PE - 3

IMPROVING SCIENCE LEARNING THROUGH STUDENT ENGAGEMENT IN OPERATING SOLAR ENERGY SYSTEM AT IBNU SINA PRIMARY SCHOOL, BANDUNG

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Abstract

This paper reports the results of collaboration between Institut Teknologi Bandung (ITB) with Ibnu Sina Primary and Junior High School, Bandung, in developing a mini solar energy generating unit as a learning media for the concept of renewable energy. This type of renewable energy generating system was designed for ease of operation and close relationship with everyday primary school activities. Therefore, students were safely involved in its operation and maintenance.

Ibnu Sina Primary School is among pilot schools for 2013 Indonesia learning curriculum. Therefore, these schools were enthusiastic with this energy system. The school’s foundation facilitated the system installation in the school field. The teachers also implemented the learning modules related to renewable energy using this system as learning media. The module was part of the theme “Energy Saving” for 4th grade students at the 2014/2015 academic year. The system was developed by ITB’s researchers and students in 2014. The mini solar generating unit was utilized to power LED lamps for school corridors lighting.

During the learning implementation, in addition to attending the class lecture, the students were also trained to operate and engaged in light maintenance of the system. The learning performance of this semester were measured and analyzed for future continuous improvement in student learning.

Key words: Renewable energy, science learning

INTRODUCTION

1.1 Background

Sustainable energy security is unavoidable issue for Indonesia’s productive generation in the next 10 to 20 years. Therefore, the concept of renewable energy should be educated to as many people as possible since their young age. One way to familiarize young children with such concept is by choosing the energy generating mechanism that they easily understand and easily integrated to their everyday activities.

Let us consider a mini solar panel system. The panel gathered the energy packed in sunlight and stored them in a battery for direct current electrical consumption, such as corridors lighting. These renewable energy systems are suitable for primary school’s science learning. The senior students, such as the 4th - 6th graders can be gradually introduced to the solar energy generating systems. They can be involved in operation, maintenance, and even in further research and development of the system.

1.2 Problem Formulation

Before this project, the lesson about the "Energy Saving" according to 2013 Indonesia's Learning Curriculum (Depdikbud, 2013) at Ibnu Sina Primary School was conducted by giving class lecture, showing relevant movie, collecting relevant articles in magazine and news papers and discussing the results. These approaches were quite common among the primary schools in Indonesia. However, the students might perceive that the energy generating system was something beyond their daily activities and therefore the idea of energy generation was easily forgotten (Huang, et. al., 2012; Ang and Wang, 2006).

Therefore, one mini solar panel system was installed in the school at 2014. Accordingly, the lessons were supported by demonstration of energy generating system. The students were also involved in measuring the system's performance, operating, and maintaining the system. The students had a group discussion about the system's implementation and opportunities of alternative developments. At various stage of the course, the student learning was evaluated quantitative and qualitatively.

2. Project and Research Description

The project covered two main activities, i.e. the design, testing and installation of solar panel system; and the measurement and analysis of the learning performance. The solar panel system design and implementation were based on the supporting researches in the Center for Instrumentation Technology and Automation, Institut Teknologi Bandung (CITA-ITB) (Bahrul, 2013; Ningtyas, 2014; Utomo, 2013). The project was funded by 2014 ITB's Community Service Program (Program Pengabdian kepada Masyarakat) and implemented at Ibnu Sina Primary School, Bandung, Indonesia. Ibnu Sina teachers facilitated the systems installation, developed the learning modules and evaluated the class performances at various learning stages in a form of class action research (Ahsan and Julianto, 2014; Aqib, 2010; Vernandani and Julianto,2014).

2.1 The Implementation of Solar Panel System

2.1.a System Design

The solar panel system was designed as illustrated in Figure 1. This system included three functional units as follows (Ekawati *et. al*., 2009; Forero *et. al*., 2006):

1. Energy gathering unit, consisted of one 100 Wp Photo Voltaic (PV) module, commonly known as solar panel. This unit was supported by a retractable pole so that students can bring down the panel for observation and cleaning, and later raise the panel for operation.
2. Electricity conversion unit, consisted of one Maximum Power Point Tracker (MPPT), one battery charging module, and one lead acid battery
3. Monitoring and control unit, consisted of one microprocessor, and one Human Machine Interface (HMI) program.

The solar panel generated varying power, due to the sunlight blocking by cloud or buildings, the panel's temperature and the system's loading. Therefore, one MPPT was utilized to operate the system at its maximum power and isolate the panel from the load (Utomo, 2013). The generated DC current was used to charge the battery. To secure the power distribution, a charge controller and buffer module was installed between the battery and the load (Bahrul, 2013).

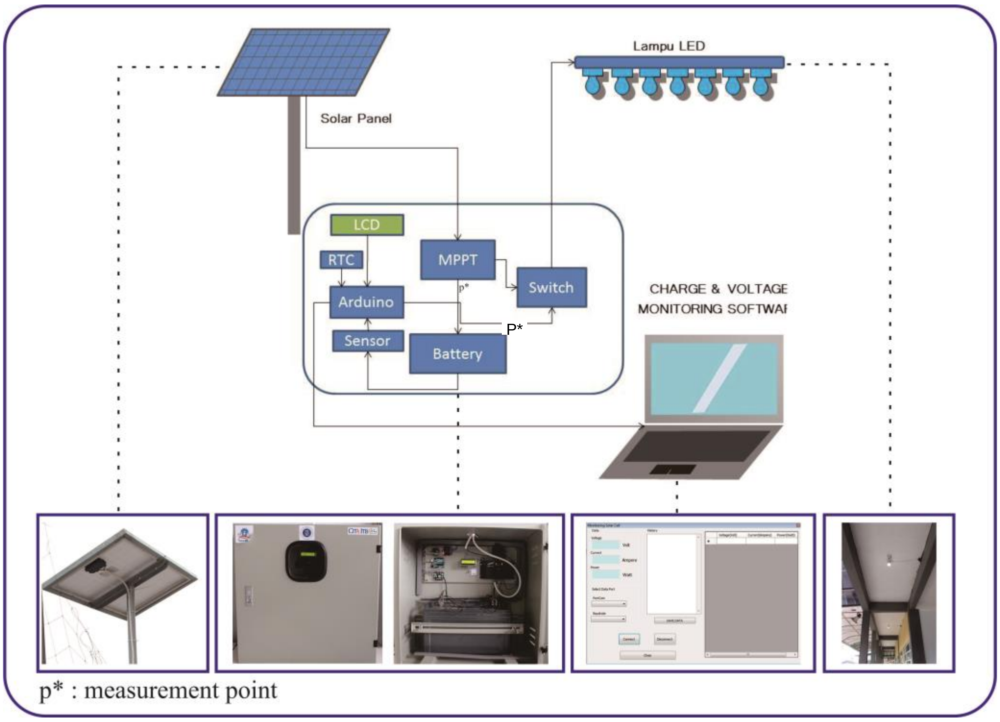

Figure 1. The Diagram of Solar Panel System

The systems operation, including the value of power generated and the rate of battery charging was monitored through one LCD display. These components were located in a panel box. One Human Machine Interface (HMI) program (Ningtyas, 2014) was also installed in a computer. This HMI could be connected to the panel and LCD Projector for monitoring the charging processes and presenting the process to the class.

The accumulated electricity was used to light one school corridor at night or at low lighting condition. Five Light Dependent Resistors (LDRs) were used as light sensors and located along the corridor. When the lighting level was low, these sensors signal the microcontroller to connect the battery with the 5W LED lamps and light the corridor.

The specifications of the PV module, battery, and LED lamps are listed in Table 1. Based on these specifications and assuming that the effective daylight during the rainy season was 5 hours, the total energy produced by the PV module (E_{PVt}) was calculated as follows:

$$E_{PVt} = V_{PVAv} \times I_{PVAv} \times t_{Ir} = 17.5 \text{ Volt} \times 5.72 \text{ Ampere} \times 5.0 \text{ hours} = 500.5 \text{ Watt hours} \quad (1)$$

$$N_L \leq E_{PVt} / (P_L \times t_L) = 500.5 \text{ Watt hours} / (5.0 \text{ Watt / lamp} \times 12.0 \text{ hours}) = 8.3 \approx 8 \text{ lamps} \quad (2)$$

In eq(1), V_{PVAv}, I_{PVAv} and t_{Ir} are the average voltage, the average current and the duration of effective daylight, respectively. In eq(2), N_L, P_L and t_L are the number, the power and the average operational time of the LED lamps. Therefore, eq (2) shows that the accumulated energy was capable to energize 8 units of 5-Watt LED lamps for 12 hours. On the other hand, the battery's energy capacity, E_{CB}, is

$$E_{CB} = V_B \times It_B = 12.0 \text{ Volt} \times 100.0 \text{ Ampere hour} = 1200.0 \text{ Watt hour} \quad (3)$$

Here, V_B, and It_B are the battery output voltage and total current capacity respectively. Therefore, the contribution of solar power to the total battery's capacity ($\%E_{PVAv}$)

$$\%E_{PVAv} = E_{PVAv} / E_{CB} \times 100\% = 500.5 / 1200.0 \times 100\ \% = 41.7\% \quad (4)$$

In order to provide sustainable energy generation and consumption cycle, the system was initiated with a fully charged battery. The battery was used to power the lamps overnight. At the next morning, the PV system charged the accumulator. Afterwards, the 24 hours cycle of powering the lamps and charging the battery would be continued.

2.2.b System Testing

The designed system was implemented and tested for actual energy consumption, and for the efficiency of energy conversion process.

The first measurement was performed at the lamp system to determine the actual energy consumption. The measurement yielded that the lamp's cabling system had increased the averaged energy consumption P_{La} to 6 Watt/lamp. Therefore, the actual energy consumption for 12 hours (E_{La}) was:

$$E_{La} = N_L \times P_{La} \times t_L = 8 \text{ lamps} \times 6 \text{ Watt / lamp} \times 12 \text{ hours} = 576 \text{ Watt hours} \quad (5)$$

Since the actual consumed energy E_{La} was greater than the designed value calculated in eq(1), and there was a possibility that the solar panel might generate lower than the expected, then the capability of PV and MPPT to serve this load was tested. Voltage and current were measured at the output of PV (V_{PV} and I_{PV}) and the output of MPPT (V_o and I_o). The objective of this measurement was to determine the accumulated energy that will be stored in the battery and to identify the power stabilization characteristics of MPPT. The measurement was executed on a daytime at the illumination of 5840 - 8250 lux for five hours.

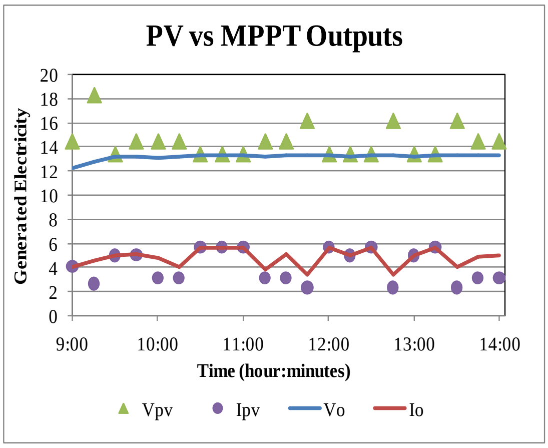

Figure 2. PV and MPPT Electricity Outputs

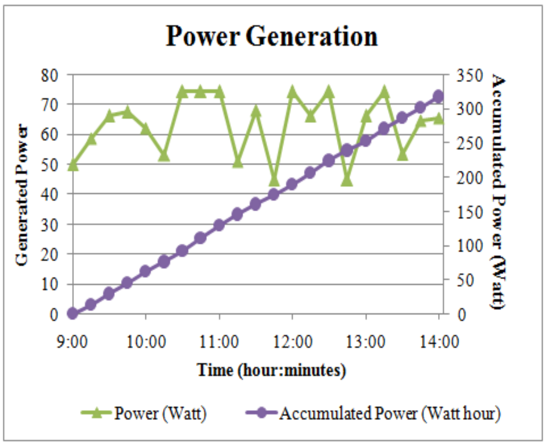

Figure 3. MPPT Power Output

shows the comparison between V_{PV}, I_{PV}, V_o and I_o and shows that the MPPT reduced the fluctuations of voltage and current. The respective instantaneous power $V_o \times I_o$ and the total accumulated power E_{PVa} was 317.90 Watt hour, as shown in **Error! Reference source not found.**.

$$E_{PVa} = \sum_{t=0}^{5} V_o \times I_o \times \Delta t_{PV} = 317.9 \text{ Watt hours} \quad (6)$$

A nonlinear regression operation was applied to obtain the current and power characteristics defined in Tsai *et. al.* (2008) as follows:

$$I_{rs}=\frac{I_{sc}}{\left(e^{-\left(\frac{qV_{oc}}{N_s kAT_c}\right)}-1\right)} \quad (7)$$

$$I_s=I_{rs}\left(\frac{T_c}{T_{ref}}\right)^3 \times e^{\left(\frac{qE_g\left(\frac{1}{T_{ref}}-\frac{1}{T_c}\right)}{kA}\right)} \quad (8)$$

$$I_{oa}=N_p I_{sc}-N_p I_s\left(e^{-\left(\frac{qV}{N_s kAT_c}\right)}-1\right) \quad (9)$$

By minimizing the current's sum of squared errors between the current data I_o and the approximated value I_{oa} based on eq (7)-(9), the PV parameters were identified and listed in Table 2. The approximated curve of output current I_o and the respective power are shown in Figure 4. This figure shows that the MPPT adjusted the output current and voltage so that the system produced power close to the maximum value at 85% of the measurement time. However, the accumulated power was only available for energizing four LED lamps. Accordingly, only four lamps were used in this project.

Table 1. System Specification Parameters

Photo Voltaic Panel		
Type		Hooray 100 MCP-2
Cell Type		Polycrystalline Silicon
Weight		9.5 Kg
Length		668 mm
Width		1131 mm
Thickness		35mm
V_{PVAvm}	Average Voltage	17.5 Volt
I_{PVAv}	Average Current	5.72 Ampere
N_P	Number of Cells	36
W_P	Weight	9.5 kg
Battery		
Type		GS Astra Premium N 100
I_{tB}	Capacity	100 Ah
V_B	Voltage	12 V
LED		
Type		HILED 5 W
P_{La}	Power	5 W
V_{La}	Op Voltage	8-12 V
K_{La}	Ilumination	450 Lux

Table 2. Solar Panel System Identified

Parameter		Value
I_{SC}	Cell's short circuit current	1.22A
q	Electron charge	1.6×10^{-19} C
V_{OC}	Open circuit voltage	13.3V
Ns	Series number of cells for a PV module	8
N_P	Parallel number of cells for a PV module	4
k	Boltzmann's constant	1.38×10^{-19} J/K
A	Ideal factor	1.30
T_C	Cell's working temperature	30
T_{ref}	Cell's reference temperature	25
E_g	Band gap energy	10^{-5}J/C
I_s	Cell saturation of dark current	1.6×10^{-16} A
I_{rs}	Cell's revere saturation current	2.8×10^{-16} A

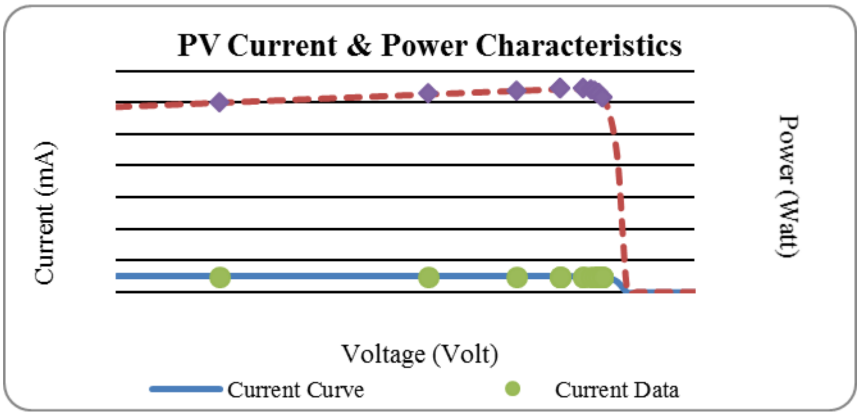

Figure 4. PV Current and Power Characteristics

These experiments justified the readiness of the system, both for solar-based lighting system, and for science learning media. The experiment results provide the baseline for the future developed learning modules.

2.2 The Class Action Research of Renewable Energy Concept

2.2.a Research Coverage

In order to support the implementation of 2013 Indonesian education curriculum (Debdikbud, 2013), the solar panel system was utilized as a learning media for 4th grade science lesson of "Energy Saving" theme at Ibnu Sina Primary School. A class action research (Aqib, 2010) was chosen as the framework to analyze the effect of utilizing the solar panel system as a learning media.

There were many class action researches about the implementation of various learning methods to improve science learning, such as the work of Ahsan and Julianto (2014), as well as Vernandani and Julianto (2014). However, to the best of authors' search, such studies had neither included the concept of renewable energy nor the utilization of solar panel system. Therefore, this project was more in line with the work of Coker *et. al.* (2010) and Huang *et. al.* (2012), using a locally developed system.

One cycle of class action research consisted of four stages, i.e. (1) planning, (2) execution, (3) observation and (4) reflection. The first stage consisted of coordination with school's headmaster and 4th grade teachers about the research, evaluation of past performances and curriculum, preparation of lesson plan, learning material and student's worksheet, creating the evaluation tools (pretest and post test and student questionnaire). The lesson plan was executed at the second stage. The third stage included the observation of the learning conditions and identification of the learning problems and obstacles. The fourth stage consisted of the analysis of learning performance and discussion of strategies to overcome the problems. Two or more cycles may be used, each introducing improvement strategies and analyzed accordingly (Aqib, 2010).

2.2.b Research Implementation

The planning. During the mid-semester evaluation before the research was executed, it was found that the students enthusiasm in science learning was low, due to limited opportunity to engage with relevant learning media. To address this problem, a two-cycle class action research was planned. Each cycle involved 21 students for 4 x 35 minutes lessons about renewable energy. The plan for first cycle's execution included a class lecture, a photo presentation about various renewable energy sources, individual reading, grouped / paired discussions and teacher's affirmation about the learning material. In the second cycle, instead of photo presentation, the students were guided to observe and to operate the solar panel system. The complete steps were listed in Table 3.

To provide the baseline of learning performance analysis, the students were given a pre-test to identify their prior knowledge about the utilization of solar energy as an alternative energy source before cycle-1 began. The result is listed in Table 4, and compared with the results of cycle-1 and cycle-2 post-tests. The threshold of learning performance is 7.5 on 0-10 scale.

The execution. The first cycle was executed at 06 October 2014. The lecture and photo presentation were performed as planned. The students were grouped in 4 or 5 people, to encourage more individual expressions about the renewable energy.

The second cycle was conducted at November 24th, 2014. During this lesson, the children were briefed about the working principle of the solar panel systems. They proceeded to observe and operate the systems. They were also trained to execute light maintenance of the system, such as lowering the panel to observe the shape of PV cells and to clean the panel. They also checked the components inside the charging panel.

Table 3. Learning Activities

No	Cycle-1	Cycle-2
1	Teachers prepared students for learning	Teachers prepared students for learning
2	Teachers described the learning goal	Teachers described the learning goal
3	Teachers explained the learning procedures	Teachers explain the learning procedures
4	Teachers relate the previous lesson with the current topic	Teachers relate the previous lesson with the current topic
5	Students observed photo presentation about renewable energy sources	CITA's team explained the working principle of solar panel system.
6	Studentsdiscussed and answered in the questions in student's workbook in a group of 4-5 people	Students observed the components of solar panel system and practices simple maintenance routines
7	Students individually read the articles about renewable energy sources	Students confirmed their understanding in question and answer session with CITA's team and the teachers
8	Students drew a mind map of renewable energy sourcesand discussed it with other student in pair	Students discussed and formulated the their conclusion about renewable energy sources in a group of 4-5 people
9	Teacher affirmed that renewable energy sources were available and were ready for residential use	Teacher affirmed that one renewable energy source was available in the premise and was ready to use for school lighting
10	Post test	Post test

Table 4. Test Scores

No	Student	Gender	Category	Scores			Improvement	
				Pre-test	Cycle-1 post test	Cycle-2 post test	Cycle-1	Cycle-2
1	A	Male (M)	IV	4	4	8	0	4
2	B	Female (F)	IV	4	4	6	0	2
3	C	M	II	6	8	8	2	0
4	D	M	I	8	8	10	0	2
5	E	M	IV	4	4	6	0	2
6	F	M	I	8	10	10	2	0

7	G	F	III	6	6	8	0	2
8	H	F	I	8	10	10	2	0
9	I	M	IV	2	4	4	2	0
10	J	F	III	6	8	6	2	-2
11	K	F	IV	4	4	6	0	2
12	L	M	III	6	4	6	-2	2
13	M	M	II	8	8	8	0	0
14	N	F	I	8	8	10	0	2
15	O	F	III	4	6	8	2	2
16	P	M	III	6	6	8	0	2
17	Q	F	II	6	8	8	2	0
18	R	F	IV	2	4	8	2	4
19	S	M	II	8	8	8	0	0
20	T	M	II	8	8	8	0	0
21	U	F	I	8	8	10	0	2
Average				5.90	6.57	7.33	0.67	1.24
Standard Deviation				2.05	2.11	1.66	1.15	1.48
Number of students exceeding learning threshold				8	11	15		
Percentage of students exceeding learning threshold				38%	52%	71%		

The observation. The students became more engaged as the cycles progressed. In cycle-1, student discussion was limited, due to inadequate description and examples of renewable energy systems. In cycle-2, this limitation was addressed. Most students showed more interests to the real solar panel system and expressed ideas and suggestions of further system development after the exercises.

The reflections. The post-test results, as shown in Table 4, were also increasing, resulting in higher percentage of students exceeded the learning threshold, i.e. from 38% before the cycle, 52% post cycle-1 and 71% post cycle-2. ANOVA analysis (Creswell, 2008) confirmed the significant difference between cycles at 5% level of confidence. The average improvement cycle-2 was 1.24, which was greater than cycle-1. Further t-student test (Creswell, 2008) confirmed that that the improvement in cycle-2 was significantly higher than cycle-1, also at 5% level of confidence.

An interesting pattern emerged when the students were grouped according their scores throughout the cycles. There were four groups, i.e. (I) the average scores were 8.67-9.33, (II) the average scores were 7.33-8.00,(III) the average scores were 5.33-6.67,(IV) the average scores were 3.33-5.33. Group IV had the largest improvement during cycle-2 (2.3). The second largest was group III (1.2) and I (1.2). The least improved was group II (0.0).This indicated that groups IV and III, who were not previously exposed to examples of renewable energy system, could benefit from practical examples and exercises related to learning material. Group I and II, on the other hand, had more exposures to learning materials prior to the lessons. However, group I showed more improvement after observing the real system than group II.

The gender was distributed alternately between 40%-60% in groups I, III and IV. Interestingly, group II that had the least improvement in cycle-2 has 4 male students and 1 female student. ANOVA analysis (Creswell, 2008) showed that there was no significant difference on the test results based on the student's gender. This showed that both gender has the equal potential to excel in science learning.

DISCUSSION

The significant improvements of learning performances in this project highlighted the importance of exposing the students to relevant system as learning media. The cycle-2's learning condition showed that some students had a need to physically engage with the system in order to grasp the underlying scientific concepts. Once they could see, touch and operate the system, they actively developed their own understanding through discussions with their peers, teachers and instructors. This was understandable, because not all family has adequate learning resources at home. Accordingly, the students who came from these families have no prior knowledge about some of contemporary issues, such as renewable energy. Therefore, having the mini solar panel system at school had provided the students the opportunity to gain the knowledge and to develop ideas about further development of the system. This finding was in line with the study of Coker *et*. *al*. (2010) and Huang *et*. *al*. (2012).

Since it was widely recognized that most primary schools in Indonesia have limited operational budget, collaborations or resources sharing with communities and other educational institutions are required. Higher education institutions such as universities produce many students' research or internship projects every year. While the products may require more developments until it is ready for industrial purpose, many of these are adequate for demonstrating important science principles to some communities, such as primary schools. Sharing these research products with primary schools would trigger many positive effects, such as:

1. Creating a sustainable learning collaboration between university and primary school.
2. Improving the quality of learning for both university students and the partner's primary school students. This was shown in the thoroughness of system's design and the learning assessments.
3. Introducing important research directions to young students and their teachers, and stimulate them to initiate their own extracurricular research projects. These projects may also evolve to enrich the existing learning modules.

The plan to sustain this collaboration is underway towards providing more structured curricular and extracurricular activities involving both ITB and Ibnu Sina students.

CONCLUSION

The implementation of solar panel system as a learning media and enabling the students to physically engaged with the system had significantly improved the students understanding towards the concepts of renewable energy generating system as demanded by the 2013 learning curriculum. Providing such system through the utilization of university's research projects and through the university's community service program was beneficial and inspirational to both institutions.

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