# Energizing the STEAM curricula with Bioenergy and Bioproducts

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

Dr. Madhumi Mitra is an associate professor of Biological and Environmental Sciences in the Department of Natural Sciences at University of Maryland Eastern Shore. She is also the Coordinator of both the Biology and Chemistry Education Programs at UMES. Dr. Mitra obtained her Ph.D degree in 2002 from the Department of Plant Biology at North Carolina State University in Raleigh, North Carolina. She is also the coordinator of Biology and Chemistry Education programs at UMES. She received her Bachelor's degree from Presidency College, Calcutta, India; thereafter received her Master's degree in Botany with a first class from the University Colleges of Sciences and Technology, Calcutta, India. Dr. Mitra is actively involved in research and teaching in the fields of biology, geology, environmental and marine sciences, and pedagogy. She is the recipient of many awards, scholarships, and grants.

**Dr. Abhijit Nagchaudhuri, University of Maryland, Eastern Shore**

Abhijit Nagchaudhuri is a Professor in the Department of Engineering and Aviation Sciences at University of Maryland Eastern Shore. Dr. Nagchaudhuri is a member of ASME and ASEE professional societies and is actively involved in teaching and research in the elds of engineering mechanics, robotics and control systems; precision agriculture and remote sensing; and biofuels and renewable energy. Dr.Nagchaudhuri received his bachelors degree from Jadavpur University in Calcutta, India with a honors in Mechanical Engineering in 1983, thereafter, he worked in a multinational industry for four years before joining Tulane University as a graduate student in the fall of 1987. He received his M.S. degree from Tulane University in 1989 and Ph.D. degree from Duke University in 1992.

**Dr. Corinne Johnson Rutzke, Corinne Rutzke**

Dr. Corinne Johnson Rutzke is a Senior Research Associate in the Department of Biological and Environmental Engineering at Cornell University. Rutzke directs a multi-state, multi-institution professional development program for educators (National Bioenergy & Bioproducts Education Programs). She also develops hands-on teaching tools, workbooks, and videos focusing on the topics of bioenergy & bioproducts. Rutzke earned a B.S. in Agricultural Sciences-Plant Pathology from The Ohio State University, an M.S. in Seed Science & Technology from Cornell University, and Ph.D. in Horticultural Physiology focusing on Controlled Environment Agriculture from Cornell University. She lives in Ithaca, NY and runs a small farm with husband Mike and two children Mikey and Ella.

**Energizing the STEAM curricula with Bioenergy and Bioproducts**


## Abstract

The mission of the University of Maryland Eastern Shore (UMES) is to prepare professionals and leaders in an ethnically diverse environment along with improving Science Technology Engineering Agriculture, and Mathematics (STEAM) instruction and research in the State of Maryland while serving a large population of underrepresented minority students. The Bioenergy and Bioproducts Educational Programs (a partnership between Cornell University and five other universities) at UMES are very well aligned with the University of Maryland System's, "green" initiative. This program is geared towards helping reform educational infrastructure by promoting multidisciplinary activities and content in the areas of bioenergy and bioproducts. Such an interdisciplinary perspective enhances interactions of investigators, K-16 teachers and faculty, and pre-service teachers across disciplinary boundaries to provide insight to some of the intractable problems related to the environment. During the one-week institute on Bioenergy and Bioproducts for STEAM teachers and faculty held at UMES in the summer of 2012, various hands-on activities along with bioenergy and bioproducts-related curriculum development materials were presented to the ten educators. The educators represented middle and high school math, technology, and science teachers; and faculty and graduate teaching assistants involved with undergraduate science and math teaching at the university. The activities implemented at the institute followed Kolb's experiential learning cycle with some adaptations. The participants got the opportunity to acquire concrete experiences involving teamwork, time management, and project execution skills; reflected on their learning experiences through presentations at the end of the institute; developed concepts related to organic chemistry, engineering design, instrumentation, plant sciences, physics, mathematics, and environmental sciences; and actively experimented with virgin and used cooking oils to generate biodiesel, designed and set up a simple algae photobioreactor for culturing algae with the eventual objective of extraction of oil from the algal species and converting the oil into biodiesel, and made environmentally-friendly soaps from the glycerin produced from the biodiesel. Tools and kits were given to the participants to assist them in instruction in the classrooms and laboratories and for further advancing their STEAM curricula with a focus on bioenergy and bioproducts. The evaluation surveys conducted reveal that the educators gained substantial knowledge in the fields of bioenergy and bioproducts and expressed their interest in implementing the content as well as laboratories in their curricula.

In the context of this project, discussions are already underway to promote such interdisciplinary efforts and synergize activities though the development of a core facility for bio-energy and sustainable bio-products. The project provides a model not just for other minority-serving institutions to accelerate reform efforts with interdisciplinary projects but also for other institutions that are examining best ways to position themselves for the future in order to maximize their key strengths. The key issues can also be captured in the multidisciplinary dimension of the terms "biodiesel/renewable energy" and "environmental stewardship" that have broad overlaps with the 21$^{st}$ Century's grand challenges espoused by the National Academy of Sciences and the National Academy of Engineering.

## 1.0 **Introduction**

In the last couple of years, significant effort has been devoted at the University of Maryland Eastern Shore (UMES) to develop a broad-based multidisciplinary framework encompassing the STEAM disciplines to promote education and research in bio-energy and bio-products. Significant support from United States Department of Agriculture (USDA) through the Agriculture and Food Research Initiative (AFRI) and 1890 Capacity Building Programs (CBG) have not only helped initiate and sustain the efforts but also have set the stage for involving 1890 land grant colleges such as to play a positive role in realizing the vision outlined in the 2012 National Bio-economy Blueprint of President Obama [1]. Today's television commercials, tea-bag messages, cartoons, and many product packages communicate the message, "your choices can change the world." Over the past decade, it has been observed that student populations are drawn to related “energy and environmental” issues. Many colleges and universities have adjusted program offerings and content to reflect the students’ interest. Just as “*Space”* inspired learning in the 1960s and beyond, the *energy and environmental issues* inspires learning today [2]. The authors are involved with several USDA funded projects at UMES that address these issues. In one of these efforts supported by USDA(AFRI) - the National Bioenergy and Bioproducts Education Program( NBBEP) led by Cornell University UMES partnering with five other universities to promote bioenergy and bioproducts related instructional and field activities among K-16 in-service, pre-service school teachers and college faculty across disciplinary boundaries. The goals of the NBBEP are: 1) better appreciation for bioenergy and bio-based products and their implications on climate change/environment, foreign policies, rural, regional, and national economies aligned with one of the outcomes of ABET inc.( the accreditation body for engineering and technology programs) ―broad education to understand the impact of engineering solutions in a global and societal context’; 2) currícula refinement in middle and high schools as well as undergraduate collages in the northeast through incorporation of more bioenergy materials in the STEAM courses and currícula; 3) motivate and inspire students to pursue careers in the STEAM disciplines with appreciation of sustainable issues; and 4) strengthening collaborations with existing partners as well as school systems for future projects (both research and education) on bioenergy and bio-based products and global climate change. Each NBBEP partner offers internships (summer field experience) and a NBBEP Institute during the summer at their site, immediately following the three-week enrichment and planning effort held at Cornell University where all the site instructors and project leaders participate. This paper focuses on the summer institute on Bioenergy and Bioproducts held at UMES led by the authors.

## 2.0 **NBBEP and the Kolb’s Experiential Learning Framework.**

Each NBBEP site targets to recruit ten participants from middle/high school in-service teachers from nearby counties and states, pre-service teachers attending their own or a partnering institutions’ teacher education program, and college teachers in any of the STEAM disciplines. The activities implemented at the institute is consistent with Kolb’s experiential learning cycle with appropriate adaptation[3] as shown in Figure 1.The weekly schedule mandates the participates to have daily attendance during the week, take part in a pre and post workshop content survey and daily readings from a primer provided to each participant. Each participant is required to develop an integrated lesson plan on a topic of their choice presented at the institute for their own classroom. They are also encouraged to provide feedback on the institute and the feedback they receive from their own classroom after implementing the lesson plan developed during the institute in the summer, in the forthcoming fall or spring term.

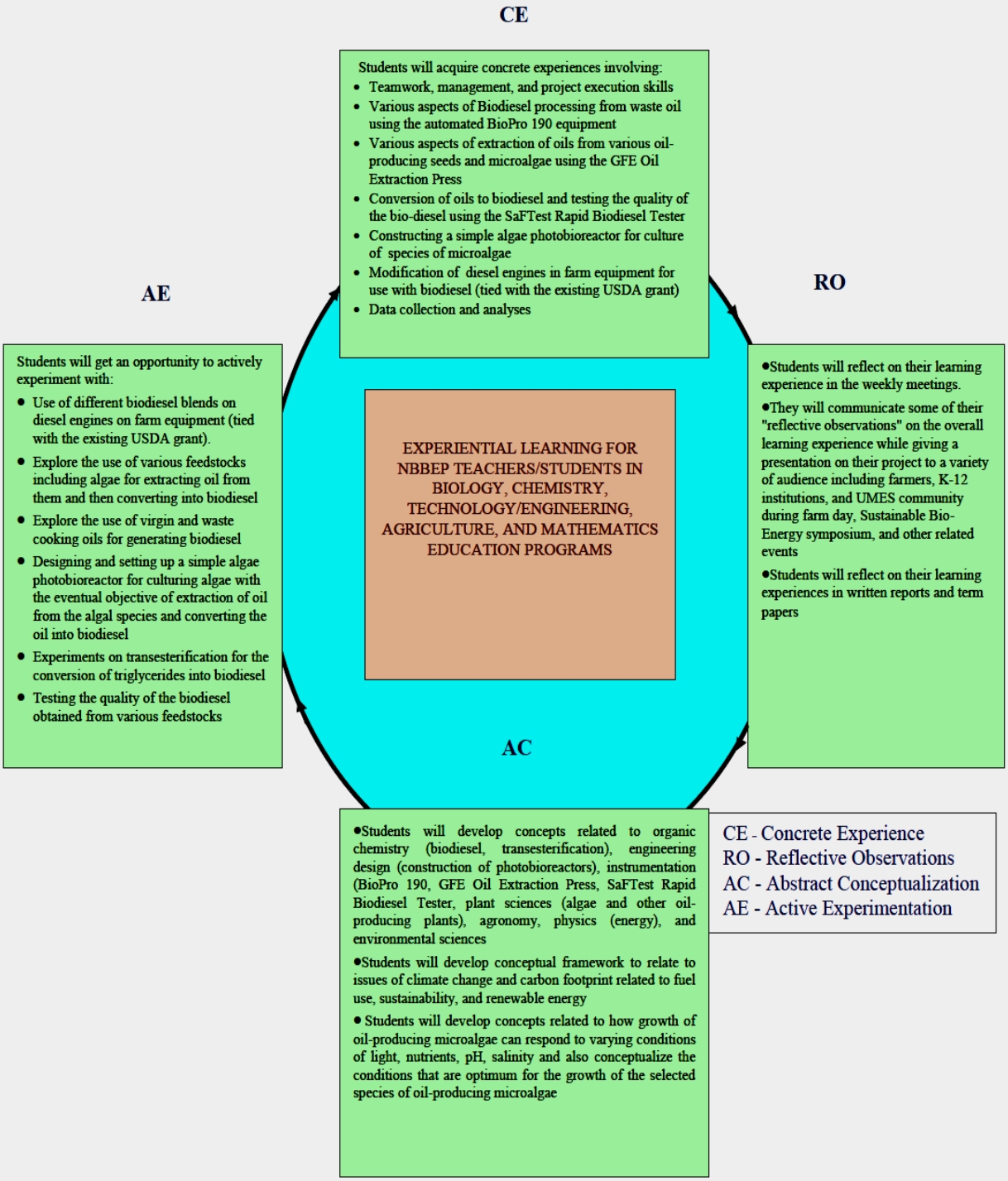


**Figure 1**: Kolb's Experiential Learning Cycle adapted NBBEP

## 3. NBBEP Institute at UMES

### 3.1 Objectives

The objectives of the NBBEP Institute at UMES are:

*1. To provide a systems-perspective in bioenergy and bio-products training program to STEAM educators and researchers:* The overarching vision of the proposed project is to expand the familiarity and knowledge of STEAM educators and researchers from agriculture, biology, chemistry, mathematics, engineering, and technology participating in the program with the complex topics of sustainable bioenergy through a systems perspective. Bio-energy systems comprise biomass resources, supply systems, conversion technologies, and energy services[9]. Through the systems approach, the educators are able to expose their students to the various perspectives related to the utilization of natural resources for bioenergy and bioproducts and 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.

2. *To develop and provide curricular materials and a set of teaching tools for educators for enhancing instruction in the areas of sustainable bioenergy and bioproducts*: In addition to training STEAM educators on a systems perspective of bio-energy, the program and the institute focus on developing and providing workbooks and laboratory tool kits for implementing classroom activities in bioenergy and bioproducts. The workbooks that are developed are aligned with national and state standards of science, technology, and mathematics and do provide sample lessons in bioenergy and bioproducts for middle and high school students. It is anticipated that the bioenergy and bioproducts teaching tools will become self-sustaining following the termination of the project.

3. *To leverage other ongoing training activities and training tools in bio-energy:* Another important objective of the program is to build upon the existing strengths and increase the efficiency of the investment in the current project by leveraging other already-existing bioenergy educational projects, educational training, and educational product development programs. The NBBEP program at UMES is specifically leveraged on the current, USDA-funded ongoing program in "Bio-Fuel, Sustainability, and Geospatial Information Technologies to Enhance Experiential Learning Paradigm for Precision Agriculture Project." These undertakings have provided a new and relevant dimension to enrich the cross-disciplinary educational experiences of educators and researchers in classrooms, laboratory, and field settings.

### 3.2 Participant Selection at the Summer Institute at UMES

In the first year, the team (primary author, coauthors, and other site directors) developed the program process and selection criteria. The selection process is based on criteria developed and agreed upon by the project investigators. The educators and researchers 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 year and second year. The Ten participants selected, were a mix of in-service teachers (Agriculture, Biology, and Technology), UMES faculty (Chemistry, Agriculture, Human Ecology), teaching technician in Chemistry, graduate teaching assistants in Biology and Environmental Sciences and undergraduate research assistants in Engineering.

### 3.3 Activities at the Institute

An important aspect of the program is to leverage existing successful efforts (training programs, engagement exercises, and training Tools such as lab kits and interactive white board

presentations) to build a multidisciplinary, more comprehensive systems-oriented training package. There are new activities developed and implemented during the one-week institute.
The following major activities are:
A) **Biofuels Race to the Pumps teaching game** –This is a systems approach to present biomass to liquid transportation fuels to both children and adults (developed by Cornell University). This is designed to teach students the concepts and steps involved in converting various biological starting materials into bio-based transportation fuels – from the farm to the fuel pump. The game also emphasizes the important benefits of research by allowing ―quick advances for players who land on a ―Cornell R&D‖ spot and are advanced more rapidly toward the goal. The biofuel pump at the end of the game states―We all win! This is reminding us of the ecological benefits that the use of biofuels will bring to the whole planet (Figure 2).

Figure 2. Race to the Pumps Teaching Game

B) **Cornell's Biomass to Sugars**-Incorporated in the institute is a lab kit for classrooms that utlizes a rapid dip-stick type color-changing glucose indicator allowing participants to make and detect sugars from a wide range of biomass feedstock and allowing them to experiment with different pre-treatment approaches (grinding, adding vinegar (acid), and other possible pre-treatments) (Figure 3).

Figure 3. Biomass to Sugars laboratory

C) **Biodiesel activities**—One of the primary foci of the institute is to teach the participants to produce biodiesel from different feedstock and algae. Biodiesel is also a carbon neutral, cleaner

burning fuel and is the preferred choice over petroleum-based diesel with regard to climate change and other pollution considerations. The STEAM educators and researchers did get an exposure of the present status and future prospects of bio-fuels from ethanol and biodiesel to biotechnological routes to biohydrogen. The handouts given out at the institute included the teaching materials and information on feedstock systems and biodiesels from various sources, instructions for the tools (each participant received a biodiesel kit from Utah Biodiesels Supply [4], and information on various resources and careers related to sustainable bioenergy. Through discussions and hands-on experiences, the participants are able to learn about making mini batches of biodiesel using different types of oil; and how to assess performance of the biodiesel to operating equipment pertaining to agriculture, engineering, and the environment; and how to evaluate information from a global perspective to present a picture of the biofuels movement, its successes, its historical failures, and its achievable goals within the next few decades (Figures 4a-b).

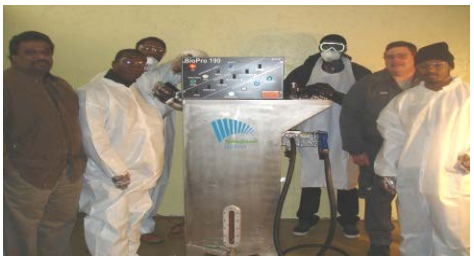

Figure 4a. BioPro 190 at the UMES Biodiesel facility for making biodiesel from waste cooking oil

Figure 4b Biodiesel making process in laboratory from virgin oils

A field trip to a local biodiesel company in Princess Anne, MD, is conducted where the participants are able to see how waste vegetable oil collected from restaurants, cafeterias, and other places is filtered, dewatered, and processed into biodiesel fuel (Figure 4).


Figure 5. Waste to fuel cycle (permission from Greenlight Biofuels)

D) **Algae Photobioreactor Kit activity**—The purpose of this activity is to learn about algae especially microalgae as photosynthetic, non-vascular, unicellular plants that can be used as an alternate energy source. Microalgae, like higher plants, produce storage lipids in the form of triacyglycerols (TAGs). TAGs can be used for the production of biodiesel via a simple transesterification reaction in the presence of acid or base and methanol. With the increasing interest in biodiesel as an alternative to petro-diesel, many are looking at the possibility of

growing micro-algae as a solution. When it comes to growing algae, there are two choices—open ponds or PBRs. A photobioreactor (PBR) can be described as an enclosed, lighted, algal culture vessel designed for controlled production of algae. PBRs have several advantages over open ponds such as: these can prevent or minimize contamination; offer better control over existing conditions (such as pH, light, carbon dioxide, temperature); prevent water evaporation; lower carbon-dioxide losses due to outgassing; permit higher cell concentrations; and allow algae to grow in any controlled microclimate. Through this activity, the participants designed and constructed a simple PhotoBioreactor (PBR) from the ―off the shelf parts. PBR pumps air to algal cultures, and uses bubble streams to keep the algae agitated and also prevents sedimentation (Figures 6 a-b).

Figure 6a. Participants constructing the PBR

Figure 6b. PBR with algal culture

E) **Glycerin Soap Synthesis with Kit**- The participants utilized glycerin (a valuable byproduct) resulting from the production of biodiesel at the UMES biodiesel facility, in preparation of environmentally-friendly, moisturizing soaps. They are able to understand the concepts and practical uses of organic chemistry (Figures 6a-d). During the soap making process, the glycerin (32oz) is heated to 180 degree F over medium heat in non-aluminum pot. The measured amount (2.49 oz) of NaOH is dissolved in distilled water (7oz) to create lye solution. The lye solution is introduced slowly into the glycerin mixture and stirred gently. A measured amount (5 oz) of fatty acid (lauric acid) is added to glycerin and mixed thoroughly (Figure 7a). Using the immersion blender the mixture is stirred until ―tracing or first formation of soap occurs (Figure 7b). The soap is poured into the mold and allowed to harden for about 24 hours (Figure 7c) and was then ready to cut into bars (Figure 7d).

7a

7 b

7c

7d

Figure 7. Glycerin soap making process

**Bioproducts Demonstrations**—a) Bio-foam demonstration--The demonstrations showed how soybean oil could be converted into foams for insulation, furniture, or construction materials (Fig. 8a); b) Shrink-Wrap demonstration—Each participant received an icecold bottle of water and a clear plastic shrink sleeve made from polylactic acid (PLA), a corn product. Utilizing hair dryers, the participants shrink-wrapped the PLA material to their bottles of water to display the potential of corn plastic packaging (Fig. 8b).

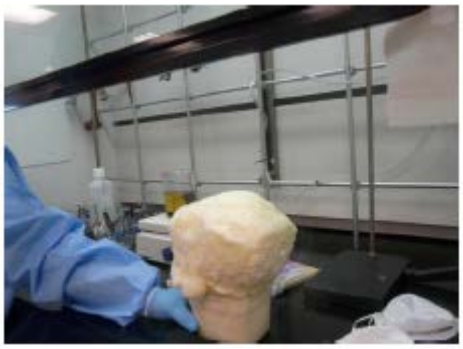

Figure 8a. Soybean oil converted into soyfoam

Figure 8b. Shrink wrap demonstration

## 4. OUTCOMES/RESULTS

On the final day of the institute, the trainees are required to make presentations on their lessons related to what they have learned at the summer institute. The workshop also included career exploration activities, invention activities, and educator/researcher graduation/completion certificates. Each participant received three kits: a biodiesel kit, a simple algal photobioreactor kit, and a soapmaking kit assembled at UMES. The biodiesel kit tools and parts are purchased from Utah Biodiesel Supply [4] and assembled at UMES to form a complete kit. The biodiesel kit contained tools that have the capabilities of filtering waste oil, producing biodiesel from new or used oils from any source, performing titrations, and performing conversion testing on finished biodiesel. The simple algal photobioreactor kit contained the materials needed for constructing the photobioreactor. This gave the participants an opportunity to use scientific methodology for designing a cost-effective algae photobioreactor where they can grow pure cultures of algae that are sources of bio-diesel. The participants in the program developed charts of how they plan to use the information and tools in their classrooms and research (Table 1).

Following the summer experience and training, the educators and researchers have been working with the primary author and co-authors and project personnel in the areas of science, mathematics, engineering and technology, and instructional design to ensure that the curricula and inclusive activities developed are aligned with national standards of science, agriculture, mathematics, and engineering/technology as well as Maryland's content standards in science and mathematics (applicable to the three in-service teachers). The principal author of this paper along with the co-authors followed up with each educator and researcher to provide support, answer questions, and visit the classroom while the teacher is incorporating the training materials. The educators have provided feedback and suggestions for improvement to the next year's participants. They will be presenting their curricular materials and how those impacted their students' learning at the sustainable bio-fuels symposium during the fifth year of the project.

| Educator/Researcher | Status | Subject Area (STEAM) | Which specific activity from the institute was incorporated in classroom or research? | How/Where was the activity implemented? |
|---|---|---|---|---|
| 1 | High School Teacher | Biology | Glycerin Soap Making Kit | 9-12 science classrooms |
| 2 | High School Teacher | Agriculture | Grasses to Sugar | 11-12 agriculture ed classroom |
| 3 | High School Teacher | Technology | PBR | 11-12 technology classrooms |
| 4 | Research Technician | Biology/Chemistry | PBR | Special Workshop on Bioenergy for undergraduate students |
| 5 | Graduate Teaching Assistant | Biology/Agriculture | Biodiesel kit | Principles of Biology I lab |
| 6 | Graduate Teaching Assistant | Environmental Sciences | PBR | Marine Botany laboratory course |
| 7 | Undergraduate Researcher | General Engineering | Biodiesel kit | Continuing research in biodiesel and presenting at regional conferences |
| 8 | Undergraduate Researcher | Electrical Engineering Technology | Glycerin Soap Making Kit | Continuing research in extracting essentials oils from organic herbs and making environmentally-friendly soaps with glycerin and extracted oils. |
| 9 | Agriculture Professor | Agriculture-Plant and Crop Sciences | Grasses to Sugar; Soap Making Kit | Plant Science laboratory courses |
| 10 | Chemistry Professor | Physical Chemistry | Biodiesel kit | Principles of Chemistry II laboratory |

Table 1 shows the activities that the participants incorporated in their classrooms and research activities

## 5. DISCUSSION AND CONCLUSIONS

The current project has been successful in engaging educators and researchers from the "STEAM" disciplines. Through hands-on learning activities in classroom, field, and laboratory settings, participants are sensitized to the critically important issues of the "carbon cycle" and its relevance to "biodiesel" and climate change and the utilization of natural resources and wastes for the generation of bio-products. Survey instruments have been developed to document and analyze feedback from the participants about the classroom, field, and laboratory components of the institute. Teacher training materials such as workbooks focusing on topics related to biodiesel and bio-products from natural resources and wastes are also developed along with assembled biodiesel laboratory kits. As a follow-up, educators have been utilizing these resources to develop unit and lesson plans and to post on the project website. The articles developed for publication in conference proceedings and archival journals will also be posted on the website. Besides contributing to the workforce development needs in areas of critical importance, the

current project efforts are enhancing awareness of environmentally-friendly 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 [5]. It is interesting to note that some of the solutions related to the environment and energy are also broadly based on agriculture and has to be dealt with using a multidisciplinary approach. The activities in the project are consistent with the recommendations of the National Academies with regard to transformational changes to agricultural, 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, and grasses to sugar) from the institute are permanently incorporated in agriculture, food, and resource sciences; marine and environmental sciences; engineering curricula; and other STEAM courses. Such an approach has been facilitating in attracting students interested in pursuing their STEAM degrees with a focus on sustainability issues. At the completion of the project, approximately 50 STEAM educators and researchers will be trained with a systems perspective of bioenergy and bio-products feedstock. 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.
Besides education the synergistic efforts are also underway to develop infrastructure for research endeavors related biofuels, environmentally friendly precision agriculture, remote sensing, and carbon sequestration efforts aligned with the 2012 National Bioeconomy BluePrint of President Obama [6].

## 6.0 Acknowledgments

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