The Development and Learning Effectiveness of a Teaching Module for the Algal Fuel Cell:
A Renewable and Sustainable Battery

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ABSTRACT

This study emphasizes student-centered learning principles in developing an algal fuel cell teaching module for a student environmental education program. Using the algal battery, one of the authors (a junior high school science teacher) conducted the teaching module in eight classes, with 67 elementary school students in grade 5, 64 junior high school students in grade 8, and 159 senior high school students in grade 10, respectively. Results from the pre- and post- achievement tests of the algal fuel cell teaching module showed that the average score of elementary school, senior high school, and junior high school students increased by 23.73, 18.09, and 17.42 points, respectively, with a significant difference between post- and pretest scores ($p<0.001$). The gross average of student responses to the questionnaire was 4.04. The mean score for elementary school students significantly differed ($p<0.01$) from junior high and senior high school students.

Keywords: *Algal, Algal Fuel Cell, Carbon Reduction, Conserving Energy, Environmental Education Program*

DOI: 10.4018/jthi.2012100101

INTRODUCTION

Environmental conservation has become a global issue given the gradual decline of natural resources. Teaching children appropriate knowledge, attitudes, and judgment about energy resources and environmental protection is becoming increasingly important. To use energy more effectively, conserve energy, and lessen global warming problems requires not only reducing carbon dioxide production and implementing green energy and low carbon dioxide policies, but also incorporating these issues into primary objectives for education.

Reducing carbon dioxide production and implementing green energy and low carbon dioxide policy are currently great concerns. Fossil fuel depletion will lead to an energy crisis, and contribute to accumulated carbon dioxide in the environment (Powell & Hill, 2009). Solving this problem requires a clean and renewable energy to replace traditional fossil fuels. "Green energy," including solar energy, wind energy, hydraulic power, biomass, and microbial fuel cell is worthy of attention. Fuel cells generate electric power through a chemical reaction that combines hydrogen and oxygen, without pollution (Pierce, 2000; U.S. Department of Energy, 1992). They are another way to produce hydrogen from split water directly into the oxygen and hydrogen in the fuel cell, in a chemical process that mimics how plants work (Energy Futures Lab, 2007). The Sony Company has developed a microbial fuel cell that achieves a power output of 50 mW (Sakai, 2007). Therefore, researchers have developed lessons or teaching materials on fuel cells for science and industrial technology students (Toay, 2004; Howell, 2007).

Energy education materials introduce various energy resources, energy production techniques, transportation and storage, the correlation between fossil-fuel-use and climate change, and how to live a low carbon life. This report proposes a new teaching material that demonstrates the possibility of obtaining energy from living algae using a simple, affordable device.

In cellular respiration reaction, sugars are used to produce biochemical energy (ATP) such as: $C_6H_{12}O_6+6O_2 \rightarrow 6CO_2+6H_2O$. However, many studies on microbial fuel cells have used different microorganisms (Bennetto, 1990; Wang, Chen, & Huang, 2010a), which produce electrons during the metabolic process. The electrons transfer to the cathode via an external leading wire, and the hydrogen ions go through the proton exchange membrane to the cathode to achieve reactions and produce electricity. The reaction equations at the anode and cathode are as follows:

The anode reaction:
$C_6H_{12}O_6+6\ H_2O \rightarrow 6CO_2+24e^-$.

The cathode reaction:
$6O_2+24e^-+24H^+ \rightarrow 12H_2O$.

This study used algae in two electrodes of an algal fuel cell, including blue-green algae (micro-blue-green algae and filamentous-blue-green algae) and green algae (micro-green algae and filamentous-green algae). Algae behave like photosynthetic machinery and absorb carbon dioxide. Algal fuel cell can be a microbial carbon capture cell (MCC) (Wang et al., 2010b).

The algal fuel cell is operated based on biological transformation of solar energy into electric energy. Energy conversion occurs inside algal cells. By supporting with electrodes and wires, the electric current can be detected and recorded during the growth of algal cells. The scientific concepts behind algal fuel cell teaching materials include photosynthesis, redox reactions, principles of electricity, and ecology. Unlike other microbe fuel cells (MFCs) that produce energy by consuming glucose, electric energy generated in the algal fuel cell derives directly from solar energy without any fuel resources such as starch (Wang et al., 2010b). The components of the algal fuel cell are commercially available, and no toxic waste is generated during and after algal fuel cell activity. Students can observe and record the changes of electric energy throughout the

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