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Integrating Bio-energy Laboratory Activities Into a Junior High School Classroom*

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This study developed a bio-energy laboratory activity as well as an outline for evaluating student performance in the activity. The goal of the study was to design and implement a laboratory procedure and assist teachers in achieving the objectives of the activity. A total of 80 junior high school students went through a six-week laboratory activity. Students' understanding of bio-energy concepts was statistically increased after completing these activities, which effectively introduced students to bio-energy technology. The objective of the activities was for the students to gain an understanding of energy education, as well as a greater confidence in investigating, questioning and experimenting with renewable energy ideas.

Keywords: laboratory activity; junior high school; bio-energy; renewable energy

1. Introduction

Renewable energy is an important and economical energy source for electricity generation. Major sources of renewable energy include hydro, biomass, bio-energy, geothermal sources, the sun and wind. Due to the monumental growth in renewable energy use for electricity generation, to keep students abreast of current engineering developments and trends, it is necessary and to develop an instructional course for students on renewable energy [1]. Renewable energy is an ideal topic for junior high school classrooms. Teachers can use a unit on renewable energy to teach the basic scientific principles of generating electricity and converting energy from one form to another. Teachers can incorporate laboratory activities on renewable energy into a unit on the environmental impact of energy use. Traditionally, renewable energy laboratory activities have not been part of the K-12 curriculum. Therefore, it is not surprising that most teachers lack a firm understanding of bio-energy practices, uses, and concepts. Few teachers learned about bio-energy laboratory activity while in school. Therefore, for teachers to feel comfortable integrating it into their classes, they will need to engage in professional development that focuses on bio-energy concepts and pedagogical strategies [2].

Traditional classroom lectures have encouraged passive learning, commonly revealing a mismatch between the way teachers teach and the way students learn. Research has shown that traditional classroom lectures are not the best teaching approach [3]. Teachers have been constantly seeking new ways to actively engage students. Actively involving students has been shown to lead to deeper questioning, improved attendance and more lasting interest in the subject compared to lecturing alone [4–5]. Hands-on activities and demonstrations have been developed and documented for teaching students [6]. Some laboratories have used technology and hands-on manipulative tools to discover concepts and theorems [7]. Laboratory instruction has been shown to help students develop their experimental skills and ability to work in teams, learn to communicate effectively, learn from failure and be responsible for their own results [8]. Learning through activity has proven to be a great success. Educational gaming activities have been progressively perceived as an effective tool for improving teaching and learning in education. The use of such play-based methodologies for education could promote practical and communication skills of great value for students' future professional development. At the same time it is possible that it could motivate students and make them more aware of their own capabilities and the learning process.

In 2007, Shyr [9] developed several laboratory activities that provided convenient and flexible methods for teaching students in Taiwan about photovoltaic systems. The key areas explored in these laboratory activities were: experimental set-up, operating instruments, constructing photovoltaic cells, measuring irradiance, measuring light, measuring temperature change and data summary.

In 2010, Shyr [10] presented a wind power system laboratory activity and an outline for evaluating student performance in Taiwan. The laboratory teaching activities introduced energy sources, wind energy technology, electricity storage and wind

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power system testing. The wind power system testing activity included eight topics: setting up the experimental module, operating instruments, wind velocity measurement, rotor diameter activity, wind speed activity, blade angle activity, blade number activity and data summary. This laboratory activity effectively introduced students to wind energy technology through activity participation.

This paper attempts to make the concept of bio-energy basic and general, for addressing junior high school students. The activity helped students gain an understanding of generating electricity from bio-energy, as well as a greater confidence in investigating, questioning, and experimenting with renewable energy ideas.

The remainder of this paper is organized as follows: Section 2 gives the teaching-learning objectives overview. The laboratory activity is presented in Section 3. The methods are shown in Section 4. Section 5 presents the results and discussion. In Section 6, conclusions are drawn.

2. Teaching-learning objectives

The educational concept behind the approach offered in this study utilized experiential learning. The theory of experiential learning [11] is propagated both through experience and by experience and learning is a process whereby knowledge is created though the transformation of experiences. One of the main exponents of experiential learning is David A. Kolb [12], who proposed a learning theory comprised of four main stages: active experimentation, concrete experiences, reflective observation and abstract conceptualization. Laboratory experiments are ideal for experiential based training, as they provide a hands-on approach to learning. Experiments allow a learner to experience data in a more familiar form, since the practical experiment proposed to the students enable them to observe and reflect on what they have just witnessed. Each experiment could therefore be seen as a starting point on the path to understand its underlying theoretical principles [13].

The objective of teaching-learning activities is for the students to gain an understanding of the concept of energy education, as well as a greater confidence in investigating, questioning, and experimenting with renewable energy ideas. Educational experiments are designed to expose the students to newer technology, and test their synthesis and comprehension skills on the material covered in previous lectures [14]. This is an important first step in promoting renewable energy technologies, and renewable energy is an ideal topic for the science classroom. Laboratory activities can help students understand renewable energy technologies. Teachers are often expected to design instructional activities that integrate theoretical knowledge and promote creative thinking [15]. Studies have shown that constructivist learners tend to explore the concepts involved in laboratory activities deeply, resulting in a richer understanding [16].

In developing the experimental module for this student laboratory activity, the first goal was to capture and maintain the attention and interest of the students. To make the content attractive, careful attention was paid to constructing clear and straightforward ways to introduce the concepts. The philosophy of education has gained its roots from Piaget's theory of constructivism, which described a learner as actively constructing knowledge instead of simply receiving knowledge transmitted from teacher to student. Hands-on learning environments are beneficial to student attitudes and learning [17].

This study first contributed a set of experiments on bio-energy that presented necessary laboratory activities. The laboratory had to serve many students. This study therefore focused on the syllabus, organizing the activity and on resource allocation. This study thirdly provided junior high school students a variety of activities to broaden their knowledge of bio-energy systems. Finally, the laboratory activity made the module easy to use and fun.

3. Laboratory activity

The purpose of this activity was for students to construct a bio-energy system. The defined activities were at an appropriate level for junior high school students. A panel of experts, including experienced researchers, university professors and experienced engineers, evaluated these activities. They concluded that the teaching materials and experimental equipment were suitable for students.

These activities combined knowledge of biomass energy and bioethanol knowledge. Topics explored included voltage polarity, ethanol fuel consumption, the effect of varying fuel concentrations, creating electricity using different types of alcohol, exploring the effects of temperature and data summary.

3.1 Topic 1—Biomass energy and bioethanol knowledge

Bio-energy is the energy that is derived from biomass. Therefore, bio-energy can be electricity produced from biomass or any other kind of energy produced from biomass. Biomass is the fuel and bio-energy is the energy contained in the fuel [18]. Biofuels are generally in the form of alcohols, esters, ethers, and other chemicals produced from biomass.

The two main types of biofuels are bioethanol and biodiesel. Bioethanol fuel is mainly produced during the sugar fermentation process. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil.

The bio-energy laboratory shows a way to create electricity using tiny quantities of biofuel mixed with water without using combustion—using a new energy conversion device called a direct ethanol fuel cell (DEFC). In the immediate term, this new ethanol fuel cell technology creates a non-toxic, easy to use and long lasting power source alternative for small electronics.

It demonstrated the technology of a newly developed DEFC, which unlike DMFC (Direct Methanol Fuel Cells) did not use any corrosive fuel. Unlike other applications where biofuel was burned for energy, DEFC did not burn ethanol, but created electricity by slowly converting ethanol to regular vinegar. The DEFC produced electricity while ethanol reacted at the anode side of the fuel cell. Hydrogen protons permeated from the ethanol solution through the DEFC's membrane, liberating electrons that were captured in an external circuit. On the cathode side, the catalytic reaction of hydrogen with oxygen from the ambient air formed water as a result.

The mechanism is as follows [19]:

(1) $C_2H_5OH \rightarrow CH_3CHO + 2H^+ + 2e^-$
(2) $C_2H_5OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$
(3) $C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$

Cathode:

$$4H^+ + 4e^- + O_2 \rightarrow 2H_2O$$

During the reaction, some of the ethanol is Oxidated completely and turns into CO_2.

3.2 Topic 2—Exploring voltage polarity

The procedure for exploring voltage polarity was explained as follows:

(1) Connect the positive (red) crocodile clip to the positive side of the fuel cell (red '+' mark), then connect the negative (black) crocodile clip to the negative side of the fuel cell (black '–' mark) (see Fig. 1). It will be noticed that the fan turns clockwise.
(2) Repeat the process, this time connecting the positive (red) crocodile clip to the negative side of the fuel cell (black '–' mark) and connecting the negative (black) crocodile clip to the positive side of the fuel cell (red '+' mark). It will be noticed that the fan turns counter-clockwise.

The current flowed from positive to negative, creating a clockwise spin of the fan. By inverting the polarity connections, the current flow was reversed and caused the fan to spin in the opposite direction.

3.3 Topic 3—Ethanol fuel consumption

When the fan began to run slower or stopped running completely, the ethanol present in the fuel cell chamber was mostly consumed. In normal temperature conditions, the majority of the ethanol inside the fuel cell chamber would turn into acetic acid, which is the main component of vinegar. This would be investigated when the fan began to run slowly.

The procedure was explained as follows:

(1) Place a piece of pH paper under the outlet of the purging tube (see Fig. 2).
(2) Open the valve slowly by sliding the switch towards right side, and release a drop of the solutions onto the pH paper, then closes the valve. It will be seen that the paper color quickly changes to a reddish color.
(3) Dip a new pH paper into the solution container. It will be noticed that the color of the PH paper changes very little.

3.4 Topic 4—Exploring the effect of varying fuel concentrations

Students could make different concentrations of ethanol fuel in the initial mix. For a 15% solution,

Fig. 1. Exploring voltage polarity.

Fig. 2. The pH test for Ethanol fuel consumption.

Fig. 3. Exploring the effect of varying fuel concentrations.

Fig. 4. Creating electricity using different alcohol.

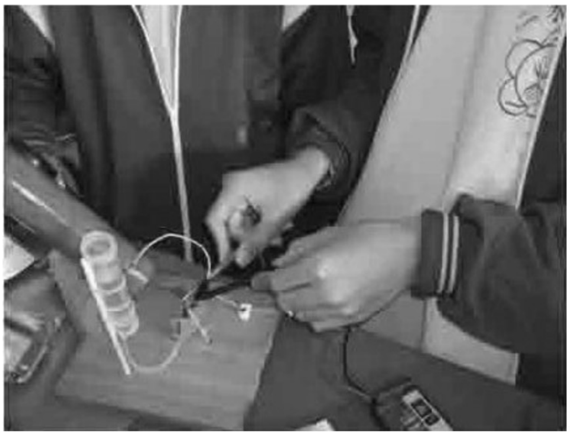

Fig. 5. Exploring the effects of temperature.

9 ml of pure ethanol was added with water to the level of 60 ml (see Fig. 3).

Through experimentation, it would be found that increasing or decreasing the concentration of ethanol did not noticeably make the fan run faster.

3.5 Topic 5—Creating electricity using different types of alcohol

Different types of alcohol were created, such as wines made from grapes or rice instead of the ethanol/water solution described earlier (see Fig. 4). Students would notice the fan might run slowly, or not at all.

3.6 Topic 6—Exploring the effects of temperature

A hair drier was used to blow hot air towards each side of the fuel cell or to place a warmer ethanol/water solution into the ethanol storage tank (see Fig. 5). It would be observed that the fan would operate at a faster speed.

3.7 Topic 7—Data summary

At the end of these topics, the data was summarized through the following:

(1) Write the balanced equation for the chemical reaction performed.
(2) Explain when the fan will turn clockwise.
(3) Explain why the difference in pH paper coloring indicates the change of the acidity level.
(4) Note if the fan runs faster when the concentration of Ethanol increases.
(5) Note if the fan runs faster when the ethanol solution increases.
(6) Note if the fan runs faster when the temperature is higher.

4. Methods

4.1 Participants

These laboratory activities took place in Erh-Shui junior high school in Changhua County, Taiwan. A total of 80 students (42 female and 38 male; average age of 15) participated in the natural and live technology course, for 1 hour per week over a period of six weeks.

4.2 Design

The study involved a single-group pretest-posttest design, which included a pretest measure followed by a treatment and a posttest [20]. A total of 80 participants took pretest surveys before the laboratory activity and posttest surveys after the laboratory activity. The questionnaire was composed of 10 questions. The pretest and posttest questionnaires were prepared and reviewed by 10 education and field experts and underwent several cycles of review and modification.

4.3 Data collection

Quantitative data were collected from the laboratory activity pretest and posttest. Students completed surveys during the first week and the last week. The data were then imported into SPSS for statistical analysis.

4.4 Results and discussion

Prior to joining these laboratory activities, students took a pretest to rate their own concepts about bioenergy. At the end of these laboratory activities they took a posttest.

Table 1. Paired sample statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pretest	39.50	80	16.451	1.839
Posttest	56.88	80	21.793	2.436

Table 2. Paired sample correlations

Pair 1	N	Correlation	Sig.
Pretest vs. Posttest	80	0.426	0.000

Table 3. Paired sample test

	Paired Differences							
				95% Confidence Interval of the Difference				
Pair 1	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pretest-Posttest	17.375	20.973	2.345	–22.042	–12.708	–7.410	79	0.000

Table 1 shows the statistics for the paired sample test. Based on the results from Table 2 and Table 3, the posttest that perceive higher for pretest was well supported (p-value = 0.000 < 0.05 = a).

The significant increases indicated that the laboratory activity was effective in helping students to improve their understanding of the concept of bio-energy.

This study could be assessed as follows:

(1) All the students possessed the same initial level.
(2) The post-test results demonstrated that the activity was valuable.
(3) Experimental results demonstrated that the proposed activity applied was an effective method in the field of renewable energy.

5. Conclusions

This study presented a laboratory activity for teaching bio-energy concepts to junior high school students. Given the advances in bio-energy system conversion technologies and the continued growth in renewable energy and its impact on electrical power systems, it is important and to develop bio-energy laboratory activities. Students could carry out laboratory activities during class to learn the concepts of renewable energy. Assessment results indicated that the proposed laboratory activity was successful in meeting teaching-learning objectives. The students in this study were generally excited about and receptive to these activities. Students participating in these laboratory activities found them extremely informative and enjoyable.

This entire laboratory activity only required one simple inexpensive setup. At the end of the activity students gained: (1) a firm understanding of the bio-energy concept, from both a principle and a practical standpoint, (2) knowledge of major renewable energies, their potentialities and possible pitfalls, (3) an ability to perform laboratory activities and record data and (4) comprehend the renewable energy concept.

However, since this study was a single-group pretest and posttest experimental design, care should be taken when any generalization is made to other environments. Therefore, further investigation of this topic is required in other control group environments.

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