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Evaluation of a Learning Platform and Assessment Methods for Informal Elementary Environmental Education Focusing on Sustainability, Presented through a Case Study (RTP)

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Abstract

Members of Lafayette College and community partners have developed an informal education platform for upper elementary and middle school-aged learners and a method for assessing the effectiveness of this learning platform. The platform consists of a series of learner-centered, experiential learning modules that are not only aligned with K12 learning standards, but are also in the spirit of ASEE's mission - promoting excellence in instruction, research, public service and practice. Our team of student leaders, along with guidance from faculty mentors and local education experts, designed the modules and trained facilitators to present them. The modules were presented primarily during an annual three-day summer STEM camp for local elementary school students, as well as during one-day campus events. Each of these educational programs was centered on the theme of sustainability.

Presented through a case study, our approach to assessment is iterative, in that we have developed new instruments for each successive educational program which have built upon previously developed assessment strategies. Our learning outcomes effectively address a call to action by the United States President's Council on Sustainable Development and are geared to provide a skill set many believe to be critical to global sustainability. The instruments are designed to elicit both quantitative and qualitative data, through pre and post assessments, via a variety of question types. Our analysis of the data collected reveals increased knowledge and awareness of sustainability issues among participants, suggesting strongly that our desired outcomes were achieved. This analysis is supported by scores at the 95% confidence level which affirms that students perform better on surveys after interacting with sustainability-themed modules. A vast majority of participants (91%) were able to accurately define the term "sustainability" compared to 32% who could do so prior to the start of the camp. There was a statistically significant improvement of student knowledge due to camp involvement. We conclude that this informal education platform is an effective way of teaching sustainability to upper elementary and middle school-aged students and therefore believe our assessment techniques to be valid.

Key Words: Informal Education, STEM, Camp, Sustainability, Assessment, K12, Case Study

Introduction

An environmental STEM (science, technology, engineering and mathematics) camp, which emphasized experiential learning, was developed using an informal educational platform. This case study presents an effective approach for enhancing upper elementary and middle school-aged learners' understanding of and attitudes towards sustainability. Key concepts of the modules of the camp were assessed. Learning outcomes, focused on increasing students' knowledge about sustainable living practices, were evaluated using questionnaires administered before and after the STEM camp. The questionnaires followed a pre and post-survey format. Although our intent was to measure change in knowledge, the term survey (to measure attitude and intention) is used in place of test (to measure knowledge) because it was thought that students might have pre-conceived negative notions about the term "test".

A gap in informal education literature has been identified. There is peer-reviewed research about teaching sustainability-based modules[1,2] (i.e., short lessons dedicated to a particular topic) focusing on the STEM disciplines to K12 students, but no peer-reviewed research about ensuring the effectiveness of these modules. The target group for this study was fourth through sixth grade students. The study was achieved using experimental learning methodology and evaluated by applying standardized formal assessment techniques to informal modules. The purpose of this case study is to report on the development of a model, presented during an environmental STEM camp, to ascertain its effectiveness as measured through a prescribed assessment process. Assessment tools were employed to measure learning outcomes for the multiple education modules. The assessment instruments were designed to elicit both quantitative and qualitative results through different question types. The emphasis of these modules was sustainable living practices supported with environmental engineering and other appropriate STEM concepts. This model is relevant for use at informal education centers such as museums, summer programs and after school venues. Our culminating analysis, which brings together several years of work, reveals increased knowledge and awareness of sustainability issues among participants, suggesting strongly that our desired outcomes are being achieved.

Background

A literature review focused on informal environmental education revealed a lack of peer-reviewed assessment techniques. This is especially evident regarding issues of sustainable living as it relates to principles of environmental engineering. Our goal was to develop informal assessment techniques to determine the extent of learning about environmental issues amongst late elementary and early middle school aged youth. We accomplished this by creating a STEM camp for this population and exposed them to critical environmental issues that will ultimately impact society's future economic, social-cultural and ecological dimensions[1,2,3,4]. We proposed that as a result of exposing students to the concept of sustainability, which is not formally taught in standard school curricula[5], students would be more knowledgeable of how to sustainably use our resources now, to ensure that future generations will have access to these same resources[6,7]. The development of assessment techniques for informal environmental education directly aligns with the mission of the American Society for Engineering Education (ASEE): promoting excellence in instruction, research, public service, and practice as well as exercising leadership and fostering the technological education of society[8].

Environmental sustainability themed modules support and/or enhance the Pennsylvania Department of Education Standards for Environmental Education taught in traditional fourth through sixth grade classrooms. Students should be able to apply the core science concepts presented in school to the ideas presented in sustainability-focused modules[5]. Informal education is described as education that takes place outside of the standard classroom learning environment, in a less structured setting that shifts the management of learning from the teacher to the student[9,10]. Traditional K12 education practices typically follow pedagogical, or teacher-centered, learning methodologies. Informal education modules, such as those developed in this case study, encourage learners to be more self-motivated and responsive to experiential, individualized learning and is commonly referred to as, learner-centered or andrological learning. Learner-centered teaching practices have been found to be a more effective approach in education[11,12,13,14] promoting long-term mastery of the knowledge and skills presented. This is more likely to lead to the adoption of attitudes and behaviors favorable towards sustainability.

As stated in a publication by the National Academies Press[15], "Science, engineering, and technology permeate nearly every facet of modern life and hold the key to solving many of humanity's most pressing current and future challenges". In the same publication the National Academies Press states a well-known fact, that the "United States' position in the global economy is declining, in part because U.S. workers lack fundamental knowledge in these fields", and goes on to present a suggested framework which outlines a broad set of science and engineering expectations for K12 education. Therefore, informal education modules with a focus on environmental engineering would serve to improve our nation's fundamental knowledge of STEM fields and enhance students' formal education experience.

The framework used to develop informal environmental modules is based on experiential learning methodology. An early study by Ruiter[16], focused on teaching basic electricity, found experimental, learner-centered teaching to be significantly superior both in the achievement of learning electrical knowledge and in the number of experiments successfully completed. Current research continues to demonstrate that students gain a better understanding and connection to topics presented, and develop critical thinking skills, when experimental learning techniques are utilized[1,2,17,18]. Part of experimental learning includes the process of inquiry. Students this age require guidance throughout an inquiry-based learning approach to learn how to think critically and draw connections and establish cause-effect relationships. Current research shows that applying a purely inquiry based approach does not work well for many[19, 20] because the use of inquiry-based methods ignores human working memory limitations[19,21,22,23,24] and any instructional procedure that ignores the structures that constitute human cognitive architecture will not be effective. In other words, minimal instructional guidance leads to minimal learning[19].

Incorporating assessment tools within the overall structure of informal education curricula is important to determine efficacy and demonstrate the value of environmental education. As found with this case study as well as through other similar studies, assessment in an informal setting can be time-consuming as well as expensive[25]. This realization explains the lack of assessment in informal education centers such as museums[26], summer programs and after school venues[27,28]. The message to take forward is that by performing quality assessment these centers can provide evidence that their programs achieved stated outcomes and increased the likelihood that students received an effective educational experience[25]. It is also worth noting that a program which provides documented, active learning outcomes delivers an ideal selling point for potential funding sources. Therefore, considering this rational, assessment tools were developed and tested iteratively throughout the development of our informal educational platform. The tools developed and used by our leadership team included observation, one-on-one interviews with youth participants and parents, and surveys (i.e., questionnaires). Questionnaires assessed the extent to which a prescribed set of learning outcomes, targeting the issue of sustainability with an emphasis on engineering, were achieved. The use of questionnaires aligns with current education practices, as described in education literature and consultations with experts in the field of K12 education.

Considerations used to Develop Assessment Tools, Learning Outcomes and Modules

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[3], was used as we considered the development of our overall assessment process. Sampson[25], suggested a two-tiered assessment strategy (i.e., pre and post surveys).

Based on a review of current practices and similar studies[30,31,32] a mixed-method approach to assessment was employed. Methods included multiple-choice, Likert scale, open-ended, and matching questions, as well as a Personal Meaning Map (PMM)[33]. A PMM is a cognitive tool for participants to provide their perceptions to a prompt. The goal of the PMM is for participants to explore the meaning of the prompt and to understand the ways in which participants identify and make connections with the prompt and how they use different cognitive frameworks to build upon personal learning experiences.

Initially three learning outcomes were developed which included student attitudes, behavioral intentions, and knowledge about sustainability, and the extent to which students

- Develop favorable attitudes towards sustainability,
- Intend to make behavioral changes to promote environmental sustainability within their personal lives, and
- Increase their knowledge, opinions and attitudes towards the environment and engineering.

These learning outcomes are supported by a number of leaders in environmental engineering. They effectively address a call to action by the United States President's Council on Sustainable Development[34]. The learning outcomes align well with the recommendations prescribed by Facing the Future[35]. In "Sustainability Education in K-12 Classrooms", Church and Kelton describe similar outcomes as critical to global sustainability[36]. These include:

1. Taking a global perspective, including a recognition that issues, people, and places are interconnected
2. Understanding how systems operate
3. Thinking critically and making informed decisions

Although not explicit within our final learning outcomes, environmental engineering and other STEM concepts were a critical component of each module and throughout the framework of the camp. Incorporating STEM disciplines enabled us to best promote an understanding of sustainable living practices.

Targeting an Appropriate Audience

We started the work that lead to this case study with a desire to be as inclusive as possible. Early investigations into the development of informal education modules included a diverse group of students from a wide age range between first and seventh grade[37], spanning between elementary and middle school aged students[38,39,40]. The lower grade choice was partially driven by an author's desire to include his own child (second grade at the time these studies began) in the educational activities. Seventh grade was chosen as an upper limit based on the developmental characteristics of students in this grade

Early on in the implementation of the STEM Camp we found it challenging to have students of such a wide age and ability range working in mixed groups.. We realized that developmentally there was a difference in how students were learning, with a distinct dividing point identified between third and fourth grade students. Based on our early findings, we began to separate the children into two sets of groups, mixed groups of first through third graders and mixed groups of fourth through seventh graders. A literature review revealed that based on the cognitive development of students between 8 and 11 years of age (i.e., between third and fourth grade), a transition from concrete to abstract learning takes place[41,42,43,44,45]. This was important as we needed to develop different modules to present the same concept to accommodate different learning needs by on their developmental level.

Furthermore, findings by Jane Healy[42] serve to substantiate our refined range of fourth through sixth graders. Dr. Healy[42] articulates in her book *Your Child's Growing Mind*, that "the early teenager must move on to manipulating abstract ideas – a transition from the security of concrete skills and rules to a world of infinite possibilities and points of view" (p. 125). Healy elaborates that "late elementary grades are an ideal time to apply skills already learned. Repeating skills and rituals lays a solid base for moving on to new challenges. Children at this age love to soak up information and facts. The most helpful parents and most successful teachers capture their wide-ranging curiosity in active, project-oriented learning" (p. 111). This transitional period in brain development, and ability to process and connect information, provides a beneficial platform for exploring the STEM disciplines through hands-on, experiential activities.

Intended learner outcomes evolved based on the literature reviews, input from education experts, and several iterations of the informal educational camps. The revised learner outcomes measure the extent to which students:

a) Increase cognizance and attitudes towards a global perspective of the environment and sustainability;
b) Could identify personal behavior changes to live more sustainably; and,
c) Could identify how society could change present behaviors to help maintain the planet's limited supply of resources for future generations.

Active learning techniques used throughout the camp provided important information about how systems operate. This allowed students to use critical thinking skills to make informed decisions about sustainable living practices. Because students were active participants in each of the modules, their mastery of the topic and potential for long-term retention of knowledge increased which supported achievement of the learning outcomes.

Case Study

This informal education model, built around the design of a STEM camp, used traditional education methodologies to build assessment tools. These pre and post questionnaires measured the extent to which learning outcomes about sustainable living practices were achieved at four events at our institution including *Brain Bowl (2011)* STEM Camp 2012: *Let's Make a Splash*, STEM Camp 2013: *Our Planet. Our Future*, and Sustainability Event 2014: *There's No Planet B.* The two more recent events are the focus of this case study. All camps were carried out at our institution and were conducted primarily in the engineering building.

Development of Methods

The STEM camp model was developed through an iterative process. Each iteration centered on a different sustainability theme and modules were developed from a single or combination of examples from books, the Internet, and embellished with the creativity and inspiration of faculty, education experts, teachers and students. The author of any particular education module was required to enhance the existing examples in some way which incorporated his/her personality, background, and formal education. Modules included detailed instructions and intended learning outcomes so that they could be easily implemented by others. Camp leaders reviewed and finalized each module for consistency and connections between all modules to a particular camp theme. After experimenting with the instructional times of modules from 45-90 minutes, it was determined that 50 minutes in length was most appropriate for the camp setting. This is in accordance with the attention span of the learners and typical class time in fourth through sixth grade classrooms, which are approximately 45 minutes.

Preparation of Educators

Faculty and students from Lafayette College were trained by the STEM Camp leaders prior to the start of the camp and served as the primary educators. Training sessions focused on learning styles, multiple intelligences, child development, and strategies to increase the comprehension of present complex science, technology, and engineering and mathematics concepts by participants. Classroom expectations and techniques for maintaining a positive learning environment were also reviewed. Trainings were presented by an elementary school teacher and a program planning and evaluation consultant.

STEM Camp 2013: Our Planet. Our Future

A STEM camp, themed *Our Planet. Our Future*, was held in July 2013. The camp centered on sustainable living practices, with a specific emphasis on the sustainable management of food, water, and energy supplies, a thread tying together environmental engineering and other STEM disciplines that was woven into all modules.

Fifty-five students from Easton, PA and the surrounding area attended the program. Activities focused on the importance of a sustainable and clean water supply, energy efficient cars, and global warming. Examples of the hands-on, interactive modules included *Moving Down the Road* and *Is it Getting Hot in Here?.* In *Moving Down the Road* students explored an electric car and then assembled their own battery powered vehicles. In *Is it Getting Hot in Here?* students learned about global warming and the negative implications of anthropogenic climate change. Table 1 depicts the complete list of activities during the three day Camp.

Table 1: Lafayette College STEM Camp 2013 Activity Modules

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.

Rain Barrels: This activity defined storm water and explained the importance of properly managing storm water. Campers learned that installing a rain barrel is part of a set of solutions to better manage our water resources. Campers had the opportunity to paint rain barrels.

Solar Energy: Campers learned about solar powered energy- specifically about solar panels as well as solar thermal conversion. Campers should now be able to identify solar powered energy as a renewable resource.

Organic Farm: While touring the College Farm, campers compared the differences between local and non-local foods. Campers also learned that how and where we grow our food can harm our environment.

Water, Water Everywhere: Campers learned what irrigation is and about some of the positive and negative implications of common irrigation techniques. Campers learned about sources of water commonly used for irrigation, such as groundwater from aquifers and surface water.

Wind Energy – I’m A Big Fan: Campers learned about the difference between renewable and non-renewable energy. Campers learned about wind energy and identified which classification of energy it falls into. Campers also learned about wind turbines and how they work.

Students were assigned groups of 10 students facilitated by one volunteer counselor. The groups rotated through each module so that all students participated in all modules. Throughout the camp, students demonstrated their ability to take core science concepts learned in school, and apply them to the ideas presented through the environmental sustainability themed modules[5]

Sustainability Event*: There's No Planet B 2014*

The Sustainability Event: *There's No Planet B* was held in March 2014. Twenty-two fourth through sixth grade students from regional upper elementary and middle schools participated in this one day program. For this particular event, students were intentionally placed in groups based on grade level. The students rotated between two hands-on, interactive environmental sustainability-themed events during the first half of the day. The second half of the day was used to reinforce lessons learned in the morning portion of the program. Table 2 provides the details of the learning activities of *There's No Plant B 2014*.

Table 2: Lafayette College STEM Camp 2014 Activity Modules

MORNING ACTIVITIES
ONE FOOT, TWO FOOT, RED FOOT, GREEN FOOT[46,47]: Students learned about carbon footprints, and how people can reduce their impact by relying more on renewable resources and less on their non-renewable counterparts.
TAKE BACK THE TAP[48]: Students defined sustainability and then identified ways in which they can make more sustainable choices in their everyday lives. Students also explored the negative environmental implications associated with the bottled water industry and conducted a taste test to demonstrate the similarity between more expensive, less regulated bottled water, and cheaper, more regulated tap water.
AFTERNOON ACTIVITIES
BRAIN BOWL: Students were divided into two groups and completed in a Brain Bowl trivia contest to reiterate and reinforce concepts presented during the morning activities.

Investigation and Development of Assessment Methods

The modules were designed to measure the extent to which participants changed their knowledge, attitude, and intentions to change behaviors about sustainable living practices. Key informant interviews were conducted with two prominent Lehigh Valley educators in the field of informal STEM education: David Smith Ph.D., Senior Director of Science and Strategic Initiatives at the Da Vinci Science Center, and Phyllis Finger, Ph.D., former Enrichment Support Specialist for Easton Area School District. The interviews revealed knowledge of informal education programs and examples of assessment strategies. They also provided guidance for the development of assessment methods. The interviews reinforced the use of multiple assessment techniques, inclusion of learning activities and teaching strategies to meet multiple learning styles, and evaluating learning outcomes.

Assessment was primarily administered through pre and post questionnaires. The questionnaires were designed to collect quantitative and qualitative data, through various types of questions (i.e., multiple-choice, Likert scale, open-ended, and matching questions, and PMM). With each iteration of the camp, adjustments were made to the questionnaires and later to the learning outcomes to reflect the content of each camp theme..

The structure and basic nature of the questions used in our questionnaires were initially based on our learning outcomes, feedback offered by our experts, and the research literature. Prior to the 2013 camp, initial (pre-) and concluding (post-) questionnaires were piloted among a focus group of five youths representing the age range of camp participants. The two goals of this focus group were to ensure that questions were not too easy or too challenging for the intended age group and to determine whether the students understood what was being asked of them. The focus group revealed valuable information regarding survey instructions. Instructions for completing the survey were clearly formulated in a formal prompt that is read to students before the questionnaires were distributed. The prompt read as follows: "*The survey you are being asked to complete is not a test. There are no right or wrong answers to the questions. Please take your time and read each question carefully. If you are not sure of an answer, provide your best educated guess. You do not have to worry about spelling and do not have to write in complete sentences. Your feedback on the survey will help us to make similar sustainability programs at our institution even better next year. Once you have completed the survey, turn it face down and I will collect it when everyone is finished.*" The students expressed that they were able to more easily convey their thoughts if not required to write in complete sentences, or worry about spelling and grammar.

With each iteration of the camp, questions were adjusted to better align with our intended learning outcomes. Questionnaires were administered to student participants at the beginning and end of each camp to determine baseline and post-intervention findings. The post-intervention assessment encouraged students to reiterate information they learned, but also afforded an opportunity for students to demonstrate how they could each apply sustainable living practices in real world situations. Through written explanations and diagrams, our intention was to assess student attainment of the three learning outcomes previously stated, thus meeting our objectives.

Pre and post questionnaires were completed in a classroom setting because the atmosphere simulated a familiar test-taking environment similar to a formal school. While the formal test-taking environment was intended to reinforce that the students took the surveys seriously, it was also important to emphasize that the survey of their experience at STEM Camp and was not a test that would be graded. We believed that this allowed students to express their thoughts more freely without fear of being wrong.

Key informant interviews of student participants and their parents and observation from primary educators throughout the events also provided valuable information. The combination of data sources allowed us to modify certain aspect of the camp to increase achievement of learning outcomes and general operation of the camp. Regional education experts and local K12 teachers were consulted to help address identified weaknesses.

Analysis of Assessment Methods

The final set of pre and post questionnaires, developed through the iterative production of the four programs which made up this case study, consisted of multiple-choice, open-ended, and matching questions, as well as a Personal Meaning Map. These questionnaires are the end product of this case study, therefore the focus of this analysis. They were distributed at the culminating event of this case study - Sustainability Event: *There's No Planet B*. The collected data was analyzed to ensure not only the effectiveness of this informal, educational environmental sustainability themed event, but to also validate the assessment strategy.

Because surveys were distributed to minors and the results were intended to be utilized for future research purposes, Lafayette College's Institutional Review Board (IRB) was required to review and approve the final questionnaires. In addition, Parent-signed consent forms were provided for all participating children - consent was obtained from all participants. Each student was assigned a number that he/she was instructed to record in a designated location on both the pre and post questionnaires. In addition to collectively analyzing the data, the one to one matching of the surveys also allows for the analysis of changes in responses of individuals students between assessments.

The pre questionnaire was comprised of twelve questions and the post questionnaire was comprised of ten questions. Seven of the questions were worded identically in the pre and post questionnaires to make a direct analysis of the change in knowledge. The personal meaning map question was modified from pre- to post- to include instructions for students to add additional images which represented new information learned. This was done to document "learning" throughout the camp. The remaining questions were captured demographic data of the students and their understanding of sustainable living practices. The final production of our pre and post questionnaire are presented in Table 3 and 4.

Table 3: Pre-Questionnaire Utilized at *There's No Planet B* Event

Question #	Question	Correct Response
1	What grade are you in?	N/A
2	What school do you attend?	N/A
3	What is your gender?	N/A
4	Have you participated in activities at Lafayette College in the past?	N/A
5	In your own words, explain the word *Sustainability*.	To meet the needs of the present without compromising the ability of future generations to meet their own needs.

6	Of the following, which would be considered the most environmentally sustainable way to live? a. Recycling all packaging that can be recycled. b. Reducing consumption of all products. c. Buying products labeled *eco* or *green.* d. I don't know.	B
7	For each of the following, fill in the oval of the most sustainable option. *When I bring my lunch to school, I should bring:* 0 A homemade sandwich. 0 A prepackaged lunch meal, such as Lunchables. *When I head to soccer practice, I should take:* 0 Bottled water. 0 A reusable water bottle. *To keep forests as a renewable resource:* 0 All the trees can be cut because they will grow back. 0 Only some of the trees should be cut to leave the environment for animal homes.	A homemade sandwich. A reusable water bottle. Only some of the tees should be cut to leave the environment for animal homes.
8	What is a *Renewable Resource*? What is *Non-renewable Resource*? Give an example of each.	Renewable Resources are resources that can be replenished naturally. Non-renewable resources are resources that cannot be replenished in a short period of time.
9	Write the letter on each line to match the type of energy with the correct energy classification. A. Renewable Energy B. Non-Renewable Energy ____ Solar Power ____ Coal ____ Natural Gas ____ Nuclear ____ Hydro Power ____ Fossil Fuels ____ Petroleum ____ Wind Power	__A__ Solar Power __B__ Coal __B__ Natural Gas __B__ Nuclear __A__ Hydro Power __B__ Fossil Fuels __B__ Petroleum __A__ Wind Power
10	Which of the following statements best describes how our society should use our natural resources? a. Renewable resources such as trees must be used no faster than the rate at which they can be replaced. b. Non-renewable resources such as fossil fuels must be used up quickly to encourage the development of renewable alternatives. c. Pollution must be emitted at current levels so that natural systems can maintain the ability to absorb them. d. I don't know.	A
11	On a scale of 1 to 10, how important is it to make environmentally sustainable decisions, with 1 being *Not Important* and 10 being *Really Important*?	N/A

12	In the space provided below, using a pencil, draw what comes to mind when you think of a *Sustainable Environment.* Label specific parts of your drawing that make it a sustainable environment. Below your drawing, write several sentences that explain why your drawing is a sustainable environment.	N/A

Table 4: Post-Questionnaire Utilized at *There's No Planet B* Event

Question #	Question	Correct Response
1	In your own words, explain the word *Sustainability.*	To meet the needs of the present without compromising the ability of future generations to meet their own needs.
2	What can you do in your everyday life to be more sustainable (Give 2 Examples)?	Possible answers included use a reusable water bottle and use less electricity.
3	What changes can your school make to become more sustainable (Give 2 Examples)?	Possible answers included recycle and install solar panels to use as a source of electricity.
4	Of the following, which would be considered the most environmentally sustainable way to live? a. Recycling all packaging that can be recycled. b. Reducing consumption of all products. c. Buying products labeled *eco* or *green.* d. I don't know.	B
5	For each of the following, fill in the oval of the most sustainable option. *When I bring my lunch to school, I should bring:* 0 A homemade sandwich. 0 A prepackaged lunch meal, such as Lunchables. *When I head to soccer practice, I should take:* 0 Bottled water. 0 A reusable water bottle. *To keep forests as a renewable resource:* 0 All the trees can be cut because they will grow back. 0 Only some of the trees should be cut to leave the environment for animal homes.	A homemade sandwich. A reusable water bottle. Only some of the tees should be cut to leave the environment for animal homes.

6	What is a *Renewable Resource*? What is *Non-renewable Resource*? Give an example of each.	Renewable Resources are resources that can be replenished naturally. Non-renewable resources are resources that cannot be replenished in a short period of time.
7	Write the letter on each line to match the type of energy with the correct energy classification. C. Renewable Energy D. Non-Renewable Energy ____ Solar Power ____ Coal ____ Natural Gas ____ Nuclear ____ Hydro Power ____ Fossil Fuels ____ Petroleum ____ Wind ____Power	__A__ Solar Power __B__ Coal __B__ Natural Gas __B__ Nuclear __A__ Hydro Power __B__ Fossil Fuels __B__ Petroleum __A__ Wind Power
8	Which of the following statements best describes how our society should use our natural resources? a. Renewable resources such as trees must be used no faster than the rate at which they can be replaced. b. Non-renewable resources such as fossil fuels must be used up quickly to encourage the development of renewable alternatives. c. Pollution must be emitted at current levels so that natural systems can maintain the ability to absorb them. d. I don't know.	A
9	On a scale of 1 to 10, how important is it to make environmentally sustainable decisions, with 1 being *Not Important* and 10 being *Really Important*?	N/A
10	Based on what you learned, using a pen, revise your original drawing of a *Sustainable Environment*. Label any additions to your drawing. Below your drawing, write several sentences that explain why the additions to the drawing make the environment sustainable.	N/A

Results

The sample size for the statistical analysis of the data collected was 22 students (45% female; 55% male). Pre and post questionnaires were matched one to one to evaluate individual student responses. A grading rubric was designed with criteria corresponding to each knowledge question to provide consistency of expected responses yielding a response as correct or incorrect, and were coded in a binary output of 0 or 1. The total score was converted into a percentage for the purpose of comparing individual and aggregate scores. Each student was given a score from 0% to 100%. Table 5 depicts the overall test results for the before and after questionnaires.

Table 5: Pre and Post Questionnaire Data Summary Table

	Initial Questionnaire	**Concluding Questionnaire**
Sample Size, n	22	22
Sample Mean, $\bar{x}$ − % Correct	74.8%	91.4%
Sample Standard Deviation, s_x	14.8%	8.6%
Minimum Score	40.0%	70.6%
Maximum Score	93.3%	100%

Multiple choice and matching questions were used to measure a change in student knowledge. An example of a matching question is #9 on the Pre Questionnaire, "*Write the letter on each line to match the type of energy with the correct energy classification*". The energy classification options were either renewable energy or non-renewable energy, and the various types of energy they were to match to these classifications with included solar power, coal, natural gas, nuclear, hydropower, fossil fuels, petroleum and wind power. Only 32% of participants (7 of 22) were able to correctly match all forms of energy to the corresponding classification during the pre-assessment. This is compared to 64% of participants (14 of 22) that were correctly able to match all forms of energy to the corresponding classification during the post assessment (Question #7). A paired t-test reveals a P value of 0.01, therefore indicating statically significant results.

Open-ended questions and Personal Meaning Map served to ascertain students' overall understanding of the concept of environmental sustainability and attitudes towards the environment. One example of an open-ended question is #5 on the Pre Questionnaire, "*In your own words, define the term Sustainability*". Student answers were considered correct if they were able to articulate that being sustainable means to use our resources now in a way such that future generations will have access to these same resources. In the pre-questionnaire (Question #5) 7 of the 22 students answered correctly as compared to 20 of the 22 students responding correctly when the same questions was asked in the post- questionnaire (Question #1). Chi-square and Fisher's Exact statistical tests result in P values of 0.0002 and 0.0001, respectively. This indicates that there is extreme significance evidence that student learning was due to camp involvement rather than chance.

Figure 1 provides a comparison of correct responses to quantitative questions. The data illustrates an increase in student knowledge documented by an average aggregate improvement of the cohort of +8 or better when comparing pre and post questionnaires and an improvement of more than double for questions 5, 6, 8 and 9. Table 6 provides details to the questions highlighted in Figure 1.

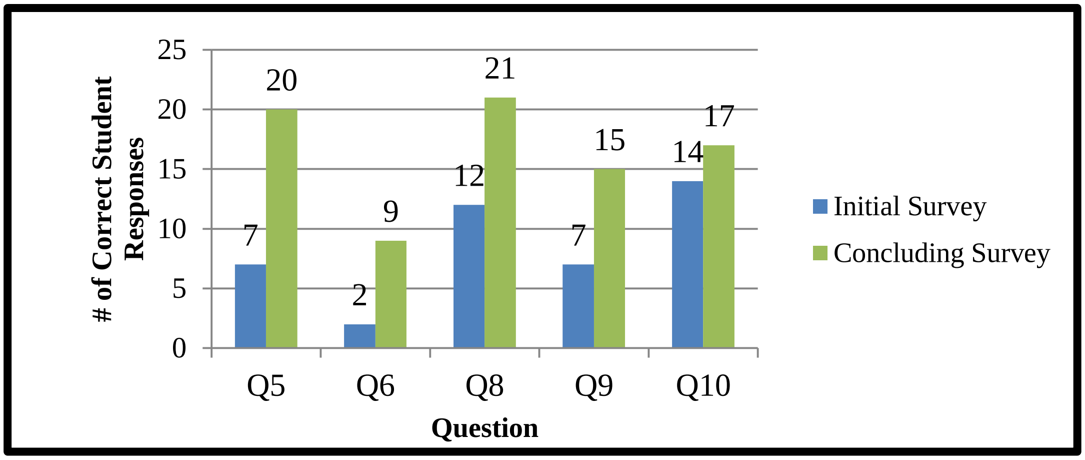

Figure 1: Graph Depicting Correct Student Responses in Pre and Post Questionnaires When Responses Are Paired One to One (Question Numbers Are Based on Figures from Pre Questionnaires)

Table 6: Questions Corresponding to *Figure 1* from Initial Questionnaire

#	Question
5	In your own words, explain the word *Sustainability*.
6	Of the following, which would be considered the most environmentally sustainable way to live?
8	What is a *Renewable Resource*? What is *Non-renewable Resource*? Give an example of each.
9	Write the letter on each line to match the type of energy with the correct energy classification.
10	Which of the following statements best describes how our society should use our natural resources?

The Personal Meaning Map (Figure 2) provided students the opportunity to qualitatively illustrate their view of the environment, both at the beginning and conclusion of the camp. At the beginning, 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 a sustainable environment"*. After interaction with the various environmental sustainability themed modules, students were asked to add or revise their drawings using a different color writing utensil, based on what they had learned throughout the program.

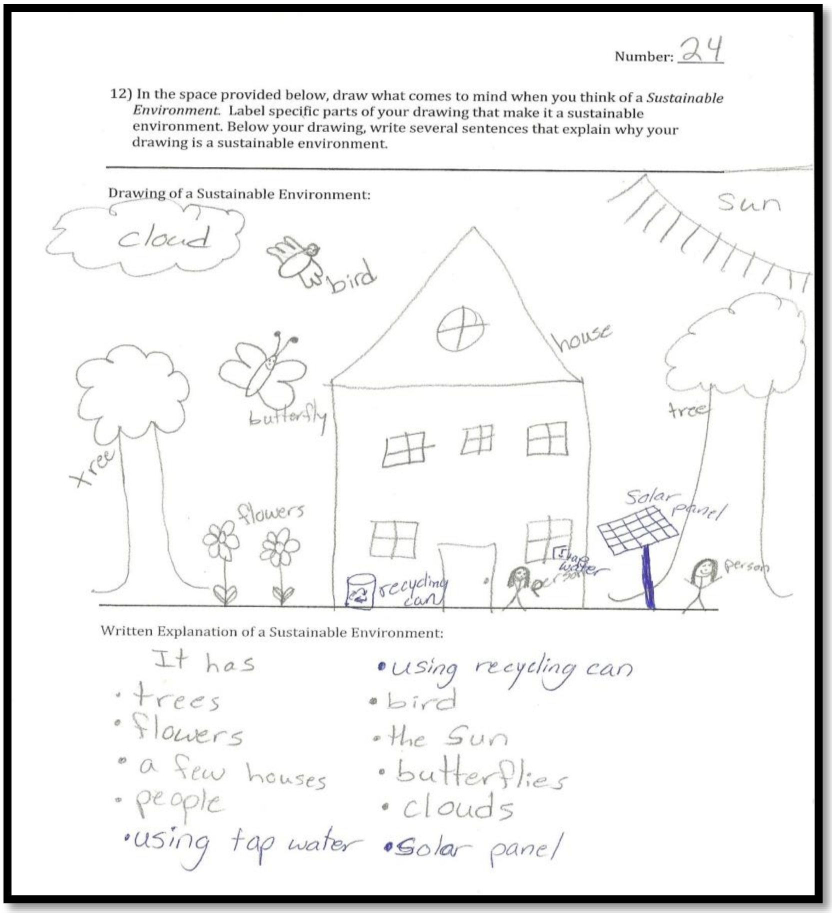

Figure 2: Student Completed Personal Meaning Map Collected from the Sustainability Event: *There's No Planet B (*Original Drawing Completed in Pencil, Drawing Revised with Blue Pen*)*

When considering the statistical validation of learning that took place when comparing pre and post questions #5 to #1 and pre and post questions #9 to #7, the results presented in Figure 1 and the qualitative improvement demonstrated through the Personal Meaning Map (Figure 2) we concluded that a cumulative increase in student knowledge was observed.

Review of the Development of the Pre and Post Questionnaires

The questionnaires distributed at the Sustainability Event: *There's No Planet B* differed from previously developed questionnaires/surveys because they included a wider variety of assessment techniques. The first surveys distributed at the Brain Bowl 2011 consisted primarily of open ended questions which were effective in measuring attitude towards the environment through their anecdotal responses. However, open-ended questions did not effectively measure changes in knowledge. Modifications were made to the surveys distributed at the STEM Camps to include matching questions, which more directly and effectively captured the students' increase in knowledge of the concept of environmental sustainability. The culminating case study iteration, Sustainability Event: *There's No Planet B,* added multiple choice questions and questions relating to the demographic information. Through the four iterations of the surveys, it became clear that the surveys needed to closely align with the learning outcomes and concepts presented in each of the environmental sustainability modules.

Parent/Child Survey

In addition to the coded quantitative data collected from the pre and post questionnaires, parents were asked to complete a survey with their student one week after the event. One week after the event, a follow up survey was distributed via email to the parents of the children who participated in the program. The parents were instructed to complete the survey with their children. The survey response rate was 36%. When asked on a scale from 0 to 10, with 10 being the best possible score, how much the child enjoyed the Sustainability Event: *There's No Planet B*, the average score was a 9.5.

The parents were then asked to provide a written response explaining what the child enjoyed most about the event. Responses included “the hands on experiences” and “that it was an interactive learning environment”. In order to measure retention of knowledge, the parents were questioned, “When asked to define the term *sustainability* how does your child respond?” and “Can your child provide an example of something he/she can do in his/her everyday life to be more sustainable?”, students responses demonstrated a clear retention of the topics presented throughout the program. Student responses included:

- “Sustainability means to take care of and save resources so that future generations can use them too. Don't waste electricity or water. Recycle when you can.”
- “Keeping the earth healthy for future generations. Carpool or ride your bike instead of driving.”

One parent commented, following the Sustainability Event: *There's No Planet B,* “I just wanted to thank you for such a wonderful event and opportunity on Saturday. My son really enjoyed it! He came home saying that he finally understood what ‘sustainability’ means and proceeded to thoroughly explain it to his younger sister.” Another parent commented, “My son had a great time at the Sustainability Event: *There's No Planet B*, in his words it was ‘awesome’”.

Lessons Learned/Implications for Future Research

Throughout this study, many important lessons were learned which could help shape future research studies focused on assessment methods for informal environmental education. Through the various iterations of developed assessment methods, the importance of tailoring a survey for a particular target audience became evident. We found that intermixing a wide variety of student age groups made teaching more difficult and therefore impacted survey results. We also learned the importance of including a variety of different types of questions in order to have a well-rounded survey which can capture various types of data, including demographical information, students’ growth in knowledge and students’ attitude changes in regards to sustainability. It would be beneficial to explore ways in which these survey techniques could become more standardized such that informal environmental education platforms, including museums, after school programs and summer camps could easily adapt the questions to their specific educational modules.

Conclusions

Through a case study, an iterative development of an informal education platform for upper elementary and middle school-aged learners, and method for assessing effectiveness of this learning platform, was presented. Our objectives are summarized as follows:

- measuring students' change in knowledge regarding sustainable living practices by exposure to multiple examples, and
- learning what students are able to take away from the experience.

Our learning outcomes evolved to include:

a) Students *increased cognizance and attitudes towards a global perspective of the environment and sustainability*;
b) Students could *identify they could change behavior to live more sustainably; and,*
c) Students could *identify how society could change present behaviors to help maintain the planet's limited supply of resources for future generations*.

Our leaning platform, a STEM camp, was used to present various teaching modules to expose students in grades fourth through sixth to sustainable living practices. These sustainable living practices, if followed, will ultimately impact society's future economic, social-cultural and ecological dimensions. In particular, students were taught to be cognizant of pressing environmental issues, such as how to sustainably utilize our planet's energy, water and food supplies, and their individual role and responsibilities for adopting a more sustainable lifestyle. As these lessons are not currently part of public school standard core curriculum, this informal education venue enhances students' formal education and supports the call to action by the US President Council on Sustainable Development.

Of the students who participated in the environmental sustainability themed modules, a vast majority, 91%, of participants were able to accurately define the term sustainability at the conclusion of the event. Students' awareness of practical everyday changes they could personally make to live more sustainably increased significantly as evidenced by quantitative and qualitative data from pre and post questionnaires composed of different question types.
The formal assessment model validated the positive change in knowledge about environmental issues, especially sustainability coupled with positive responses from parental follow-up communications.

It should be clear to the reader that, although assessment is time intensive, the benefit of evaluating the impact of a program quantitatively and qualitatively outweighs the costs. Additional benefits include individual student growth, strengthening of community connections, support of formal education practices and establishing evidence of valuable informal programming. These outcomes are essential to sustain long term support and funding necessary for environmental awareness programs to continue and to support long-term impact of behaviors promoting sustainability. In order to demonstrate the effectiveness of informal environmental education, assessment tools must be utilized in coordination with the education modules to measure achievement of learning outcomes, including enhanced student knowledge, opinions, and attitudes towards the environment.

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