sustainably manage our food, water and energy supplies. Approximately fifty students from throughout Pennsylvania's Lehigh Valley attended the program, where they had the opportunity to participate in various sustainability focused activities. The activities were developed to be hands-on, interactive experiences, with concepts building upon what students were formally taught in a classroom based setting. Throughout the duration of the camp, students demonstrated their ability to take the core science concepts they had learned in school, and apply these concepts to the ideas presented in the sustainability modules.

College faculty and students were taught in formal trainings sessions prior to the camp, and were the primary educators throughout the program. Training sessions educated students and faculty on how to present complex science, technology, engineering and mathematics concepts in a way

that would be understand by the students attending the camp. Examples of the hands-on, interactive modules include *Moving Down the Road,* during which students explored an electric car and then assembled their own battery powered vehicles, as well as *Is it Getting Hot in Here?*, where students learned about global warming and the negative implications of anthropogenic climate change. *Figure #1: Lafayette College S.T.E.M. Camp Activity Summaries* depicts the complete list of activities that the students participated in throughout the duration of the three day program.

MOVING DOWN THE ROAD: This activity compared the benefits and challenges of alternatives to the conventional automobile, such as hybrids and fuel cell vehicles. Campers assumed the role Mechanical Engineers to build and race model electric vehicles.

IS IT GETTING HOT IN HERE?: Campers learned about the effects of carbon dioxide on the climate system and investigated temperature and carbon dioxide levels over the past 400,000 years. This knowledge helped campers understand anthropogenic climate change and the need for a sustainable lifestyle.

FUTURE WORLDS: Campers learned about the roles of mathematics and analytical methods in understanding and developing sustainable solutions to environmental issues. The activity consisted of two parts including 1) Mathematical modeling kits, which allowed the campers to practice combining different pieces to make a complete structure and 2) Interaction with "Future Worlds", a cyber-learning platform for informal explorations in sustainability, which enables campers see how our choices as a society today can affect our planet in the future.

HOME GROWN: How we manage our food resources has a big impact on the health of our environment. This activity introduced campers to food sustainability, and introduced terms and ideas including free dairy products, rBGH, sustainable seafood, humane treatment and organic foods. The activity concluded with a game of Food Origins Bingo.

WAY TO FLOW: Where does our water come from and where does it go? Campers learned the steps it takes to bring water from our rivers or aquifers to our houses, and what happens when water goes down the drain. Campers also discussed why it is important to conserve water. Campers competed in a game of Water Jeopardy to conclude the activity.

Figure #1: Lafayette College S.T.E.M. Camp Activity Summaries

Before and after questionnaires were distributed to the students both the morning of the first day of the camp, as well as during the afternoon of the final day of the program, in order to evaluate the effectiveness of the camp. The camp was intended to both increase students' cognizance of the concept of sustainability, as well as motivate a change in attitude towards the environment. Two-tiered assessment strategies were developed to evaluate these objectives, with the goal of

not only measuring student increase in knowledge, but learning more specifically what students were able to take away from the experience.[2] The purpose of the two-tiered assessment strategies was to encourage students to not only reiterate information they had learned, but to give them the opportunity to demonstrate how this information can be applied to real world situations. Through written explanations and diagrams, students were able to demonstrate not only an increase in knowledge, but also an increased cognizance of the importance of protecting our environment, and recognizing how changing our behaviors now, can positively impact future generations.

Key Ideas and Methodologies

In order to assess the sustainability modules, and substantiate that the intended learning outcomes are being grasped by students, assessment tools were utilized during the Lafayette College S.T.EM. Camp. The definition of *Assessment,* "the process of gathering and discussing information from multiple and diverse sources in order to develop a deep understanding of what students know, understand, and can do with their knowledge as a result of their educational experiences", as articulated by the National Research Council, was used as the basis for this research.[3] The assessment tools were designed to both quantitatively and qualitatively measure student learning outcomes, as a result of interaction with the sustainability themed modules.

The before and after questionnaires consisted of multiple choice questions, open ended questions, and Personal Meaning Maps. The multiple choice questions were used primarily to measure a collective increase in student knowledge, while the open ended questions served to ascertain the students' overall understanding of the concept of sustainability and attitudes towards the environment. One example of an open ended question was, *In your own words, define the term sustainability,* while an example multiple choice question was, *Of the options listed below, circle those that are examples of renewable forms of energy.* The Personal Meaning Maps gave students the opportunity to illustrate their view of the environment, both at the beginning and conclusion of the camp. At the beginning of the program, the students were given a blank piece of paper that stated at the top, *In the space provided, draw what comes to mind when you think of the environment.* After interaction with the various sustainability themed modules, students were asked to add or revise their drawings using a different colored writing

utensil, based on what they had learned. The before and after questionnaires were matched one to one so that individual student responses could be evaluated. Aggregate data was also collected and analyzed from the questionnaires. The data illustrated a cumulative increase in student knowledge, combined with an increase in awareness and concern for the environment, which substantiates the importance of both informal sustainability education, as well as assessment strategies to verify the effectiveness of these modules.

Conclusion

Through interactive, hands-on experiences, students can effectively apply knowledge gained in a classroom based setting to practical environmental engineering topics, specifically focusing on sustainability. By exposing students to these critical concepts at an early age, they will be more cognizant of pressing environmental issues, such as how to sustainably utilize our planet's energy, water and food supplies so that both present and future generations will have access to these resources. Environmental engineering modules should be developed with the goal of not only increasing student knowledge, but should also be designed with the intention of increasing students' opinion and attitudes towards the environment. In order to substantiate the effectiveness of informal environmental engineering education, assessment methods must be utilized in correspondence with the sustainability modules, to ensure intended learning outcomes are achieved.

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