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Hands-on activities to enhance renewable energy learning

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ABSTRACT: Both the development of a hands-on laboratory activity to enhance learning and an outline for evaluating student performance are described in this article. The laboratory activities involve establishing an experimental module, which uses a digital multi-meter to measure: thin-film-solar cell output voltage, electrolysis of water, hydrogen-fuel cell load voltage, and hydrogen-fuel cell load current. These activities are introduced to Taiwanese junior high school students via this study, thus enabling them to participate in thin-film-solar-hydrogen-fuel cell technology. The hands-on activities are effective in introducing students to the concept of renewable energy through activity evaluation.

Keywords: renewable energy, junior high school, laboratory activity

INTRODUCTION

Renewable energy laboratory activities traditionally have not been part of the K-12 curriculum. Thus, it is not surprising that most teachers lack a firm understanding of renewable energy practices, uses and concepts. Few teachers learn about energy laboratory activities while in school. Therefore, for a teacher to feel comfortable integrating these activities into their class generally will require that they engage in teacher professional development that focuses on energy concepts and pedagogical strategies to teach this discipline [1].

Renewable energy is an ideal topic for junior high school classrooms. Teachers can use a unit on renewable energy to teach basic scientific principles: converting energy from one form to another or generating electricity. Teachers can incorporate laboratory activities on renewable energy into a unit on the environmental impact of energy use.

Traditional classroom lectures encourage passive learning, frequently causing a mismatch between the way teachers teach and the way students learn. Teachers constantly seek new ways to engage students. Actively involving students results in deeper questioning, improved attendance, and a more lasting interest in the subject than with lecturing alone [2]. Research shows that hands-on activities and demonstrations are well-documented and developed [3].

Some laboratories use technology and hands-on manipulative tools to discover concepts and theorems, demonstrating learning through play with great success [4]. The educational use of such play-based schemes improves numerous practical and communication skills of great value to students' future professional development. The schemes also motivate students and create more awareness of their own abilities and the learning process.

Educational experiments not only expose students to new technology, but also test their skills in comprehending and synthesising material covered in previous lectures [5]. Laboratory activities can help students understand renewable energy technologies. Schools often expect teachers to design instructional activities that integrate theoretical knowledge and promote creative thinking [6]. Studies have shown that constructivist learners tend to deeply elucidate concepts in laboratory activities, resulting in a richer understanding [7].

In 2007, the authors developed various laboratory activities that provide convenient and flexible approaches to teaching photovoltaic systems to students in Taiwan [8]. The key areas covered in these laboratory activities include experimental set-up, operating instruments, constructing photovoltaic cells, measuring irradiance, measuring light intensity, measuring change in temperature and data summary.

In 2010, the authors produced a wind power-system laboratory activity and an outline for evaluating the performance of Taiwan students in working with a wind power system [9]. The laboratory teaching activities introduced energy sources, wind energy technology, electricity storage and wind power system testing. The wind power system testing activity covers eight topics: establishing the experimental module, operating instruments, measuring wind velocity, rotor diameter, wind speed, blade angle, blade number and data summarisation. Participation in these laboratory activities effectively introduces students to wind energy technology.

In 2010, the authors proposed a bio-energy hands-on activity to enhance learning in the classroom [10]. The activity combines biomass energy and bio-ethanol knowledge; explores voltage polarity, ethanol fuel consumption, and the effect of varying fuel concentrations; creates electricity with different types of alcohol; explores the effects of temperature; provides a data summary; and develops instructional materials. This hands-on activity proved effective in introducing students to the concept of bio-energy via activity evaluation and improving their understanding.

The set of laboratory activities presented in this article offers a convenient and flexible way for junior high school students in Taiwan to learn about thin-film-solar-hydrogen-fuel cells. The key steps in these laboratory activities include establishing an experimental module which uses a digital multi-meter to measure: thin-film-solar cell output voltage, electrolysis of water, hydrogen-fuel cell load voltage and hydrogen-fuel cell load current.

To begin the study, the concepts that underlie thin-film-solar-hydrogen-fuel cells are outlined in a manner suitable for junior high school students. A set of designed experiments include necessary laboratory activities, considering that a laboratory must serve numerous students. The current work covers diverse activities that broaden junior high school students' knowledge of thin-film-solar-hydrogen-fuel cell systems.

Finally, laboratory activities to make the module easy to use and fun are described and demonstrated in the study. The activities were designed to help students not only understand electricity generation, but also give them greater confidence in investigating, questioning, and experimenting with renewable energy-related concepts.

LABORATORY ACTIVITY

The goal of this activity is to construct a thin-film-solar-hydrogen-fuel cell system. A panel of experts, including experienced researchers, university professors and experienced engineers, evaluated these activities and concluded that the teaching materials and experimental equipment were suitable for students.

Topic 1 - Establishing an Experimental Module

Before beginning laboratory activities, students must understand the experimental module setup by reading relevant information on how the system is structured for successful experimentation. This experimental module combines a thin-film-solar cell, a hydrogen-fuel cell, a digital multi-meter, a motor load and a water tank, adopted to construct a thin-film-solar-hydrogen-fuel cell system.

Topic 2 - Using a Digital Multi-Meter

The experimental module includes a digital multi-meter to measure voltage or current. To measure voltage, the multi-meter must be connected in parallel and to measure current, it must be connected in series. The students are given clear, step-by-step instructions on how to operate it:

1. Insert the black probe into the black *ground* jack and the red probe into the red jack.
2. Always begin at the highest value of the property being measured, and reduce it. The selection ranges are shown in red. Match the red test probe jack to the red input and the black jack to the black input.
3. Apply the test probes to the two points where the voltage or current readings are to be made. Take care not to touch any energised conductor with any part of the body.
4. Turn the dial to the next lower range for a more accurate reading, only if the reading is within that range.
5. After making all of the measurements, disconnect the test probes from the tested circuit.

Topic 3 - Measuring the Thin-Film-Solar Cell Output Voltage

In this activity, the student uses a digital multi-meter to measure accurately the effect of the light source on the thin-film-solar cell panel. The student must assemble the circuit for making the measurement.

Figure 1 shows the circuit diagram. Connect the multi-meter to the thin-film-solar cell with the (+) connected to the red and the (-) connected to the black. Turn the dial to *voltage*. Use the thin-film-solar cell and the multi-meter to measure voltage for different light sources, and then record the reading.

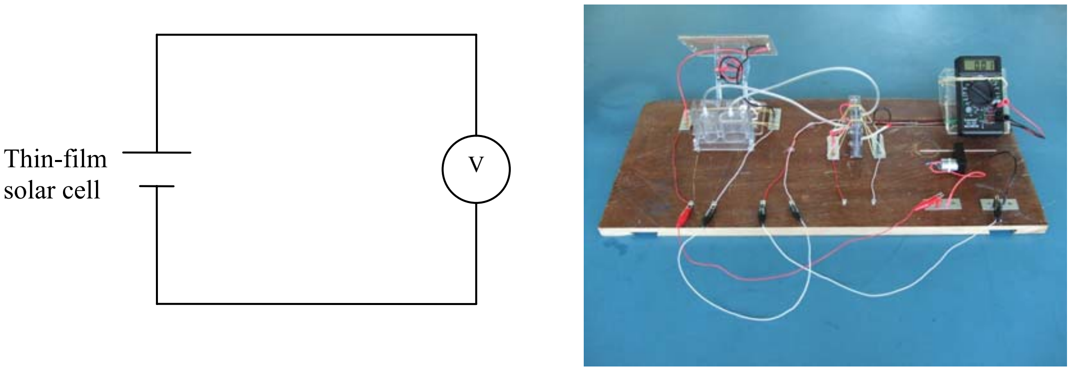

Figure 1: Schematic circuit for measuring output voltage of thin-film-solar cell.

Topic 4 - Electrolysis of Water

The goal of this activity is to use an electrical current to separate water into the two components, hydrogen and oxygen. The student performs a flame test to determine which gas is hydrogen and which gas is oxygen. An electrical current is used to separate water. Laboratory workers are typically warned against the dangers of electricity in water. In this activity, the student applies a small current (from the thin-film-solar cell) that is safe for use in the classroom.

Connect the wires from the thin-film-solar cell (+ and -) to the electrodes. Place the electrodes in the water and fold their tops to hang them onto the edge of the tub. Set the electrodes approximately 4-10 cm apart from each other in the water. The apparatus is now ready to split the water. The current should pass from the solar cell (+) through the wire to the (+) electrode, then through the water to the (-) electrode, and finally back up the wire to the solar cell (-). If everything looks ready, shine the light source onto the thin-film-solar cell to start splitting the water into hydrogen and oxygen, as presented in Figure 2.

Some points regarding safety need mentioning. Students must wear safety goggles when working with open flames. Safety issues related to electricity and water require discussion. The current from the thin-film-solar cell is safe, but the current from a wall outlet can be fatal. Matches and candles need monitoring to reduce any *playing with fire*. Any student, who plays with fire even once, is removed from the lab and must sit alone for the rest of the class.

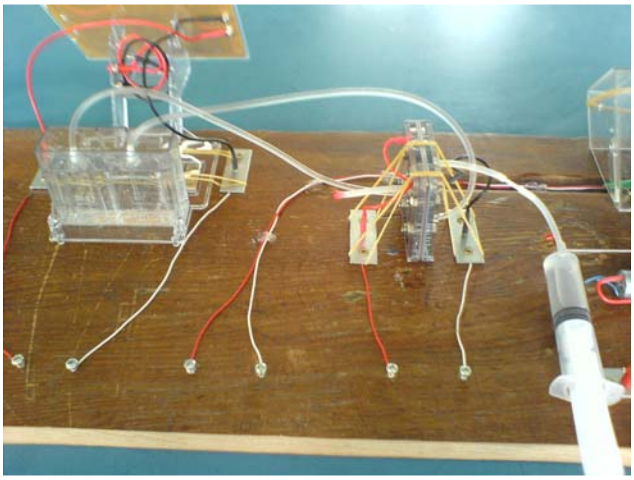

Figure 2: Electrolysis of water.

Topic 5 - Measuring Hydrogen-Fuel Cell Load Voltage

Voltage measurement is simple: it involves connecting the multi-meter in parallel with the circuit. A student can connect to the points on the motor (M) connected to the multi-meter, as shown in Figure 3. The voltage on the multi-meter requires reading and recording.

Topic 6 - Measuring Hydrogen-Fuel Cell Load Current

The student measures the current after measuring the voltage. To measure the current, the student must connect the multi-meter in series with the motor (M) in the circuit. After correctly changing all of the electrical connections, the student must turn on the multi-meter, and shine the light source onto the thin-film-solar cell. After a moment, the rate of electrolysis will appear stable; then, the current on the multi-meter needs to be read and recorded. Figure 4 shows the circuit diagram.

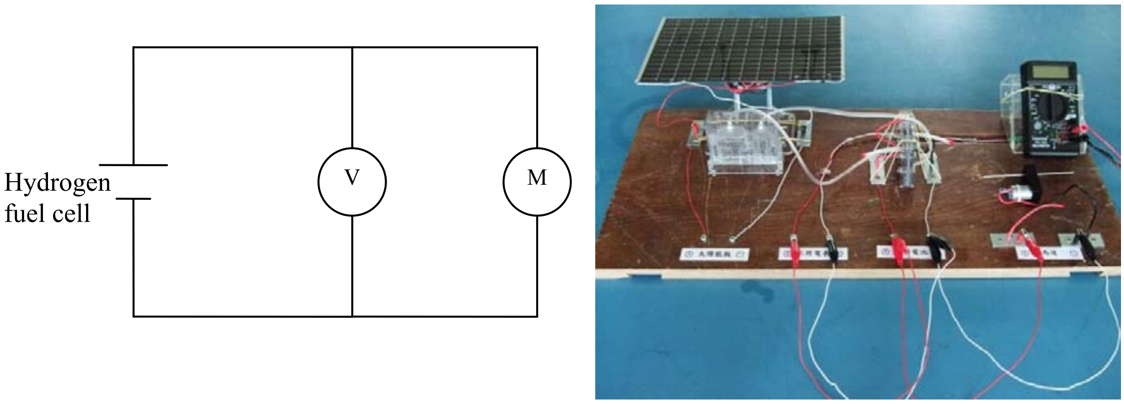

Figure 3: Schematic circuit for measuring the hydrogen-fuel cell load voltage.

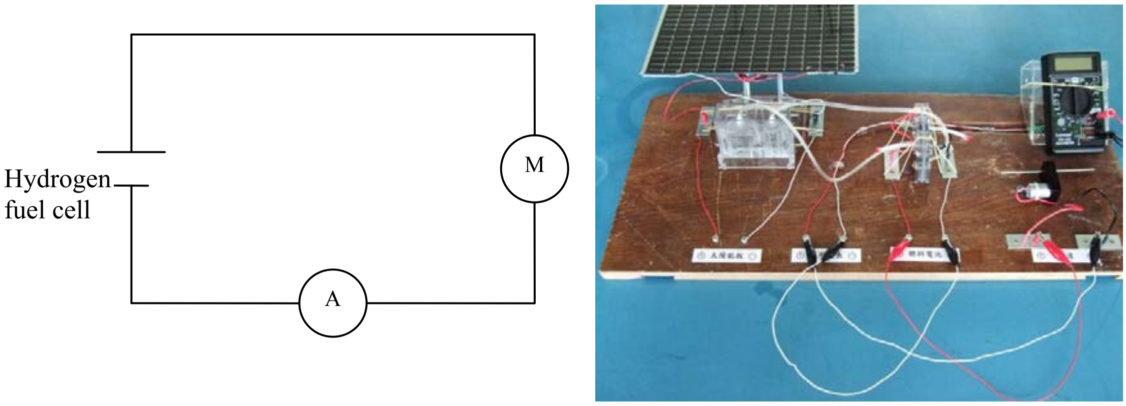

Figure 4: Schematic circuit for measuring the hydrogen-fuel cell load current.

Figure 5: Students were involved in experimental activities.

METHODS

Participants

These laboratory activities were conducted in a Taiwanese junior high school. Twenty-seven students (average age of 15) participated in the activity (Figure 5), for 1 hour per week over a period of six weeks.

Design

The design of this study was pre-experimental (one pre-test group and one post-test group), which included a pre-test measure followed by a treatment and a post-test [11]. Twenty-seven participants took pre-test surveys before the laboratory activity and post-test surveys after the laboratory activity. The questionnaire was composed of ten questions. The pre-test and post-test questionnaires were prepared and reviewed by eight education and field experts. Several cycles of review and modification were then applied to the questionnaires.

Data Collection

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

Results and Discussion

Before joining these laboratory activities, students took a pre-test to rate their own concepts on renewable energy. At the end of these laboratory activities, they took a post-test. Table 1 shows the statistics for the paired sample test. The results in Table 2 show there was a significant improvement of post-test over pre-test ($t=-3.676$, $df=26$, $p<0.05=\alpha$). The significant increases indicated that the laboratory activity was effective in helping students to improve their conceptual understanding of renewable energy.

The following assesses this study: 1) All students possessed the same initial level as none had ever participated in a laboratory activity; 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.

Table 1: Paired sample statistics.

	Mean	N	Std Deviation	Std Error Mean
Pre-test	41.78	27	15.465	2.976
Post-test	50.81	27	13.714	2.639

Table 2: Paired sample test.

Pair 1	Paired Differences					
	Mean	Std Deviation	Std Error Mean	95% Confidence Interval of the Difference		t
				Lower	Upper	
Pre-test – Post-test	-9.037	12.775	2.458	-14.091	-3.984	-3.676*

*p<.05

CONCLUSIONS

A laboratory activity to enhance understanding of renewable energy for junior high school students was presented in this article. Students can carry out laboratory activities in class to learn renewable energy concepts. Evaluation results indicate the proposed laboratory activity was successful, and students in this study were generally excited about, and receptive to, these activities. Students who participated in these laboratory activities found them to be extremely informative and enjoyable.

This entire laboratory activity required only one simple inexpensive setup. At the end of the activity, students gained: 1) a firm understanding of the renewable energy concept, from both a theoretical and 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 is a single-group pre-test and post-test experimental design, future studies should exercise caution when making any generalisation to other environments. This topic requires further investigation in other control group environments.

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BIOGRAPHIES

Dr Wen-Jye Shyr is a Professor of the Department of Industrial Education and Technology at the National Changhua University of Education (NCUE), Taiwan. He earned his PhD from NCUE in 2003. His current research interests include mechatronics, graphical human interface, sensors, energy education and engineering technology education. Prof. Shyr has published more than 60 technological and educational papers in refereed journals and conference proceedings in his field. He has been published in, among others, *World Transactions on Engineering and Technology Education, IEEE Transactions on Education, International Journal of Engineering Education, European Journal of Engineering Education, Computer Applications in Engineering Education, International Journal of Continuing Engineering Education and Life-Long Learning, International Journal of Digital Content Technology and its Applications.* He is an individual member of the World Institute for Engineering and Technology Education (WIETE).

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