BIOENERGY ACADEMY FOR TEACHERS (BEAT) PROMOTES MULTIDISCIPLINARY CONTENT IN STEM EDUCATION

Dr. Madhumi Mitra Ph.D, University of Maryland, Eastern Shore

Dr. Madhumi Mitra is currently a professor of environmental sciences in the department of Natural Sciences at the University of Maryland Eastern Shore. She is also the coordinator of Biology and Chemistry Education. Dr. Mitra is actively involved in teaching and research in the areas of biofuels and renewable energy; applications of algae in food and environment; and water quality. She has published several peer-reviewed articles in journals and conference proceedings, and is the recipient of various awards and competitive grants. Dr. Mitra received her baccalaureate degree from Presidence College in Kolkata, India with honors in Plant Biology, Geology, and Physiology. She received her master's degree from University of Calcutta, India, and her doctoral degree from North Carolina State University, Raleigh, NC in 2002.

Dr. Abhijit Nagchaudhuri, University of Maryland, Eastern Shore

Dr. Abhijit Nagchaudhuri is currently a Professor in the Department of Engineering and Aviation Sciences at University of Maryland Eastern Shore. He is a member American Society for Mechanical Engineers (ASME), American Society for Engineering Education (ASEE) and, American Society for Agricultural and Biological Engineers(ASABE) and is actively involved in teaching and research in the fields of (i) robotics and mechatronics, (ii)remote sensing and precision agriculture, and,(iii) biofuels and renewable energy. He has published more than 70 refereed articles in journals and conference proceedings. Dr. Nagchaudhuri received his baccalaureate degree from Jadavpur University in Kolkata, India with honors in Mechanical Engineering. Thereafter, he worked in a multinational industry for a little over three years before joining Tulane University as a graduate student in the fall of 1987. He received master's degree from Tulane University in 1989 and doctoral degree from Duke University 1992.

Mr. Xavier Shastri Domnique Henry
Ms. Courtney RC Shirvani, University of Maryland Eastern Shore

Student development and programming professional with experience in academic, enrichment and recreation program development, implementation and evaluation. M.A. in Foundations of Education from Hofstra University.

BIOENERGY ACADEMY FOR TEACHERS (BEAT) PROMOTES TRANSDISCIPLINARY CONTENT IN STEM EDUCATION

Abstract

Although the emphasis of various programs for STEAM (Science, Technology, Engineering, Agriculture, and Mathematics) educators provide general enrichment activities, there are a very few that are focused on the topics of bioenergy and bioproducts with a multidisciplinary approach. By training educators (grades 6-16), it is anticipated that the students at middle and high schools, and four year colleges will not only be reached, but also become more aware of greenhouse gas emissions, climate change, and the deleterious effects arising due to dependence on foreign oil. During the one-week summer institute on Bioenergy and Bioproducts, held at the University of Maryland Eastern Shore, educators across STEAM participated. The two objectives of the BEAT program are: 1) to provide a systems-perspective in renewable energy with a particular focus on bioenergy and bioproducts to STEAM educators and researchers; and 2) to develop and provide curricular materials and a set of teaching tools for educators for enhancing multidisciplinary instruction in the areas of sustainable bioenergy and bioproducts. The academy focuses on lessons and activities pertaining to sustainability, systems thinking, bioenergy, bioproducts, bioheat, biopower, and environment and policies related to energy issues. The participants got the opportunity to acquire concrete experiences involving teamwork, time management, and project execution skills; reflected on their learning experiences through presentations and the end of the institute; developed concepts related to organic chemistry, physics, engineering design, instrumentation, mathematics, biological and environmental sciences, and actively experimented with feedstock to generate biodiesel and environmentally friendly soaps using glycerin produced from biodiesel. In addition, the engineering and physics faculty, who were participants also conducted peer-teaching in Bioheat and Biopower with related hands-on activities such as energy generation using a microbial fuel cell and *Biolite* demonstration, where biomass such as wood fueled a dual cooktop/phone charger. A microbial fuel cell was constructed using electrogenic bacteria that were already present in mud sentiments and appropriate electrodes were chosen to power up a Light-Emitting Diode (LED) light. The BITES (Building, Industry, Transportation, Electricityy Scenarios) simulation tool developed by National Renewable Energy Laboratory (NREL) of the United States Department of Energy (DOE) and made freely available over the internet allowed participants to play out scenarios to reduce carbon foot print based on various situations that can be realized through policy decisions leading to building improvements, reduction of industrial pollution, use of alternative fuels, electric cars, and other design modifications in the transportation sector, and cleaner more efficient conversion technologies for electricity generation and conservation. A total of forty one educators have been trained through this program over a period of four years. The evaluation surveys (content and perceptions) reveal that educators gained substantial knowledge in the fields of sustainability, bioenergy, and bioproducts, and felt comfortable in implementing the content in their courses and laboratories. Various STEAM courses have been impacted positively through the infusion of components in sustainability and renewable energy offered by the program. This further supports the successful implementation of the multidisciplinary approach in the curricula. The key issues on “environmental stewardship” across disciplinary boundaries

have broad overlaps with the 21st century's grand challenges espoused by the National Academy of Sciences and the National Academy of Engineering.

1. INTRODUCTION

1.1 Background Information

The Planet Earth is facing several crises and with the unsustainable trends continuing, the world will witness increasing interconnected problems such as overpopulation, elevation of greenhouse gases leading to disruptive climate, poverty, resource depletion, loss of biodiversity, food and water scarcity, and political instability. These will eventually cause the life support systems enter a state of disequilibrium[1]. Although being "green" or eco-conscious is a positive step towards a sustainable world, the term "sustainability" encompasses more than ecological integrity[2]. The three pillars or E's of sustainability (environment, economics, and equity) relate to fostering of communities that are healthy, safe, secure with economic opportunity for everyone while keeping the Earth's life support system viable[3].

Education is one of the effective means for providing solutions to the problems related to the "trilemma" of food, energy, and environment. Programs geared toward providing functional knowledge, concepts, principles and policies with respect to the global "trilemma" can be very beneficial for developing awareness among students. Renewable energy and environmental education can motivate students to make efforts towards development and implementation of various strategies to face challenge encountered by the energy sector including the provision of meeting this crisis in an eco-friendly manner. The values and attitudes of students toward harnessing renewable energy sources and associated socio-economic and environmental dimensions can play crucial roles in shaping a more sustainable world for tomorrow[4,5,6,7]. With the publication of Education for Sustainability: An Agenda for Action in 1996 by the United States President's Council on Sustainable Development, global sustainability has become prevalent in the curricula of K-16 classrooms. Sustainability and Renewable Energy education do provide the context or foundation for education in many subject areas as it transcends disciplines. The concepts and activities on sustainability can also provide ample opportunities for educators to reinforce skills of critical thinking, systems thinking, collaboration, and communication[7].

The diverse "green initiatives" of the University System of Maryland (USM) as a whole (http://www.usmd.edu/usm/sustainability/) have provided the foundation for the existing program titled, "BEAT (Bio-Energy Academy for Teachers) the Energy Crisis and Enhance BLT (Bio-Energy Literacy for Teachers)." outlined in this paper. By providing today's educators with a comprehensive overview that "green" industries are complex systems requiring a wide range of skills, more of today's students (tomorrow's workforce) are getting training to develop a systems perspective of the STEM (Science, Technology, Engineering, and Mathematics) fields and are learning to appreciate the wide range of skills necessary to address the challenges. Through directed training and programs such as the BEAT, the students reached so far have been developing a systems approach in problem solving, and increasing the likelihood of long-range improvements in the multitude of aspects encompassed in the "sustainability" issue. The primary

goal of the BEAT program aligns with the overarching vision to expand the familiarity and knowledge of university faculty, in-service (middle, and high schools) as well as pre-service STEAM (science, technology, engineering, agriculture, and mathematics) teachers participating in the program with the complex topics of sustainable bio-energy and bio-products through a systems perspective. By training educators, it is anticipated that the students will become more aware of the greenhouse gas emissions, climate change, and the deleterious effects arising due to dependence on foreign oil. Exposing middle, and high school students, and university students and their faculty to these topics will not only foster greater awareness but also generate increased interest in STEAM careers. It probably does not come as a surprise that the recommendations made by the National Academy of Engineering for transforming engineering curricula for the new millennium echo that of the National Academy of Sciences and encourages sweeping changes that promote the integration of life-skills and civic responsibility outcomes along with academic outcomes as part of the overall educational experience of STEAM[8].

1.2 Objectives

The two objectives of the BEAT program are: a) To provide a systems-perspective in bio-energy/biofuel and sustainability issues to middle and high school in-service and pre-service teachers as well as university faculty. The overarching vision is to expand the familiarity and knowledge of middle school, and high school level STEAM teachers and undergraduate pre-service teachers as well as university faculty from agriculture, biology, chemistry, mathematics, engineering and technology participating in the program with the complex topics of sustainable bio-energy through a systems perspective. Bioenergy systems comprise biomass resources, supply systems, conversion technologies, and energy services[9]. Through the systems approach, the educators are exposing their students to the various perspectives related to the utilization of natural resources for bio-energy, ways to mitigate the global climate change, and understand the complexities that are involved in modern scientific and technological challenges. The students are also exposed to career choices in the cutting-edge STEAM disciplines; b)To develop and provide curricular materials and set of teaching tools for educators for enhancing instruction in the areas of sustainable bio-energy and sustainability in their classrooms--In addition to training the STEAM educators on a systems perspective of renewable energy, the program includes developing and providing curricular materials and laboratory tool kits for implementing classroom activities in bio-energy/bio-fuels and sustainability. The curricular materials are aligned with the national and state standards of science, technology, and mathematics and do provide sample lessons in bioenergy for middle, and high school students.

2. PROGRAM OVERVIEW

2.1 Participant selection

The team (primary author and the coauthor) developed the program process and selection criteria. The educators submitted their resumes and a description of how they would use the training materials and/or training experience in their classrooms or research. Ten participants were selected during the first, second, and third years and eleven in the fourth year. The institute hosted a total of 41 educators for a period of four years. The educators were a mix of in-service

teachers, pre-service teachers, university faculty, teaching technicians, and graduate students. The high school teachers are represented cumulatively in the greatest number at 32%, followed by middle school teachers and university faculty at 22%. The graduate assistants represented 17% of the total participants across four years and the pre-service teachers made up 7% of the overall program participants (Table 1).

Table 1: Teaching Partner Professional Distribution

All Teaching Partners	Total of 41	100%
Teaching Partner Occupation	Total Number 2011-2014	Total Number as Percentage
Faculty	9	22%
Research Assistants	7	17%
High School Teachers	13	32%
Middle School Teachers	9	22%
Pre-service Teachers	3	7%

2.2. Activities at the Institute

An important aspect of the BEAT program is to leverage the existing successful efforts (training programs, engagement exercises, and training tools such as lab kits) to build a multidisciplinary, more comprehensive systems-oriented training package. Some of the highlights of the program activities during the one-week summer institute over the period of four years are delineated below:

Biodiesel

In the biodiesel activity, participants are introduced to the environmentally-friendly alternative to petro-diesel that is capable of being used in many of today's vehicles with diesel engines. The concepts of carbon neutrality are also expounded upon since it is an integral reason for the adoption of biodiesel as an alternative in today's carbon-heavy economies. Using products that are readily available from many "big-box" and automotive stores (HEET, a source of methanol and Drain opener, a source of sodium hydroxide), in addition to vegetable oils that were pressed from grains produced at the UMES research fields, small amounts of biodiesel were created in the lab to demonstrate the ease with which that fuel can be synthesized. The synthesis of the fuel also led to discussions concerning the market penetration of the fuel in the US versus other global markets as well as the viability of the byproduct, glycerin, which was used in the glycerin soap making. This activity culminated in a brief tour of the university's biodiesel facilities where the fuel is regularly made from waste cooking oil for the use in farm equipment as well as for the

diesel power generator powering the Integrated Multi-trophic Aquaculture (IMTA) facility where both shrimp and *Gracilaria* are produced in an attempt to address food, energy, and environment concerns in the future bioeconomy in a sustainable way (Figure 1).

Gracilaria to Bioethanol

Another biofuel to which participants were exposed was bioethanol. Here, macroalgae grown in the IMTA system is used to demonstrate the synthesis of ethanol which can be used as an additive to traditional gasoline or as its own alternative fuel in newer technology vehicles. The *Gracilaria* grown in the IMTA tank is commonly referred to as a nuisance alga since it readily forms pervasive blooms around the MidAtlantic region. Fortunately, from a biofuels perspective, the seaweed is comprised of quantities of easily fermented sugars, which is what the participants make use of in this lab, by simply macerating the alga and then treating it with basic baker's yeast and allowing the medium to culture over a 24- hour period. Thereafter, the medium can be filtered of solids and distilled to reveal the small amount of crude ethanol liberated by the process. In a retrospective discussion, participants were given the opportunity to again surmise as to the viability of such techniques and products in the current market place and to how the process may be improved to increase future viability (Figure 1).

Algal PBR

In this activity, participants were exposed to the concepts and of algal bioenergy and algal production systems. The scenario began with a brief lecture on algal ecology, to include micro and macro algae, eutrophication, algal storage compounds and other pertinent information. The activity then culminated in the participants constructing their own algal photobioreactors (PBR's) complete with *Arthospira platensis* inoculums and growth media using two 500ml plastic water bottles, aquarium air hoses, and an aquarium air-pump (Fig 2a). After constructing their PBR's, participants were also exposed to the implications of using PBR's in research and were allowed to tour current investigations using various scales of PBR's for the bioenergy and bioremediation efforts being undertaken at the university.

Glycerin Soap Synthesis

In this activity, participants were introduced to a potentially valuable byproduct of biodiesel production using biodiesel glycerin (also known as glycerol). The glycerin that was previously obtained from the synthesis of biodiesel on campus was used to make environmentally-friendly soaps (Figure 2b). Kits, produced at the university, contained all the necessary materials to allow for the saponification reaction to be satisfied safely. The basic reaction, an acid plus base, utilizes the fatty acids present in the triglycerides within the biodiesel glycerin and react with sodium hydroxide (Lye), to produce the soap (a salt) and glycerin, which serves as a moisturizer. Essential oils from a variety of sources were also added based upon the individual's preference to add another dimension of originality to the soap making process. After completing the reaction in the classroom, the participants were exposed to several methods which they could employ to test the quality and safety of their soaps. Once the soaps were allowed to set and dry after 24 hours, they were also given the opportunity to create decorative bars as gifts and mementos.

Sustainable Bioproducts

Given the common misconceptions surrounding "green" and organic products, the bioproducts activity was designed to expose participants to the many facets of these up–and-coming products. Firstly, a discussion of what it means to be "green" and organic was held to arrive at a consensus. At this point, several product demos and trials were convened to put these products through their paces. Some of the activities included a tasting of algal food products such as seasoning and chips and the synthesis of a biopolymer packaging peanut to protect an egg during an egg drop activity. There was also a comparative assessment of various traditional versus green cleaning products against common day-to-day stain causing compounds. Interestingly enough, the participants concluded that many of the green alternatives met or in some cases exceeded their expectations in comparison with the performance of the traditional products.

Mudwatt Microbial Fuel Cell

The Mudwatt Microbial fuel cell (MFC) activity was centered on the potential for harnessing energy from living microorganisms. The MFC's is a bioelectrical device that takes advantage of the natural metabolic activities of microbes to produce electrical power directly from organic material. In this activity, the participants collected mud from the banks of a river located on the UMES campus, and prepared it for use in the MFC. The MFC chamber was then filled with the mud and allowed to sit until a steady pulse of light was emitted from the diode indicating peak productivity. The participants were also able to check the voltage obtained from their cells and compared it with different mud preparations (Figure 2c). The resistance of the MFC was also varied and its effect on the system was also recorded.

Biolite

Using the BioLite stove, the participants were exposed to the concept of thermodynamics, thermoelectric materials, the Seebeck effect, and the practical applications of their use in today's society in addition to how the varied energy densities of feedstock may impact the energy production regime. The participants were given an opportunity to collect various materials from outside and then test their suitability for combustion within the stove. Thereafter, the stove was used to charge several mobile devices and also to roast marshmallows and make green tea for the participants to enjoy (Figure 2d).

BITES

Buildings, Industry, Transportation, and Electricity Scenarios (BITES) tool can be accessed from the URL:https://bites.nrel.gov/education.php. It has been developed by National Renewable Energy Laboratories (NREL) and allows users to create 'what if' scenarios to explore and compare outcomes related to baseline reference cases of the carbon footprint by adjusting energy inputs to buildings, industry, transportation, and electricity generation sectors in the United States. An activity developed in consultation with developers of the tool at NREL was integrated in the institute in the third year. The educators participating expressed that the tool allowed them to better comprehend the broader dimensions of the overall picture that provides relevance for the emphases on bioenergy and bioproducts during the institute. In particular, they could readily

see the carbon implications of using more biofuels in the transportation sector, as well as increased use of biomass for heat and power generation for buildings, industry, and electricity generation sectors.

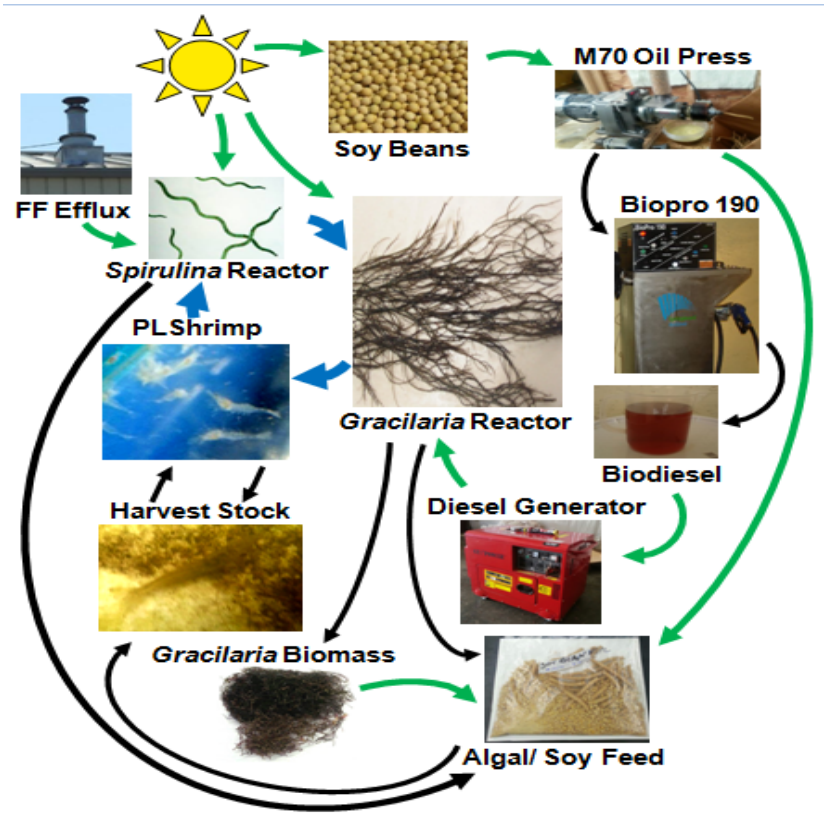

Figure 1. Schematic of IMTA System depicting the production of oil from oil seeds for biodiesel synthesis, the use of the biodiesel to meet the IMTA's electrical needs, and the production of *Gracilaria* biomass for bioethanol production.

Figure 2. **(a**) Participants receiving a brief lecture on algae ecology and putting the final touches on their water bottle PBR systems; **(b**) Bioproduct soap making with biodiesel glycerin **(c)** Demonstration of the Mudwatt microbial fuel cell; **(d)** Participants using the Biolite to prepare roasted marshmallows and charge their cell phones.

3. RESULTS: PROGRAM IMPACT

3.1 Content Knowledge and Perception Surveys

The educators were administered a multiple-choice test consisting of 20 questions. Teaching partners took this test twice: once before the institute and the second time after the institute to measure the impact on the content knowledge in the areas of sustainability renewable energy with a particular emphasis on bioenergy, and bioproducts. The pre-test scores before attending the institute were much lower than the post-test scores. The data indicated that there was an improvement in the scores of the post-tests for all the four years of the institute. Figure 3a shows that the average pre-institute score on this test was 42% while the average post-institute test score among educators was 77%. The online perception survey was also a pre and post-assessments comprised of eleven questions in which the educators rated their comfort level teaching the topics within the following areas: Agriculture, Sustainability, Forestry, Systems Thinking, Biomass, Biodiesel, Ethanol, BioHeat, BioPower, BioProducts, and Environmental Policy. The chart below shows the pre-test to post-test scores of 2011-2014 participants. The two different columns in the light blue and dark blue show the pre vs post-test percentages of educators who selected the criteria designations ‘somewhat comfortable’ or ‘very comfortable’ to describe their comfort-level with each of the listed topics. Comparing these two columns and the overall results of the pre-institute to post-institute perception survey scores, it can be inferred that there was an increase in the content knowledge and comfort level of teaching topics such as sustainability, bioenergy, and bioproducts for the participants. This change is indicated by a shift toward increased levels of comfort through a self-assessed rating, where each participant indicated his/her perceived comfort level with a given topic on a 5 point scale ranging from ‘very

uncomfortable',' somewhat uncomfortable',' neutral ', to somewhat comfortable and very comfortable. Specifically, this change evidences a percentage shift and increase with respect to the above-neutral scale designations 'somewhat comfortable' and very comfortable'. Prior to the institute, an average of 25% of the participants selected the rating designations 'somewhat comfortable' and or 'very comfortable' in describing their level of comfort in teaching the given workshop topics: Environmental Policy, Bioproducts, Biopower, Bioheat, Ethanol, Biodiesel, Biomass, Systems Thinking, Sustainability, Agriculture and Forestry. However, at the conclusion of the institute almost 76% of the participants selected the higher comfort level ratings of 'somewhat comfortable' and or 'very comfortable' to describe their familiarity and competencies with these topics (Figure 3b).

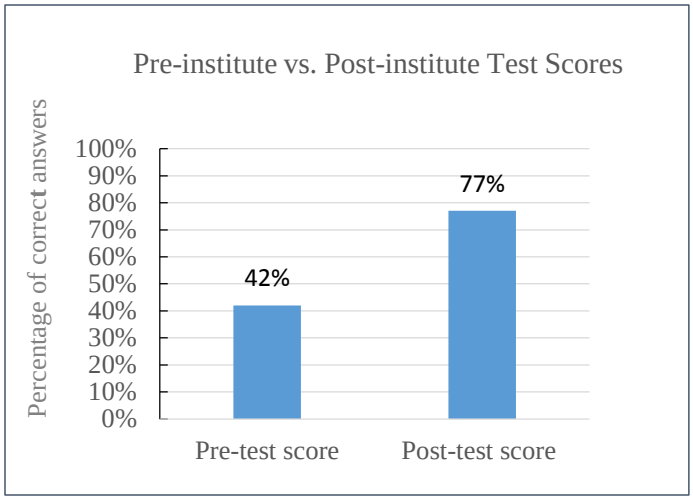

Figure 3A. Pre vs. Post Institute Test Scores

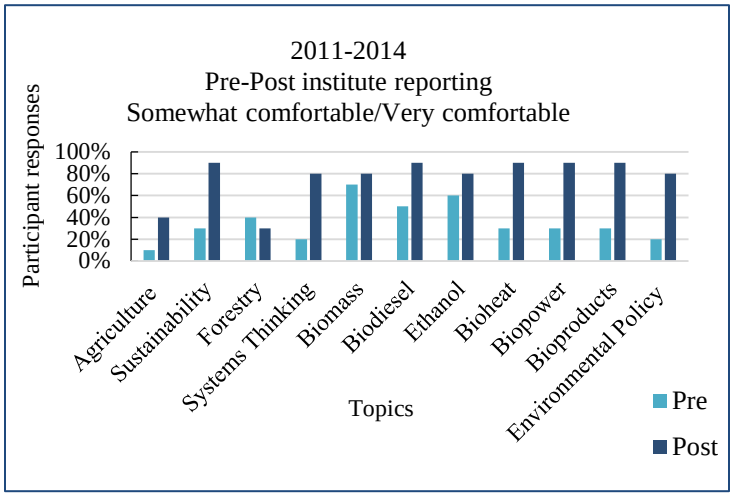

Figure 3B. Pre vs. Post Institute Perception Survey

3.2 Ratings for Program Labs/Activities

The program has also developed another survey related to educator perception of the quality of the institute. This survey was completed the final day of the institute. It provided educators with statements related to BEAT program curricula, to which they responded on a five-point likert scale where 1 represents poor/low, 2 fair, 3 good/medium, 4, very good/medium high and 5 excellent/high. Each of the BEAT program lectures, labs and activities were included in this survey. A total of eleven labs and hands-on activities and six lectures were rated. Each of the categorized lab exercises/activities and or lectures had some variation of the following criteria (depending on whether they referenced a lecture or lab):

1. Knowledge of the subject by presenter (*same for both)
2. Clarity of presentation or clarity of presentation and lab activity
3. Time management (*same for both)
4. Application to classroom (*same for both)
5. Quality of power point lecture or quality of lab activity

The surveys were completed by all the forty one participants for the four institutes. Figure 4 depicts an example of the survey for individual lab/activity/lecture.

BIOENERGY ACADEMY FOR TEACHERS EVALUATION OF ACTIVITIES *Please rate from 5 to 1, with 5 as Excellent and 1 as Poor.*					
EXAMPLE					
LAB/ACTIVITY/ LECTURE 1:					
Knowledge of the subject by presenter	5	4	3	2	1
Clarity of presentation and or activity	5	4	3	2	1
Time management	5	4	3	2	1
Application to classroom	5	4	3	2	1
Quality of power point presentation	5	4	3	2	1
Comments:					

Figure 4. Example of survey for individual lab/activity/ lecture component

With respect to lab exercises/activities, the photo bioreactor lecture and lab, soap lab, grasses to sugar lab and sustainability activity received solely the ratings of ‘excellent’ and ‘very good’ for all of the four insitutes. (Figure 5).

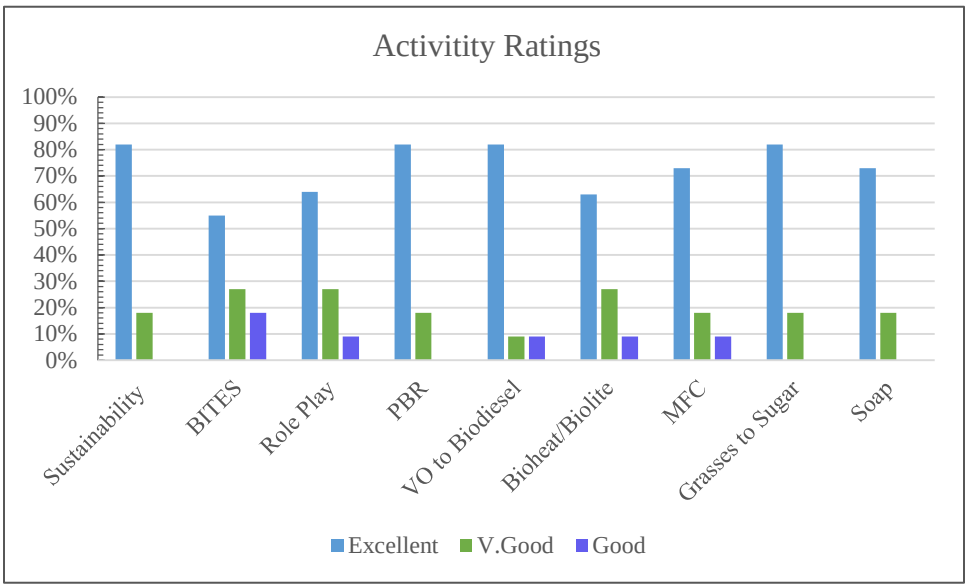

Figure 5. Site Activity Ratings

4. STUDENT IMPACTS

4.1 Classroom Implementation: Activity Implementation (2011-2013)

From program years 2011-2013, 26 out of the 30 (86%) Teaching Partners who participated in the BEAT program implemented one or more of the activities presented during BEAT in their home classrooms. Data across these first three years shows that the Soap lab and Vegetable Oil to Biodiesel lab were tied as the most frequently implemented classroom exercises by participants. The algal photobioreactor lab was the second most popular activity. Many participants also implemented one of the following: Grasses to Sugar lab, Bioproducts, BITES, and Sustainability (lecture and teacher-designed activity) (Figure 6.)

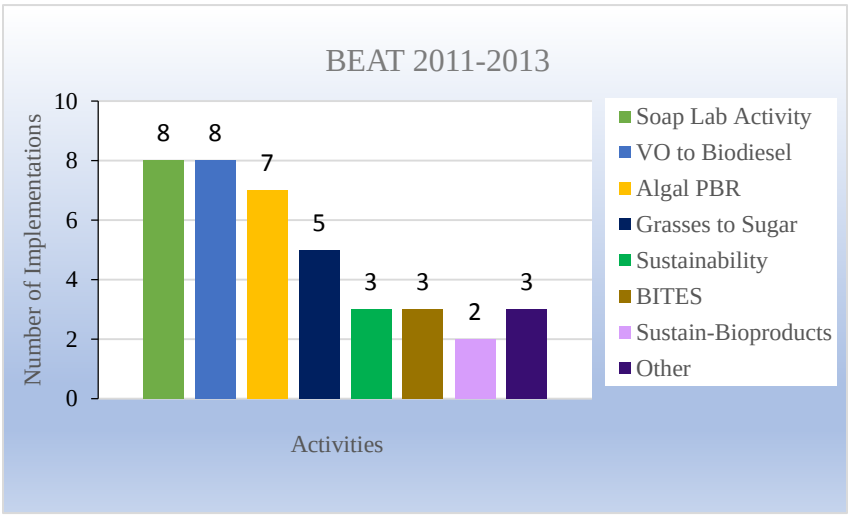

Figure 6. Activities Implemented 2011-2013 (Years 1-3)

4.2 Classroom Implementation: Projected Activity Implementation (2014-2015)

As of January 2015, six out of the eleven participants (54%) have implemented one or more of the activities in their classrooms. Of all the lessons, the Photobioreactor and Soap labs were the most frequently implemented. The Sustainable Bioproducts and BITES were tied as the second most popular activities followed by the Sustainability lecture and designing of sustainable office. home, and city/town. Other activities that are scheduled to be implemented in the current year include the Microbial Fuel Cell, Biolite, and Vegetable Oil to Biodiesel (Figure 7).

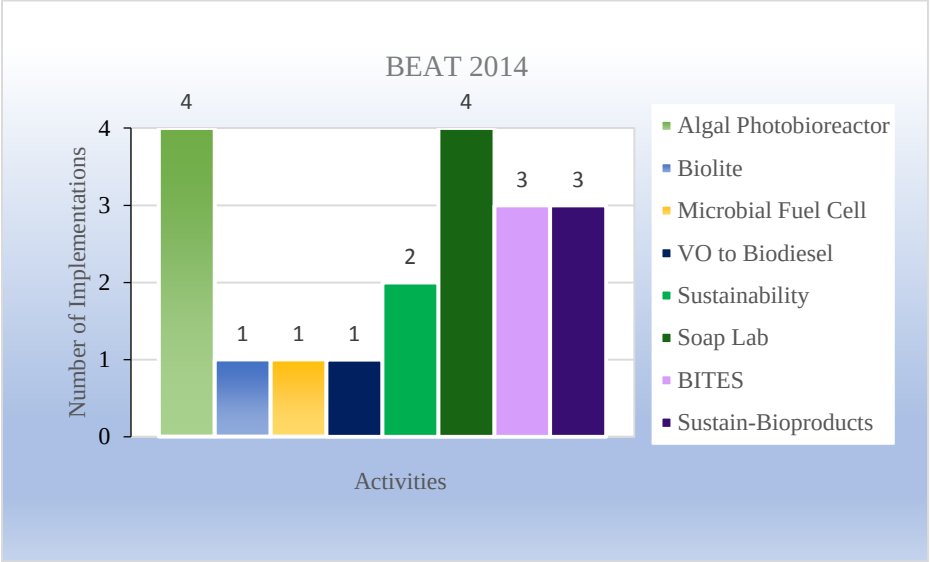

Figure 7. Projected Activities Implemented 2014 (Year 4)

4.3 BEAT Interdisciplinary Impacts

The following table (Table 2) summarizes the activities which were implemented in various courses in middle and high schools as well as undergraduate classrooms.

Table 2.Activities, disciplines, and level implemented and impacted

Activity	Disciplines Impacted	Level
Algal PBR	Plant Science, Technology, Biology, Marine Botany, Materials Science, AP Chemistry, General Integrated Science	Middle School, High School, Post-Secondary
Soap Lab	Marine Botany, Biology and Earth Science, Biology and Environmental Sciences, Chemistry, Transdisciplinary Class, AP Chemistry, Materials Science	Middle School, High School, Post-Secondary
VO to Biodiesel	Biology, Chemistry, Technology, General and Analytical Chemistry, General Integrated Science, Biology and Environmental Sciences, AP Chemistry	Middle School, High School, Post-Secondary
Bioethanol lab from feedstock and algae	Ag. Science, Plant Science, Marine Botany, Chemistry, Biology, and Environmental Sciences	High School, Post-Secondary
Sustainability activity-design of homes, office	General Integrated Sciences & Human Ecology, Transdisciplinary Class	Middle School, Post-Secondary
Earth as an Apple	Earth Science & Biology	High School
Sustainable Bioproducts	Chemistry, General Integrated Science, Materials Science, Transdisciplinary Class	Middle School, High School, Post-Secondary
BITES	Pre-Algebra, Biology and Environmental Science, Environmental Science, AP Chemistry	Middle School, High School,
Biolite	Engineering, Transdisciplinary class	Post-Secondary
Microbial Fuel Cell	Physics, Transdisciplinary class	Post-Secondary

4.4 BEAT Student Reach and Activity Impact

The reach and student impact for each activity offered through the BEAT program is measured by the following conditions:

- Number of course implementations per activity
- Average course attendance numbers during these implementations - including multiple course sections, where relevant.
- Program year in which each activity was implemented. This tracks cumulative projections based on the first two conditions.

It is estimated that more than 2300 students have been reached through the implementation of various BEAT activities in classrooms of middle and high schools as well as universities. The following table (3) shows the breakdown of the number of students impacted per activity.

Table 3. No. of Students Impacted Per Activity

Activity	No. of Students Impacted
Algal PBR	526
Soap Lab	598
VO to Biodiesel	536
Grasses to Sugar	285
Sustainability Activity	128
Earth as an Apple	72
Sustainable Bioproducts	128
BITES	113
BIOLITE	20
Microbial Fuel Cell	10
Totals:	2316
	>2300 Students Reached

4.5 Student Learning Reporting: Perception Survey Data

Following the classroom implementation of BEAT activities, the teachers have collected and reported students' feedback through Student Feedback and Perception Surveys developed by the primary author of this paper. These qualitative record students' perception of learning outcomes though BEAT activities implemented in their classrooms. The students surveyed responded to the following statements on a 5-point likert scale in which 1 represents strongly disagree and 5. represents strongly agree. Based from data collected and compiled, it is evident that the majority of the students who took part in the surveys either agreed or strongly agreed with the following statements (Figure 9):

- This activity gave me a deeper insight into the topic.
- This activity complemented my understanding of in-class learning
- This activity was meaningful within my coursework and studies
- This activity helped to advance my academic growth in STEM

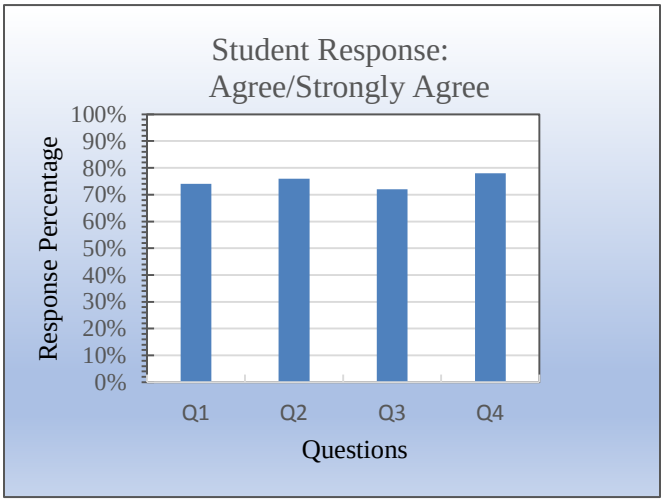

Figure 9. Student Perception Survey Data

5. CONCLUSIONS AND DISCUSSION

The program has been successful in engaging educators from the "STEAM" disciplines. Through hands-on learning activities in classrooms, fields, and laboratory settings, participants are more aware ofthe critically important issues of the "carbon cycle" and its relevance to renewable energy with a special focus on biomass, sustainability, climate change, and the utilization of natural resources and wastes for the generation of bio-products. Survey instruments for students' perception and appreciation of topics related to renewable energy and sustainability are currently being developed to document and analyze feedback from the high school and university students. Teacher training materials such as workbooks focusing on topics related to sustainability, bioenergy, and bio-products from natural resources and wastes have been developed along with assembled biodiesel, algal photo-bioreactor, and soap kits. As a follow-up, educators have been utilizing these resources to develop unit and lesson plans and to share with their peers so that more educators and their students are positively impacted. Besides contributing to the workforce development needs in areas of critical importance, the BEAT program efforts are enhancing awareness of sustainable practices such as reducing waste, promoting recycling, and advancing the green initiative on campus as well as on the lower Eastern Shore. Sustainable approaches to deal with issues related to energy, the environment, and agriculture are prominent in the grand challenges of the 21st Century as identified by the National Academy of Science and the National Academy of Engineering (http://www.engineeringchallenges.org)[10]. The activities in the program are consistent with the recommendations of the National Academies with regard to transformational changes to agriculture, science, and engineering education for the new century and provide a foundation for continued education endeavors. Some of the activities (algae photobioreactor, biodiesel from cooking oil, environmentally-friendly soap making, microbial fuel cell, Biolite, and BITES) from the institute are permanently incorporated in agriculture, food, and resource sciences; marine and environmental sciences; engineering curricula; and other STEAM courses at UMES. The tool has been also used by the co-author of this paper in the "Thermodynamics" course that is offered to engineering juniors. At the summer institutes, only the "Basic Mode" of BITES tool was utilized. Currently, the engineering students are exploring the "advanced mode" of the tool that looks into the further details within each adjustable component of the "basic mode". This is assisting in developing a more comprehensive understanding of the tool and providing insight with policy decisions and their consequences. Overall, the BEAT program along with other existing experiential learning activities on renewable energy and sustainability at the university has been attracting in the STEAM with a focus on sustainability issues. The program has trained forty-one educators over a period of four years and more than two-thousand students have been reached in grades 6-16. It is anticipated that if the educators continue to implement the lessons in their classrooms there will be a greater impact of the students reached. The classroom tools, lab kits, and workbooks are self-sustaining for the educators not just in their classrooms but to other teachers through sharing of resources. The knowledge in the training sessions is transferable to other regions of the country.

Acknowledgements

The authors would like to acknowledge the generous support by the Unites States Department of Agriculture's Capacity Building grant # 2012-02586 and Food Research Initiative (AFRI) Competitive Grant no. 2011-67009-30055 from the United States Department of Agriculture.

Special thanks are extended to Drs. Das and Zhang for peer-teaching Microbial Fuel Cell and Biolite respectively. The graduate and undergraduate research assistants of the interdisciplinary research group, "Renewable Energy and Sustainability" led by Drs. Mitra and Nagchaudhuri are also acknowledged.

References

[1]Cortese, A. "Foreward." In Holley Henderson, "*Becoming a Green Professional: A Guide to Careers in Sustainable Architecture, Development and More*. New York: John Wiley, 2012, xi-xiii.

[2]Costanza, R, et al. 1997. The value of the world's ecosystem services and natural capital. *Nature*, **387** (5): 253-260.

[3]Elkington, J. 2012. *The Zeronauts: Breaking the Sustainability Barrier*. New York: Routeledge.

[4]Jennings, P., and Lund, C. 2001. Renewable energy education for sustainable development. *Renewable Energy*, 34: 435-439.

[5]Berkovski, B. 1998. Global renewable energy education and training: In: *Proceedings of the sixth international symposium in renewable energy education.* Tata Energy Research Institute. New Delhi: November 1998, 11-23.

[6]Kandpal, T. and Broman, L. 2014. Renewable energy education: A global status review. *Renewable and Sustainable Energy Reviews* 34: 300-324.

[7]Sallee, C., and Edgar, d. 2013. Student perceptions of instructional methods towards alternative energy education. Journal of Agricultural Education, 54 (2): 130-142.

[8]Mitra, M, Nagchaudhuri, A, and Rutzke, C. 2013. Energizing the STEAM curricula with Bioenergy and Bioproducts. 2013 Proceedings of the American Association of Engineering Education, Atlanta, June 2013.

[9]McCormick, 2010. Communicating Bioenergy: a growing challenge, *Biofuels, Bioproducts and Biorefining.* **4** (5): 494-502.

[10]21st Century Grand Challenges of Engineering: http://www.engineeringchallenges.org/