AC 2007-1957: INTRODUCING NATIVE AMERICAN COMMUNITY COLLEGE STUDENTS TO ENGINEERING THROUGH HANDS-ON EXPLORATORY PROJECTS

Wei Lin, North Dakota State University

Dr. Wei Lin is an Associate Professor of environmental engineering in North Dakota State University. He also serves as the Director of the interdisciplinary Environmental and Conservation Sciences graduate program. Dr. Lin teaches environmental and water resources courses at undergraduate and graduate levels. His research areas include water and wastewater treatment technologies, wetland studies, and river water quality modeling and management. He has participated in the ONR, NASA and ND EPSCoR funded Native American educational outreach projects as program coordinator and program director. He has worked collaboratively with tribal college instructors and high school teachers. He serves as the faculty advisor for American Indian Science and Engineering Society (AISES) Student Chapter at NDSU.

G. Padmanabhan, North Dakota State University

Dr. G. Padmanabhan is a Professor of Civil Engineering in North Dakota State University. He also serves as the Director of North Dakota water Resources Research Institute. He served as the Chair of the Civil Engineering Department from 1999 through 2003. Dr. Padmanabhan has more than twenty five years of teaching experience in engineering. He has attended several engineering education conferences. He has served not only as PI or CoPI but also as instructor of several educational outreach projects to motivate women and Native American middle and high school students to enroll in science, technology, engineering, and mathematics (STEM) programs in colleges. Funding sources for his projects include NSF, Office of Naval Research (ONR), NASA, and Funds for the Improvement of Primary and Secondary Education (FIPSE). The NSF, NASA, and the ONR funding supported a sustained effort to increase Native American participation in STEM areas for the last seven years. Activities of the effort are continuing with funds from the North Dakota EPSCoR program. He has presented and published the experience in American Society of Engineering Education conferences. Dr. Padmanabhan is a member of ASEE. He is a Fellow of the American Society of Civil Engineers.

Scott Pryor, North Dakota State University

Dennis Wiesenborn, North Dakota State University

Introducing Native American Community College Students to Engineering through Hands-on Exploratory Projects

Wei Lin[1], G. Padmanbhan[1], Scott Pryor[2], Dennis Wiesenborn[2]
[1]Civil Engineering, [2]Agricultural and Biosystems Engineering
North Dakota State University

Abstract
Each year in the past seven years, a summer camp at North Dakota State University has attracted tribal college students and tribal high school graduates from the Indian Reservations in North Dakota to learn science, technology, and engineering. One of the activities of the camp is to engage the participants in exploring specific science/engineering subjects through hands-on activities. Students are provided with opportunities to select topics they are interested in. They are divided into small groups, usually 2 to 3 students in a group, and spend one week with university professors working on different projects. Professors from 5 engineering departments and 2 science departments have participated in this activity. Through the years, various topics have been selected to connect students to key subjects of different disciplines, to expose them to contemporary engineering issues and challenges, and to attract them to engineering programs. Professors are encouraged to develop project activities that cover fundamental science/engineering concepts, stimulate critical thinking of the students, and introduce students to procedures of scientific thinking and research. Based on experiences and lessons learned from working with Native American students, professors have been constantly looking for methods to connect with these students by improving hands-on activities to engage them in exploratory learning. In this paper, a set of instructional projects are used as examples to illustrate different approaches and activities that have been used to involve students in active learning through experimental studies. Methods and materials developed in this program have received positive responses from participating students and professors and are applicable to other student groups who are interested in learning science and engineering.

Introduction
Finding ways to increase enrollment and graduation rate of Native American students in science, technology, engineering, and mathematics (STEM) disciplines is a challenge to Native American and other educators. A nationwide increase of enrollment of Native Americans in college program has been observed in recent years due to improved high school completion rate (Bacbo, 2005). However, Native Americans and other underrepresented minorities (blacks, Hispanics) still do not enroll in or complete post-secondary education at comparable rates as whites (National Science Board, 2006).

Native American community is the largest minority in North Dakota. Native American population is approximately 5.2% of the total North Dakota population as compared to a national average of 1.0% (U.S. Census Bureau). Most of the 35,000 North Dakota Native Americans reside on five Indian Reservations in remote rural areas, where unemployment rate is usually higher than 50% (Lam, 1997). Forty three percent of this population is under the age of 20 years. Improving education, especially STEM education, on reservations has been a priority of both tribal government and the state. Education of this young population will play an important role in improving economic conditions on reservations.

Each of the Indian reservations in North Dakota is served by a tribal college. Great efforts have been made by these tribal colleges in developing and sustaining various 2-year STEM and vocational programs. These colleges are vital links for higher education on reservations. A collaboration between North Dakota State University (NDSU) and 5 North Dakota tribal colleges has continued for 8 years to strengthen tribal college STEM programs, and to attract tribal college students to four year university by building a pathway for Native American students entering STEM careers (Padmanabhan et al., 2004). The major components of this program include: summer camps for tribal college students, tribal college instructors and high school teachers held at the university, summer camps for middle and high school students held at the tribal colleges, a weekend academy for tribal high school students during the academic year (Lin et al., 2006), and research collaboration between the university and tribal colleges. The first two authors have been involved in this program since its inception. A group of engineering faculty has been working with tribal high school teachers and tribal college instructors on this program and has been teaching Native American high school and tribal college students various topics on mathematics, science and engineering during summer camps and weekend academies.

This paper focuses on one of the activities of the program, summer camp for the tribal college students. Through the years, efforts have been made to gain better understanding of special needs of and difficulties faced by these students, and to develop lesson materials and hands-on activities to suite their learning style and interest. Through this experience, the faculty determined the use of hands-on exploratory projects an effective way to make camp instruction interesting to the students, to teach them scientific methods, and to stimulate their critical thinking. Also these projects serve the purpose of introducing the tribal college students to engineering.

Summer Camp

The two-week summer camp is organized at the North Dakota State University for tribal college students. Students coming to the camp include first year and second year tribal college students, and high school students who have been accepted into the tribal colleges. Number of students attending the camp is limited by the budget. Number of participating students has varied from 12 to 17 (Lin et al., 2007). Tribal college program coordinators recruit students. The objectives of the camp include introducing the students to different science and engineering disciplines and exposing the students to ongoing research activities and career opportunities. The activities of week 1 include visits to science and engineering departments, research centers, and laboratories, tours of industrial and municipal facilities, and presentations by Native American engineers and professionals. In the second week, students work in small groups with professors on specific projects involving hands-on exploratory activities. Details of the camp can be found in another companion paper presented in this conference (Lin et al., 2007).

Topic Selection

North Dakota is a sparsely populated state with well developed agricultural and rich energy resources, such as oil, lignite coal, wind and biomass. North Dakota ranks number one in wind energy and is among the tops states for biomass energy production potentials. Corn, soy beans, canola oil produced in North Dakota plus its vast grasslands provide the basis for future ethanol and biodiesel productions. North Dakota tribes recognize that development of renewable energy is a key step toward protection of the environment and offers potential for a new industry on reservations. Both Turtle Mountain and Spirit Lake Reservations have built a windmill on their land. The tribal council of the Three Affiliated Tribes gave the tribal college, Ft. Berthold Community College (FBCC), a mandate to develop a renewable energy program. Turtle Mountain Community College (TMCC) built its new campus using geothermal heating and cooling. TMCC also installed solar panels on a laboratory building, which is constructed using straw bails as building blocks. TMCC is currently building a windmill on its campus. All these activities reflect the current enthusiasm of the Native American community in developing renewable energy, sustaining a healthy environment, and developing cutting edge industries in their land. The Native American youth are becoming increasingly aware of and interested in these topical areas. Therefore, it was decided to offer project topics in these areas with the hope that the students will see the relevance of the topics to their land and social conditions. For instance, environment, renewable energy, and nanotechnology were selected as the focus areas for the summer camp of 2006.

Each year, 2 months before the summer camp, projects were solicited through the university's biweekly newsletter. Many different engineering and science faculty have proposed research projects for the students. Table 1 shows the summer camp topics that were selected for the past three years and their sponsors.

Activity Design

The projects were carefully developed so that the students will have the opportunity to go through discovery learning, critical thinking, and engineering skills. In fact we provided the students opportunities to explore using scientific and methodical ways. We deliberately tried to include all elements required of a scientific inquiry or research. There are many existing lesson materials available for teaching the concepts and conducting experiments. Instead of using off-the-shelf materials, we decided to introduce students to commonly followed steps in science and engineering research (Kumar, 2005) and engage them in exploratory project activities.

Table 1. Example topics and sponsors of summer camp projects

2004	2005	2006
Composite Skateboard Design, R. Pieri, Mechanical Engineering	**Vacuum and Applications**, U. Bergurhause, Chemistry	**Biofuel Production**, S. Pryor and D. Wiesenborn, Agricultural and Biosystems Engineering
Production of Hydrogen Gas from Electrolysis, W. Lin, Civil Engineering	**Operations Research: Science of Making Decisions**, D., Tjokroamidjojo, Industrial & Manufacturing Engineering	**Water Quality Monitoring and Testing,** G. May and D. Crompton, International Water Institute
Plant Reproduction and Propagation, C. Lee, Plant Sciences	**Computer Aided Design and Manufacturing (CAD/CAM)**, R. Melaki, Industrial & Manufacturing Engineering	**Synthesis of Luminescent Nanoparticles**, J. Zhao, Chemistry and T. Freeman, Electron Microscopy Center
Water Conservation, E. Khan, Civil Engineering	**Laser and Optics**, I. Lima, Electrical and Computer Engineering	
Prosthetics, B. Jang, Mechanical Engineering		

In the following section, two student projects used in the camp are described to explain how the projects are developed and implemented.

Project Examples

<u>*Production of hydrogen gas through electrolysis*</u>
While visiting a wind turbine site, students learned that amount of electricity generated from wind power is unstable and can be intermittent. The site engineer explained several solutions to this problem. One of the methods suggested was to store energy in the form of hydrogen by using electricity to generate hydrogen from water. Returning to the campus, a group of students wanted to try it out.

1**. Learning the concept of electrolysis.** As the first task, we asked students to search the Internet for definitions, articles, and experimental methods for production of hydrogen from water. From their Internet research, students learned the concept of electrolysis, how and what gases are generated from electrolysis of water, and how to build a simple setup to electrolyze water.

2. **Verifying the concept through experiment**. We provided students with space in a wet chemistry lab and materials needed to set up a simple experiment for electrolysis. Using a beaker, tap water, a 6-V battery, electrical wires, and pencil lead as electrodes, students assembled a system for electrolysis and observed generation of gases at the two electrodes. They noticed that two volumes of gas was generated at the cathode for each volume generated at the anode, thereby giving visual proof that hydrogen gas and oxygen gas were generated in a 2:1 molar ratio. This helped explain the concept that each water molecule consists of two hydrogen atoms and one oxygen atom. Students were happy for the opportunity to do most work and explain the results by themselves, but did not feel they were challenged.

3. **Design of experiments for improving system performance.** To further students' understanding of the process to stimulate their thinking, the question "What should we do to increase the production of the gases?" was asked. With some help, students came up with a list of tests they would like to do on the following parameters to learn their impact on hydrogen production:

- Size of electrodes (Length of pencil lead);
- Distance between the two electrodes;
- Salinity of water (Dirty water versus clean water);
- Applied Voltage (Number of batteries); and
- Different electrode materials.

4. **Data collection and interpretation**. We provided materials for students to test their ideas. A simple device was made to vary the distance between electrodes. Copper wire and stainless steel rods, all with the same diameter as regular pencil lead, were used as alternative electrodes. A concentrated salt solution was prepared for adjusting water salinity. Because the generated gases were not collected, it was not possible to determine quantitatively how gas production rate was

affected by various experiment conditions. Instead, electrical current was measured and assumed directly proportional to gas production rate, to establish quantitative relationships with different variables. Figure 1 shows the lab setup and students observing production of hydrogen and oxygen gases from electrolysis.

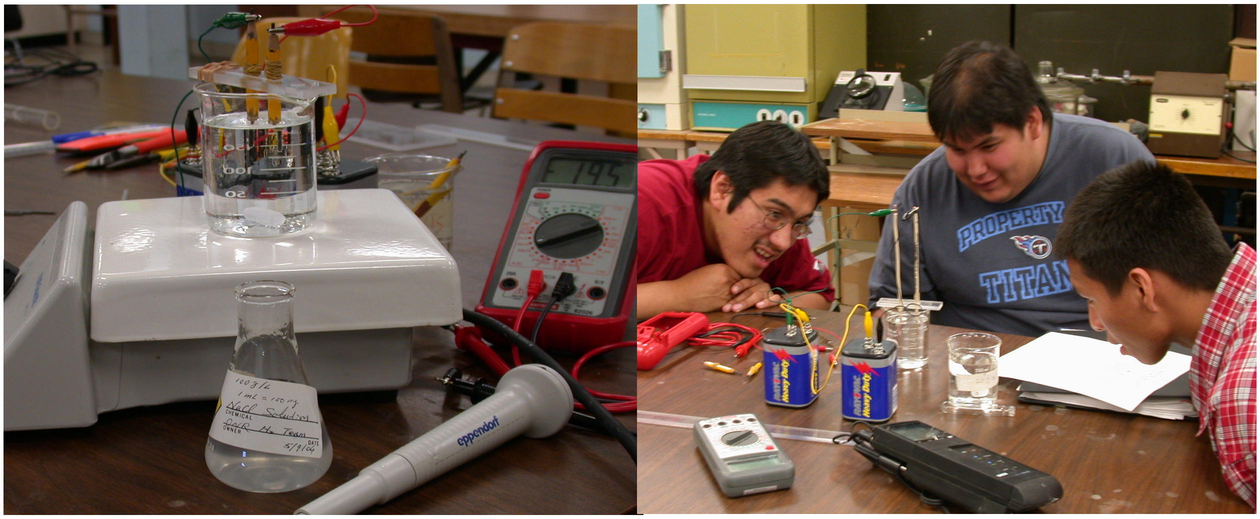

Figure 1. Experimental setup and observation of hydrogen production from electrolysis

Students collected data from the experiments varying electrode lengths, distance between the electrodes, salt concentration, and electrical voltage. In order to see the relationship between variables students were asked to graph the data collected using Excel spreadsheet. This presented an opportunity for students to learn to use Excel. Students did record and graph the data using Excel (as shown in Figure 2). We used this opportunity to explain the students how to read graphs and how to interpret data.

Students also tested the stainless steel and copper as electrodes. The results showed that stainless steel electrodes produced similar results to pencil-lead electrodes. However, after a period of operation, corrosion on the surface of the stainless steel anode was noticeable. When copper was used as electrodes, students observed no production of oxygen gas from the anode. Instead, a blue color cloud gradually formed and corrosion of the copper anode was apparent. The material generated with blue color was later tested to be copper sulfate. Through these experiment students learned why graphite (pencil lead) is recommended as electrodes.

5. **Design a device to collect the gases**. To Design and building a device to collect the gases generated from electrolysis unit was the last assignment given to the students. After finishing the earlier tasks successfully, students were excited about this new challenge. Having no experience or training in design, students struggled to transfer their ideas to paper. However, they did not give up. We encouraged the students to be creative and helped them in put their ideas together. After about two hours, they finally came up with a design that would work. We fabricated the design and students collected hydrogen and oxygen gases successfully using the unit (See Figure 3)

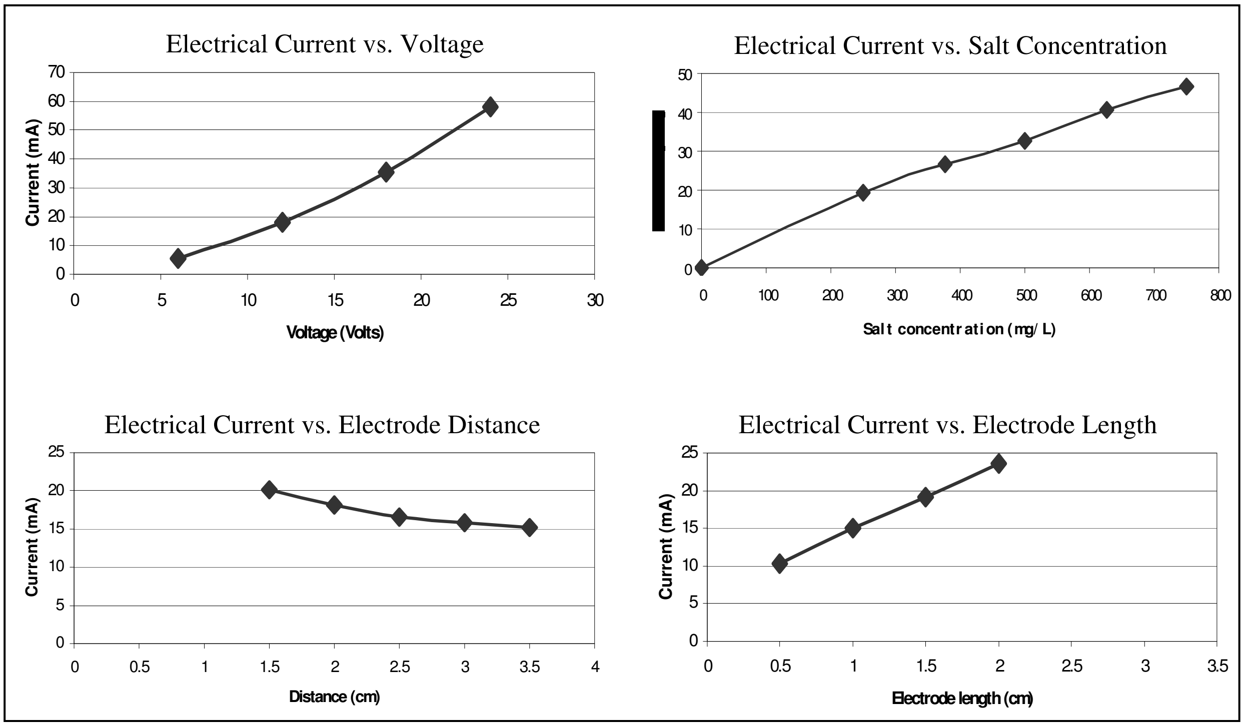

Figure 2. Experimental Results

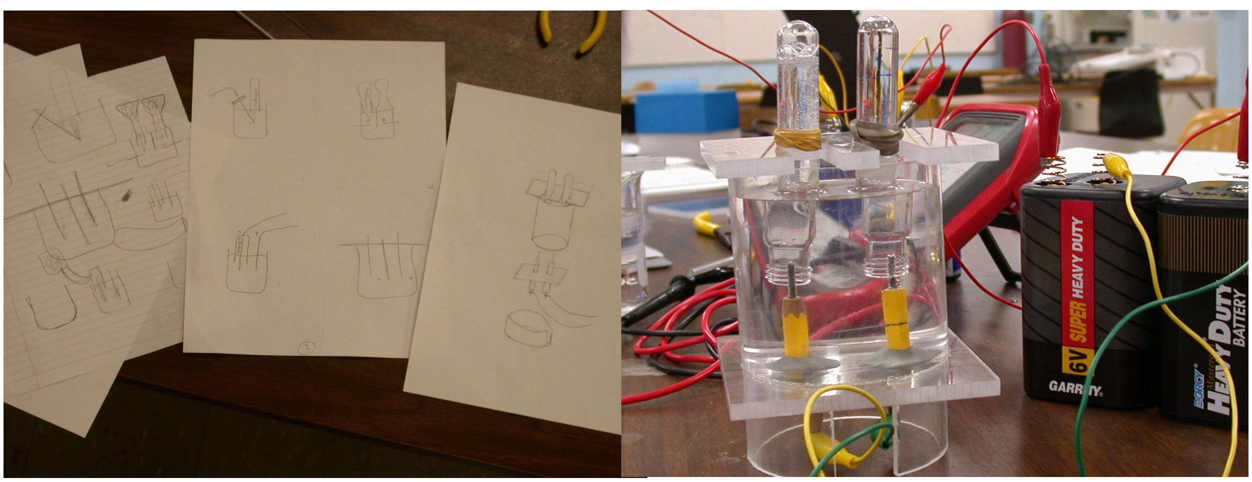

Figure 3. Student Drawings and the Gas Collection Apparatus

Biofuels Production

During the first week of the summer camp, students visited various science and engineering departments around the campus to see and hear about the research being conducted and to learn about the specific research activities that they could take part in the following week. In the Department of Agricultural and Biosystems Engineering, the students were provided with a brief background on the broad scope of work being done in the department and the opportunities available to graduates of our department.

A bioenergy-themed game was used to introduce students to bioenergy topics. Students were divided into several teams of three and were asked a series of multiple choice questions that were related to biofuels. Two points were allocated for a correct answer and one point was given to any competing team who chose the correct answer after an initial incorrect response. Gift cards to the University bookstore were offered to the game winners as further incentive to participate and think more about questions that they didn't immediately know the answer for. Questions were designed to gauge student background knowledge in biofuels-related topics. The game served not only as a pre-assessment tool, but also as an engaging forum for educating the students about potential biomass energy sources and the related economic and environmental impacts. This was seen as especially beneficial for the students from the group who would be working on projects other than bio-fuel during the remainder of the program. Sample questions from the game are shown in Table 2.

Table 2. Sample questions from introductory bioenergy-themed quiz game used as a teaching and pre-assessment tool.

Question	**Answer**
E85 is a blend of 15% gasoline and 85% what?	Ethanol
What type of fuel can flex-fuel vehicle use?	Any blend of gasoline and ethanol
Which country is ***not*** one of the top 7 countries for petroleum reserves?	The United States (other choices: Russia, Iraq, Saudi Arabia)
Which country produces the most ethanol?	Brazil
The Kyoto protocol is an international treaty to control emissions of what?	Greenhouse gases
Which oil or fat is the main source of biodiesel in the US?	Soybean oil
Which one of the following properties describes the ability of a liquid to flow?	Viscosity
What music star has his or her own brand of biodiesel?	Willie Nelson
Where does the carbon in a plant come from?	Air
What is the most abundant plant material on earth?	Cellulose
What molecule is a building block of both starch and cellulose?	Sugar (glucose)
Which material ***cannot*** be readily used to produce ethanol?	Clay (other choices: corn, grass, wood)

This introductory game was seen as a fun and useful tool for assessment and education. Students enjoyed the format and were happy to participate. It was evident that all students learned various things from the game. Basic science questions seemed to be the easiest for students while some of the questions concerning current events and global perspectives were more difficult. By mixing up the difficulty level or questions and potential answers, all students were able to participate and show that they had some relevant introductory knowledge on the topic.

Three students remained in the Agricultural and Biosystems Engineering group for the remainder of the program and worked on bio-fuel projects. Two fuels, corn ethanol and canola oil biodiesel were selected for the projects. As an introduction to the biofuels production laboratory, corn grain samples were distributed and we discussed the obviously difficulties in trying to fuel a vehicle with a solid material. We then discussed how we could take that corn grain and in several days transform the grain to a liquid that could indeed be used as a fuel.

Students participated in all process steps for the production of corn ethanol including: grain milling, malting, mash/fermentation, and ethanol distillation. Although conventional ethanol production utilizes industrial enzymes for starch hydrolysis, malting was done to demonstrate the biological nature of the enzymes and to allow students to better understand the origins of the key materials used to make ethanol. Malting and fermentation required longer time periods than were available for the program so the instructors prepared some materials approximately one week before the program for students to use in subsequent steps. Students performed all activities associated with each step but in some steps they used materials that had been prepared earlier. Although corn grain was used as the feedstock in the laboratory, there was discussion about the use of other starting materials including other starch crops, grasses, and cellulosic biomass 'waste' products such as corn stover and wheat straw. Learning objectives for the activity were as follows:

1. Students will be able to describe the process for making ethanol from corn including the biological, chemical, and physical processes that occur at each step.
2. Students will be able to describe the main differences between making ethanol from corn grain and from cellulosic biomass.
3. Students will be able to identify the main challenges for making ethanol from either corn grain or cellulosic biomass.
4. Students will be able to discuss the energy content of ethanol produced in their experiment with laboratory-grade ethanol.
5. Students will be able to describe the effect of the experimental condition on fermentation and ethanol production.

During the first morning of activities, the ethanol process was discussed and students started the corn malting steps. They checked and processed the malt in subsequent days but used pre-malted and dried grain for the fermentation laboratory. They ground and measured corn grain and malt for the afternoon experiments which included cooking, liquefaction with malt enzymes, inoculation with brewer's yeast, and setup with fermentation locks. Students decided what conditions to use for control and experimental treatments and calculated fermentation rates over the following days based on gas (carbon dioxide) evolution from fermentation flasks. After fermentation, students recovered the solid residue, called distillers grains, and the economic importance of these distillers grains was discussed. Ethanol concentration in each of the treatments was first estimated using hydrometers. Following partial distillation, a sample of each product was placed in a small crucible and burned to demonstrate its fuel value. Heating values were estimated by burning samples under a known volume of water and monitoring temperature increase.

The 48-hour ethanol fermentation period allowed students to participate in a complementary study demonstrating the production of biodiesel from canola. Students used a screw press for oil extraction and then used refined oils from canola and sunflower seed to produce methyl esters (biodiesel) and glycerol co-product. Steps included transesterification with methanol in the presence of a base catalyst, co-product separation, biodiesel washing, drying, and viscosity measurement. The viscosity of the final product was one-tenth that of the initial oil, showing that the students achieved full conversion of the oil to biodiesel.

Summary

A summer camp for Native American students from North Dakota tribal colleges is being conducted every year for the past seven years at North Dakota State University. The objectives of the camp include stimulating students' interests in STEM disciplines, introducing students to scientific concepts and engineering processes through engaging activities, and to build students' confidence in learning math, science and engineering. Through the experience gained from working with Native American students for the last seven years, the university team of faculty recognizes that Native American students enjoy learning better through hands-on exploratory activities than through any other mode of instruction. Therefore, in this 2-week summer camp, the first week is designed for exposing the students to various science and engineering disciplines and the second week for engaging the students in project type of hands-on activity. The faculty team also recognizes that in order for them to be engaging and meaningful learning experience for the students, the projects need to be designed and implemented in such a way that they demand a spirit of inquiry, critical thinking, applying scientific methods, observation and measurement skills, presentation and interpretation of results, and communication skills. The faculty team developed several student projects on contemporary research topics of interest to the Native American Reservations and used them as exploratory projects for the students in the camp. Specifically two projects on renewable energy topics are described in the paper. Students enjoyed working on the projects. It is hoped such learning through exploratory projects will attract students to STEM disciplines and improve retention of those students in the STEM disciplines.

Acknowledgments

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