High Scope Program conference on Asia-Pacific scinence education

The Practice of Inquiry-Based Learning in High School

The green-energy curriculum with project-based instruction connecting high school and university educations

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Abstract

The purpose of this study was to develop a green-energy curriculum for promoting students' scientific literacy, attitudes toward energy-science and connecting their high school and university educations. This curriculum, with the contents of energy-saving and carbon-reduction was supported by National Science Council in Taiwan and has been developed for three years for the public policy of connecting curriculum. There were 250 students of 10^{th} -11^{th} graders in 5 classes and 9 teachers voluntarily participated in this study. Subjects of this curriculum included physics, chemistry, and biology, and the topics included solo energy, wind energy, biomass energy and energy efficiency. The curriculum with project-based instruction and group-cooperation learning was implemented two hours per week during one year. The topics in the curriculum were partly immerged in the regular science curriculum and partly arranged in the weekend. Questionnaires about students' scientific knowledge and attitudes toward energy-science, students' learning portfolio, students' performance exhibitions, the interviews for the students who participated in the project and teachers' reflections were the tools for evaluating the curriculum before, during and post developing. The results of the green-energy curriculum developed were based on the suggestions: the applicable practice in the science classrooms of high schools, the effectiveness for connecting high school and university educations.

Key words: green-energy curriculum, project-based instruction, connecting curriculum

Introduction

Technology and Science in the world are explored and created in more and fast progress; however, science curriculum is often reformed with spending longer duration slow speed (Fullan, Bertani, & Quinn, 2004). It is not easy to make the curriculum reform in short time and extend overall. Contents of current curriculum are not always satisfied the real-world needs. This is one of the reasons causing the gaps between middle education and higher education. However, large-scale curriculum reform is not easy for any country or state. Reform projects require a " sophisticated array of activities, structures, teaching strategies, and philosophical understanding" to ultimately be effective (Fullan, 2001, p.78). In Taiwan, the initiation of a reformed curriculum with large-scale varies widely from grass-roots efforts by groups of teachers, educators, curricular experts, and top-down administrative decisions. Therefore, it is required to make a reform or creative small-scale curriculum which is initiated by researchers, educators, or teachers, and always funded by national academic institution, such as National Science Council (NSC) local, urban and systemic initiative programs. These NSC initiatives have routinely involved curriculum-based-on and provided extensive in-service training for teachers to be able to use materials and teach in an innovative pedagogy expected to meet the needs of Taiwanese K-12 needs. High Scope Program (HSP) is initiated by NSC in Taiwan from 2006 till 2011, and it is for connecting the education between the senior high school and university education. One of the most important reasons is to reduce the gaps of both educational curriculums. Since the goals of middle educations under the national standards can not meet the pre-knowledge of university expectation and the progress of science and technology. All the senior high schools cooperating with university can voluntarily participate this program if their HSP proposals were accepted by NSC committee. This program in this study was one of the HSP subprograms accepted.

The purpose of this study was to develop a green-energy curriculum (GEC) for promoting students' energy concept, attitudes toward energy-science and connecting their high school and university educations. This curriculum was supported and funded by National Science Council in Taiwan and has been developed for three years.

Theoretical Frame

Research on the NSC systemic initiative curriculum has focused on designing teaching materials, implementation and evaluation. The topics of students' exploration for energy-saving and carbon-reduction were guided towards Stirling engine, hydrogen production, hydrogen storage, biomass and biotechnology.

A Stirling engine is a heat engine that operates by cyclic compression and expansion of air or other gas, the working fluid, at different temperature levels such that there is a net conversion of heat energy to mechanical work. The engine is like a steam engine in that all of the engine's heat flows in and out through the engine wall. This is traditionally known as an external combustion engine in contrast to an internal combustion engine where the heat input is by combustion of a fuel within the body of the working fluid. Unlike the steam engine's use of water in both its liquid and gaseous phases as the working fluid, the Stirling engine encloses a fixed quantity of permanently gaseous fluid such as air or helium. As in all heat engines, the general cycle consists of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle. Originally conceived in 1816 as an industrial prime mover to rival the steam engine, its practical use was largely confined to low-power domestic applications for over a century. The Stirling engine is noted for its high efficiency, quiet operation, and the ease with which it can use almost any heat source. This compatibility with alternative and renewable energy sources has become increasingly significant as the price of conventional fuels rises, and also in light of concerns such as peak oil and climate change. This engine is currently exciting interest as the core component of micro combined heat and power (CHP) units, in which it is more efficient and safer than a comparable steam engine.

The role of Hydrogen Energy Center in any country is to facilitate the adoption of hydrogen energy technologies and enhance the relationship between hydrogen and renewable energy sources. These centers do this by designing and installing hydrogen energy systems; educating others about hydrogen and its energy uses; assisting and encouraging individuals, start-up companies and existing businesses who participate in the renewable hydrogen economy; and connecting businesses and individuals to others who share this vision of hydrogen's role.

Hydrogen gas is so much lighter than air that it rises fast and is quickly ejected from the atmosphere. This is why hydrogen as a gas (H_2) is not found by itself on Earth. It is found only in compound form with other elements. Hydrogen combined with oxygen, is water (H_2O). Hydrogen combined with carbon forms different compounds, including methane (CH_4), coal, and petroleum. Hydrogen is also found in all growing things — for example, biomass. It is also an abundant element in the Earth's crust.

Hydrogen has the highest energy content of any common fuel by weight (about three times more than gasoline), but the lowest energy content by volume (about four times less than gasoline). Therefore, this topic was guided by teachers in this study for the reform curriculum.

Energy carriers move energy in a useable form from one place to another. Electricity is the most well-known energy carrier. We use electricity to move the energy in coal, uranium, and other energy sources from power plants to homes and businesses. We also use electricity to move the energy in flowing water from hydropower dams to consumers. For many energy needs, it is much easier to use electricity than the energy sources themselves.

Like electricity, hydrogen is an energy carrier and must be produced from another substance. Hydrogen is not currently widely used, but it has potential as an energy carrier in the future. Hydrogen can be produced from a variety of resources (water, fossil fuels, or biomass) and is a byproduct of other chemical processes.

To many people, the most familiar forms of renewable energy are the wind and the sun. But biomass (plant material and animal waste) supplies almost 15 times as much energy in the United States as wind and solar power combined—and has the potential to supply much more. There are a wide variety of biomass energy resources, including tree and grass crops and forestry, agricultural, and urban wastes. It is the oldest source of renewable energy known to humans, used since our ancestors learned the secret of fire. Contents for biomass include: 1. Types of Biomass; 2. Converting Biomass to Energy; 3. Potential for Biomass; 4. Environmental Benefits. Biomass is a renewable energy source because the energy it contains comes from the sun. Through the process of photosynthesis, chlorophyll in plants captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates, complex compounds composed of carbon, hydrogen, and oxygen. When these carbohydrates are burned, they turn back into carbon dioxide and water and release the sun's energy they contain. In this way, biomass functions as a sort of natural battery for storing solar energy. As long as biomass is produced sustainably—with only as much used as is grown—the battery will last indefinitely. From the time of Prometheus to the present, the most common way to capture the energy from biomass was to burn it, to make heat, steam, and electricity. But advances in recent years have shown that there are more efficient and cleaner ways to use biomass. It can be converted into liquid fuels, for example, or cooked in a process called "gasification" to produce combustible gases. And certain crops such as switchgrass and willow trees are especially suited as "energy crops," plants grown specifically for energy generation.

There are many types of plants in the world, and many ways they can be used for energy production. In general there are two approaches: growing plants specifically for energy use, and using the residues from plants that are used for other things. The best approaches vary from region to region according to climate, soils, geography, population, and so on.

Purpose and questions

The purpose in this study is to develop one curriculum which goal is to meet the national requirement concerning the energy and connect middle school and university education. The contents of green-energy curriculum (GEC) in this study include topics: Stirling engine, Stirling car, hydrogen production and storage, biomass and biotechnology. This curriculum was supported and funded by National Science Council in Taiwan and has been developed for three years. Project-based instruction was designed for students' learning. This research will examine the appropriateness and the effectiveness. Therefore, the following items have to be completed:

1. Developing the green-energy curriculum (GEC) for high school;
2. Valididdating the green-energy curriculum;
3. Developing the instruments for research tools;
4. Implementing the green-energy curriculum;
5. Examining the appropriateness and the effectiveness.

Method

Mingdao is a large urban district middle school, but students come from all districts in Taichung City and there are over 100 school buses for over 6,000 students. Mingdao has been adopted as one project of HSP programs, NSC in Taiwan. This green-energy curriculum (GEC) of NSC-funded project in this study has been implemented three years. There is evidence that teachers' use of reform-based practices within these funded systemic reform projects is related to higher student achievement (Cohen & Hill, 2000; Von Secker, 2002). However, in this study, there were 250 students of 10th -11th graders in 5 classes for the experimental group and 9 teachers voluntarily participated in this study. 250 non-participants were randomly chosen for the control group. Subjects of this curriculum included physics, chemistry, and biology, and the topics included solo energy, wind energy, biomass energy and energy efficiency. The curriculum with project-based instruction and group-cooperation learning was implemented two hours per week during one year. Participants can join anyone of the 5 experimental classes and they have to take four credits instead of selected curriculum. Non-participants have to select 4 other credits of normal science curriculum arranged normally by school. The topics in the curriculum were partly arranged in the weekend and partly in the regular weekday. Questionnaires about students' scientific knowledge and attitudes toward energy-saving and carbon-reduction , students' learning portfolio, students' performance exhibitions, the interviews for the graduate students participating in the project and teachers' reflections were the tools for evaluating the curriculum before, during and post developing.

Instruments

In order to examine the effectiveness and appropriateness of green-energy curriculum (GEC), instruments were developed cooperatively with university educators. The Attitudes toward Energy-Science Inventory (Appendix A) and Scale Assessing Knowledge about Hydrogen Energy (Appendix B) were developed for pre- and post-intervention. The reliability of Cronbach α are .86 and .92 respectively.

Instructions

Since 1991, the Model-Assisted Reasoning in Science (MARS) project at the University of Pittsburgh's Learnig Research and Development Center has worked to investigate and promote model-centered as a means of improving middle school science education (Raghavan, Kesidou and Sartoris, 1993; Raghavan and Glaser, 1994; Raghavan, Glaser and Sartoris, 1995). In MARS instruction, students learn to use models the way scientists use them, as communication and reasoning tools that they can help them describe physical-world phenomena, to depict and test ideas about underlying causes and to identify and explore relationships between ideas. Models and student-centered learning were also used in the green-energy curriculum (GEC) in this study. Mingdao provided and help to construct models of Stirling engine, wind power, hydrogen production lab, and hydrogen-fuel cell and car as well as MARS project did. There were 6 main phases included in the project-based learning model in this study: 1. questions discovered and identified; 2. experiments designed; 3. information collected; 4. data collected; 5. report written and discussed; 6. performance presented. Teaching design and phases for Hydrogen-Energy Curriculum with project-based Learning is listed on Appendix C.

Green Energy Curriculum (GEC Curriculum)

The green energy curriculum will be immerged into the chemistry curriculum of senor high, and the units are "production and storage of hydrogen," "fuel cell," and "hybrid fuel cell integrated of solar power and hydrogen." It is hoped that with the related specialty and curriculum of "production and storage of hydrogen," "fuel cell," and "hybrid fuel cell integrated of solar power and hydrogen" as well as expert participation from the teaching domain to complete the research and development of this curriculum. The objectives of the developed curriculum were: (1) Enhancing Chemistry teachers' professional competencies about green energy including:

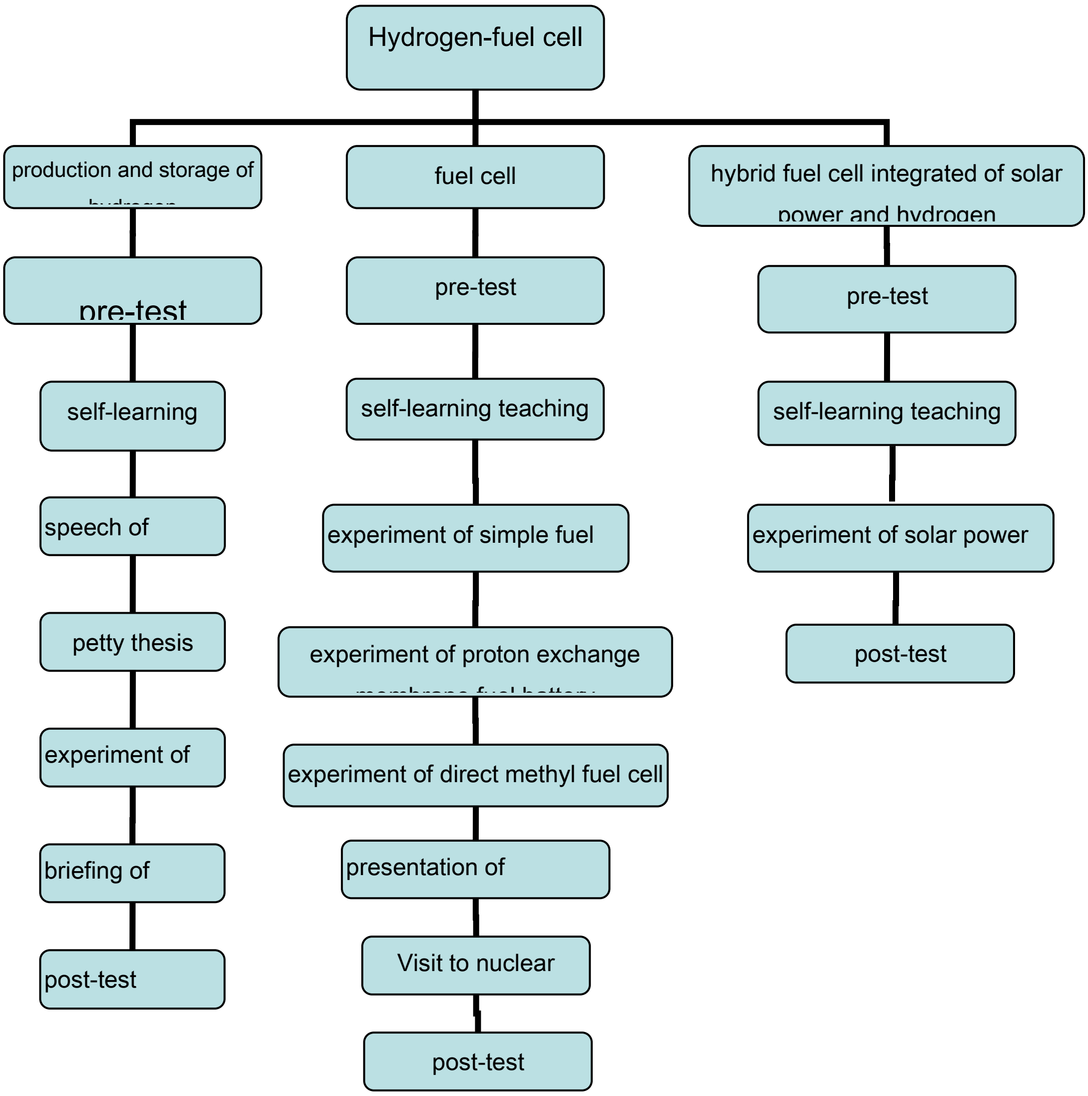
hydrogen energy, fuel cell, and its application; (2) Promoting students' learning interests and scientific literacy about energy; (3) Cultivating students' inquiry and problem-solving abilities; (4) Connecting the curriculums between high school and university.

The project is divided into four years, and the content and time-span for the design of the curriculum development by year is found as follows:

1. Planning of the holistic structure of curriculum – including the design concept and objective for the curriculum of three units. Second, the first year research and development is of the first theme – "production and storage of hydrogen" program, and explorative teaching is conducted so as to collect related information on the implementation of program.
2. For the second, it is of the modification and confirmation of "production and storage hydrogen" program, and to complete the holistic design and assessment of. Then, it will come to the second theme as "fuel cell" program and explorative teaching is carried out.
3. For the third year, it is of the modification and confirmation of "fuel cell" program, and to complete the holistic design and assessment of. Afterwards, it will come to the research and development of the third theme as "hybrid fuel cell integrated of solar power and hydrogen" program, explorative teaching is carried out.
4. For the fourth year, it is of the modification and confirmation of "hybrid fuel cell integrated of solar power and hydrogen" program, and to complete the holistic design and assessment of. At the end, the teacher's guide, student's manual on experiment operation, and student's evaluation manual on the curriculum content integrated of these three major themes will be completed of production. Besides, it will also proceed with the promotion work for innovative curriculum.

As different from regular and convention teaching, the design of this curriculum would focus on the transformation of role between teacher and student as the role of teacher will no longer be the leader, but rather as assistant. Learning activity will place on student as the primary to carry out design, while teacher will help to assist and guide. Furthermore, student can master the focus of learning from self-learning teaching materials on related program as provided by teacher as well as their own learning. In addition, should learn process encounter with difficulty or doubt it is not necessary that teacher needs to rush to offer answer for student, but rather it is hoped that student can cultivate the capability to explore and resolve problem through a series of well-designed explorative learning activities.

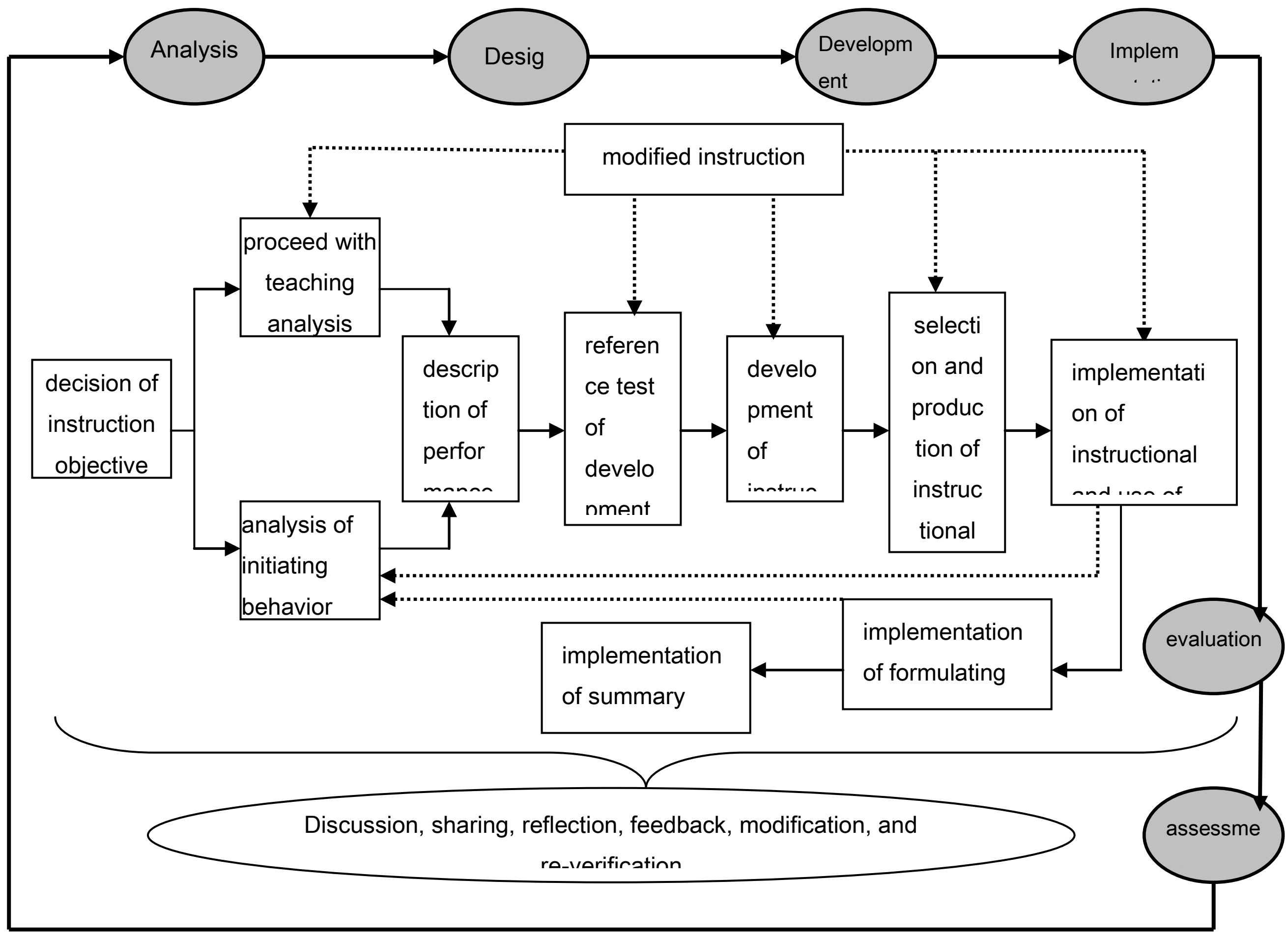
Edgar (1969) put for the concept of learning pyramid as if teacher uses different instruction method it can have rendered diverse impact on the learning content student can retain. For instance, with the use of narration method student can but retain about 10% of the content learned; with reading, student can retain 205 of the content learned. In fact, these two methods of instruction cannot help students to have high percentage of content retention; however, if the instruction method can resort to the manner of learning with doing and student can operate by themselves, they can have retained 75% of the content learned. In view of it, to enhance learning retention and effect for students we have thus design a series of experiment activities with manual operation, so that students can make use of manual operation to carry out explorative learning, Besides, students can, during the process of experiment operation, work with team discussion and brain-storming as they observe, record, and organize experiment figures, in the hope to resolve problem they encounter during the experiment and put forth strategy. Meanwhile, at the part of cultivating student with analysis and presentation capability we have designed to help student to product presentation file to release after the conclusion of the experiment activity. Thus, the students can be strengthened of their learning effect during the stage as student learns to share and discuss. The concept structure and content of this curriculum are indicated in the following chart:



The method of instruction used in ths study was based on “5E Cycle – participation, exploration, explanation, refinement, assessment” by developed by Trowbridge and Bybee (1990). The developed instruction was developed as the following:

1. Instruction design

The design of instruction has employed the design model (revised version) of systemized instruction by Dick and Carey (1996), and it is found in six major steps as: analysis, design, development, implementation, evaluation, and assessment.



Analysis
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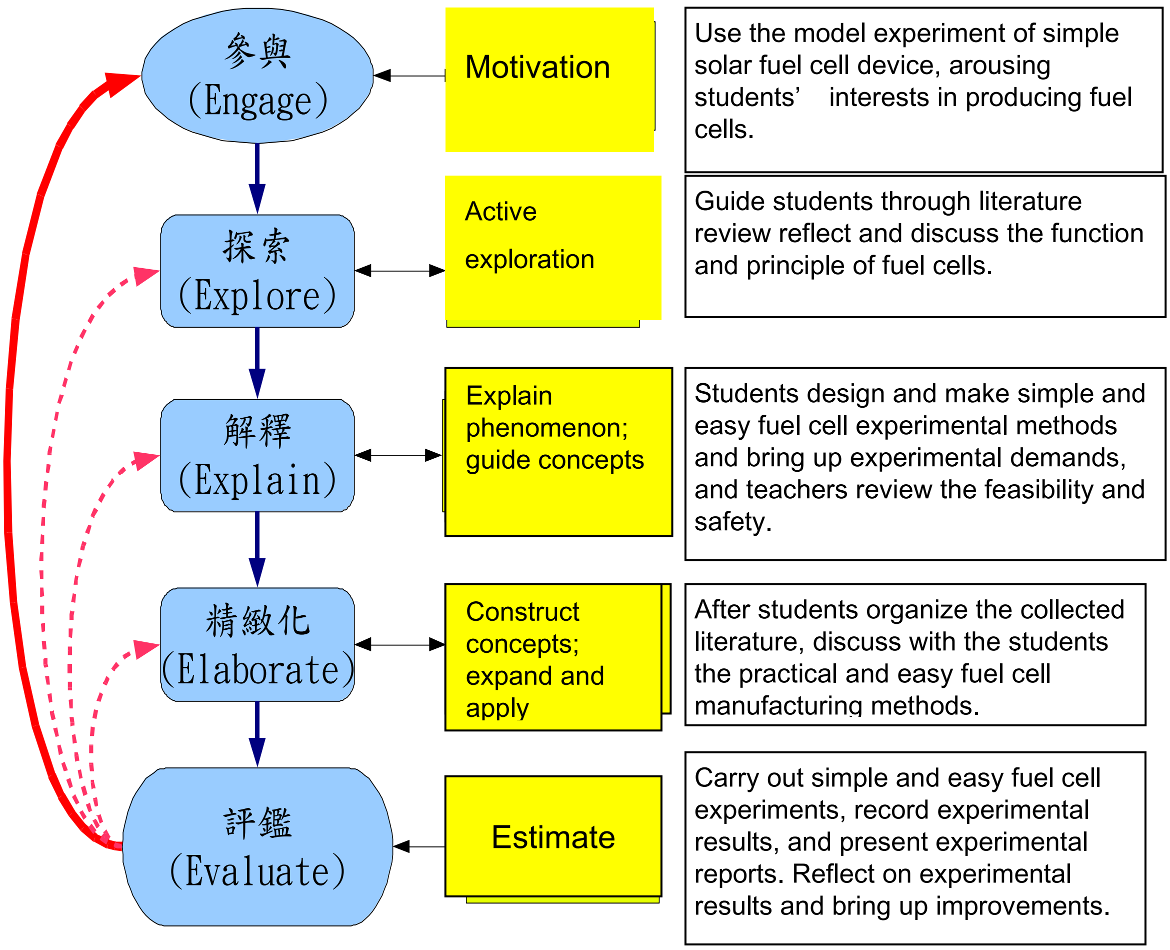
instructional
analysis of
initiating
behavior
evaluation
implementation
of formulating
implementation
of summary
Discussion, sharing, reflection, feedback, modification, and
assessme

2. Teaching Method

The model, "5E cycle : engagement, exploration, explanation, elaboration, and evaluation", is designed for the teaching activities as below chart.



3. Student's learning activities

Innovation: This course is designed to have series of exploratory experiments and innovative experimental devices. We designed a series of experiments, including hydrogen production experiments of electrolyzed water, simple and easy fuel cell experiments, and proton exchange membrane and direct methanol fuel cell experiments, making students use hands to conduct inquiry-learning operations. In the experimental operation process, students observe, record, and organize experimental data; through group discussion and brainstorm, they solved problems encountered in the experimental process. During the experimental process, students presented strategies, changed experimental variables to seek for better experimental conditions to enhance the results, and discussed and shared at each stage. After exploring experimental activities, students made presentations files for release, summarized the explorative results, and shared and discussed with other groups.

By brainstorming among group members, innovative and stunning experiment devices often can be put forward. Take simple and easy fuel cell explorative experiments implemented by students for example, like the experimental equipment of the following drawing. Students increased the voltage through series connection; in order to prevent electrolyte leakage from the side of the tube as electrolysis, they specially use rubber hoses to connect, and it can also avoid hydrogen produced in the negative pole from a broken circuit because over collection.

4. Teacher’s teaching activities

Innovation: The course uses 5e cycle inquiry teaching methods; at the same time in teaching activities, we take students as the learning characters, so that students can learn the contents of major themes through experiencing learning process.

We changed the past teaching steps and used inquiry-based teaching methods for students to work out new experiments to find the best battery power by observation, operation, and group discussion, and through changing the experimental variables, from simple and easy fuel cell experiments. For example, like the simple and easy fuel cell experiments, students try to change the type and concentration of electrolyte, electrode material, and even experimental devices, we discussed how to efficiently prepare and produce hydrogen under different manipulative variables, and then drive alarm clocks, not only to make the pointer walk for a long time and let the alarm clock be sounded.

In addition, in the activities of visiting Institute of Nuclear Energy Research, we invited students to be reporters to record the activity process. By this kind of role-playing activities, students can be trained to plan to interview what kind of news, division of labor between news photographer and journalist, press finishing, typesetting and output. We also reminded students that being a photojournalist is not a perfunctory job that only by preparing a camera to photograph, but they must understand the contents of the matters to interview, in order to get the focus and sense of photography. They need to use the most appropriate photo to do the most powerful performance and most clear explanation. A good photo may already contain the content expressed in a 500 press release, and an outstanding photo can broadcast the atmospherics and shock force that a written report may not achieve.

Results and conclusions

The results section will be presented in two parts. Results from the development of GEC will be the first. In the second section, the evaluation of GEC will be reported. The GEC was a four-year energy-saving and carbon-reduction curriculum which included units: Stirling engine and Stirling car, wind Power, solar power, producing hydrogen, storing hydrogen, hydrogen-fuel cell, biomass, and biotechnology. The units, subjects associated, and credits are listed as Table 1. All the teaching materials were developed by 9 teachers, discussing every two months and valididated through experts and educators.

Table 1

Teaching Units for Green-Energy Curriculum (GEC) Program

Objectives	Teaching Units	Subjects	Credits
Energy Saving and Carbon Reduction	Stirling Engine and Strling Car	Physics	2
	Wind Power	Physics	2
	Solar Power	Physics	2
	Producing Hydrogen	Chemistry	2
	Storing Hydrogen	Chemistry	2
	Hydrogen-Fuel Cell	Chemistry	2
	Biomass Energy	Biology	2
	Biotechnology	Biology	2

From the students' performances presented, it found that students often search information for designing and completing their research with website information. Appendix D, E, and F are students' referred Information from website about wind power, students' findings about hydrogen production, and the main referred topics of students' exploring from website about biomass.

Comparing the experimental and controlled groups with ANCOVA, data from the pre- and post- tests of the Attitudes toward Green-Energy Inventory showed that the attitudes toward energy science for the two groups exit significant difference ($p< .05$) as shown in Figure 1. Triangulation with data from the interviews for the students who participated in the project also appeared that more interest toward energy-science. Teachers' reflections also showed students' more positive attitudes toward green-energy.

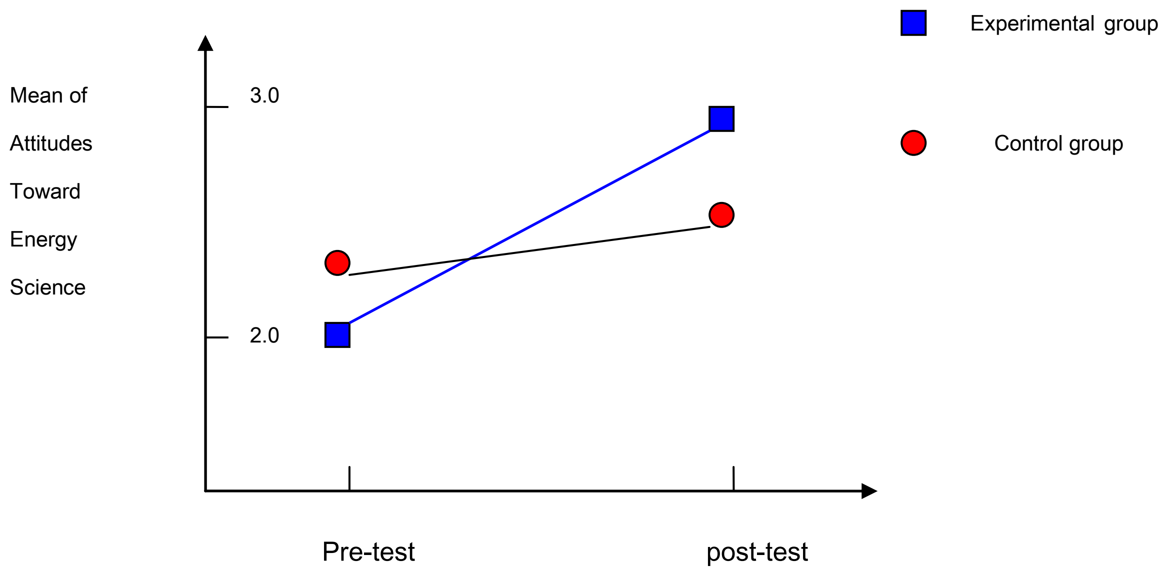


Figure 1: The difference of mean of attitudes toward energy science between two groups

Comparing the experimental and controlled groups with ANCOVA, data from the pre- and post- tests of scale assessing knowledge about hydrogen energy showed that students' knowledge the two groups exit significant difference ($p < .05$) as shown in Figure 2. Triangulation with data from students' learning portfolio and students' performance exhibitions also appeared that students in the experiment group have more knowledge about hydrogen energy.

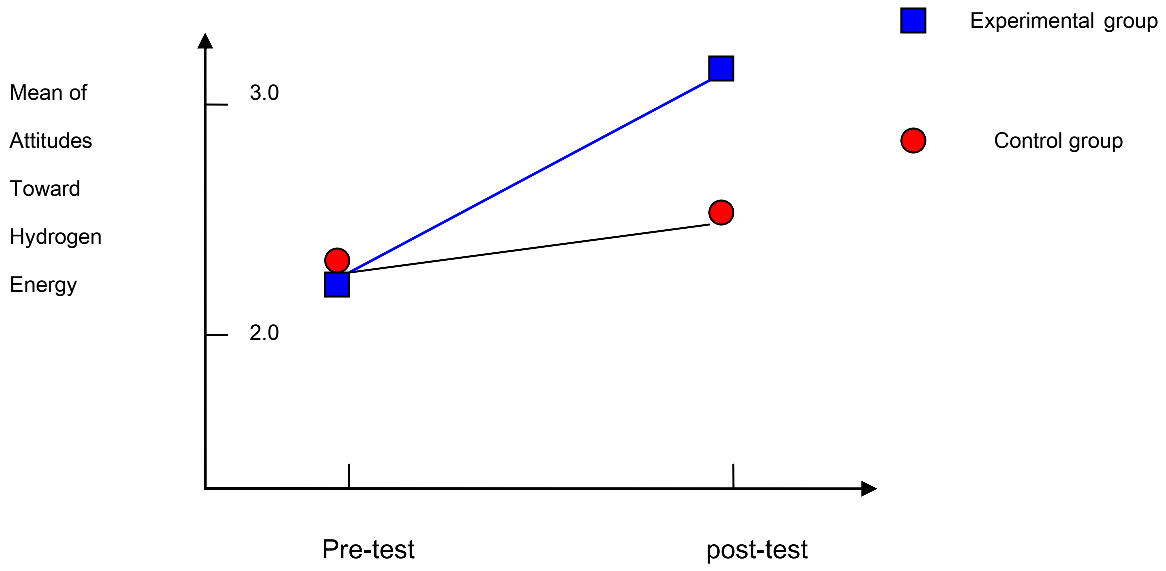


Figure 2: The difference of mean of scale assessing knowledge about hydrogen energy between two groups

Suggestions

This study was conducted to compare the difference for students' knowledge and attitudes toward green-energy between. The results of the green-energy curriculum developed have successfully showed the applicable practice in the science classrooms of high schools, the effectiveness for connecting high school and university educations. However, the nature of a curriculum implementation is a complex task; this study focused on student' s achievement and attitudes toward energy science. From teachers' interviews, it is evident that school support played a large role in the

nature of the innovative curriculum implementation.

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Appendix A: The Attitudes toward Green-Energy Inventory

明道高中高瞻計畫　　　　　　　　　　　　　　施測班級：高一 12 班、高一 13 班

節能認知量表(待翻譯成英文)　　　　　　　　　　高一　　班　　號

說明：請你就你所知回答以下問題，每題後面皆為 5 個選項：非常同意、同意、沒意見、不同意、非常不同意，請勾選一個最能代表你答案的選項，每題均要回答！
這份評量的目的在讓教師更了解學生，不會影響你的學習成績。

題號	主　要　概　念	選項：非常同意	同意	沒意見	不同意	非常不同意
※	節能概念					
1	「節省資源」就是「節能」。	☐	☐	☐	☐	☐
2	因為能量守恆定律，因此，「可利用的能源」不會變少，不需要節能。	☐	☐	☐	☐	☐
3	目前已經有很多國家利用潮汐發電，達到節能的目的。	☐	☐	☐	☐	☐
4	目前已經有很多國家利用地熱發電，達到節能的目的。	☐	☐	☐	☐	☐
※	綠建築					
5	普通玻璃可以有效地阻隔可見光進入室內。	☐	☐	☐	☐	☐
6	普通玻璃可以有效地阻隔紫外光進入室內。	☐	☐	☐	☐	☐
7	普通玻璃可以有效地阻隔紅外光進入室內。	☐	☐	☐	☐	☐
8	因玻璃有溫室效應之虞，只要使用玻璃，就無法節能。	☐	☐	☐	☐	☐
9	空中花園的設置目的是－－為了降低室內溫度。	☐	☐	☐	☐	☐
10	明道中學明謹大樓有使用綠建築的概念，達到節能的目的。	☐	☐	☐	☐	☐
11	明謹大樓外牆的「金屬格板」的設置目的是－－為了降低室內溫度。	☐	☐	☐	☐	☐
※	光源					
12	我知道傳統鎢絲燈泡屬於一種較節能的光源	☐	☐	☐	☐	☐
13	我知道 LED 屬於一種較節能的光源	☐	☐	☐	☐	☐
14	我知道 SMD 形式的 LED 屬於一種較節能的光源	☐	☐	☐	☐	☐
※	引擎與汽電共生					
15	現在汽機車多使用內燃機當作動力來源。	☐	☐	☐	☐	☐
16	內燃機（引擎）相對於外燃機（引擎）較可達到節能減碳的目的。	☐	☐	☐	☐	☐
17	氣電共生系統可以減少大型企業的用電支出	☐	☐	☐	☐	☐

※	風力					
18	只要有風，均可用來發電。	☐	☐	☐	☐	☐
19	中台灣的自然環境適合發展風力發電。	☐	☐	☐	☐	☐
20	風力發電機的能量轉換效率一般都在 30%左右。	☐	☐	☐	☐	☐
21	明道中學的風力發電機的風車是使用「水平翼」形式的。	☐	☐	☐	☐	☐
※	太陽能					
22	中台灣的自然環境適合發展太陽能發電。	☐	☐	☐	☐	☐
23	陰天時，現今的太陽電池無法蓄電，不能使用。	☐	☐	☐	☐	☐
24	陰天時，現今的太陽能熱水器無法使用。	☐	☐	☐	☐	☐
25	太陽能發電的能量轉換效率最高只有 10%左右。	☐	☐	☐	☐	☐

謝謝你「用心」的勾選，請「再檢查」是否有漏答或重複勾選的情形，再次謝謝你！~~

Appendix B: Scale Assessing Knowledge about Hydrogen Energy

以下 1~20 題是有關製氫與儲氫的問題，請依你所知所學給分，5 分代表「完全同意或完全瞭解」; 4 分代表「大致上同意或大致上瞭解」; 3 分代表「沒意見或不知道」; 2 分表示「不太同意或不太瞭解」; 1 分表示「完全不同意或完全不瞭解」。

敘述	給分
1. 我知道氫氣是每莫耳燃燒時，能放出最多能量的燃料。	□5 分□4 分□3 分□2 分□1 分
2. 我能在實驗室中製造氫。	□5 分□4 分□3 分□2 分□1 分
3. 我瞭解目前儲存氫氣最常見的方法是液態儲氫。	□5 分□4 分□3 分□2 分□1 分
4. 我知道電解水時，氫氣是在負極產生。	□5 分□4 分□3 分□2 分□1 分
5. 我知道銀是一種常見的氫氣觸媒，能活化氫的反應。	□5 分□4 分□3 分□2 分□1 分
6. 我學過在電解氫氧化鈉水溶液時，外接的電源必須是直流電。	□5 分□4 分□3 分□2 分□1 分
7. 我知道某些金屬和強酸或強鹼作用都能產生氫氣。	□5 分□4 分□3 分□2 分□1 分
8. 壓縮儲氫簡單、方便，而且成本很低，我相信是未來儲氫方法的主流。	□5 分□4 分□3 分□2 分□1 分
9. 我知道從化石能源製氫，步驟繁瑣而且耗能多，甚至還會排放出溫室氣體。	□5 分□4 分□3 分□2 分□1 分
10. 我知道什麼是綠色能源。	□5 分□4 分□3 分□2 分□1 分
11. 我瞭解關於儲氫合金的相關知識。	□5 分□4 分□3 分□2 分□1 分
12. 我明白若將熱值的單位定義為 kJ/g，則氫的熱值遠大於其他化石燃料。	□5 分□4 分□3 分□2 分□1 分
13. 我聽說過工業上能用甲醇製氫。	
14. 目前氫能車的儲氫方式是以金屬氫化物(固態儲氫)為主。	□5 分□4 分□3 分□2 分□1 分
15. 氫能用在交通工具上，最早是太空計劃的固態氫燃料。	□5 分□4 分□3 分□2 分□1 分
16. 若用氫氧化鉀當電解水的電解質，正極發生的是氫氧根(OH^-)得電子的反應。	□5 分□4 分□3 分□2 分□1 分
17. 若要將液態氫作為氫能使用的主流，運送過程維	□5 分□4 分□3 分□2 分□1 分

持低溫必為首要課題。	
18. 鈉、鉀的氧化物溶於水形成鹼性物質，同時放出氫氣。	□5 分□4 分□3 分□2 分□1 分
19. 電解製氫技術成熟，但以耗能所需的成本來看，是不符合經濟效益的。	□5 分□4 分□3 分□2 分□1 分
20. 使用氫能的最大優點是反應後的產物無污染，又能回收再利用。	□5 分□4 分□3 分□2 分□1 分
21. 以氫能發展來說，主要的關鍵點還是在於製氫儲氫的技術。	□5 分□4 分□3 分□2 分□1 分
22. 水煤氣製氫是一種氧化還原反應。	□5 分□4 分□3 分□2 分□1 分

23. 請簡述三種製氫的方式。(如有方程式更好)

答：(1)______________________________

(2)______________________________

(3)______________________________

24. 請簡述一種儲氫的方式，並評論其優缺點。

答：______________________________

25. 如果你是一間氫能公司的老闆，請規劃一個你認為能獲得最大利益的氫能運用流程。

答：

Appendix C: Teaching Design for Hydrogen-Energy Curriculum with Project-Based Learning

Teaching Objective	Activities	Teacher's guide	Resources	Time	Assessment	Learning Phases
1. Students can perceive the possibility of hydrogen as energy and the method of producing hydrogen.	1.進行製氫與儲氫前測 2.閱讀製氫與儲氫的教材，提出問題並討論解決問題的方法。	1.輔導學生進行前測 2.引導學生提問與問題歸納。	明道大學教學藝術研究所提供問卷	20分鐘 100分鐘	提問與討論的參與程度。	1-1 使學生能夠自行閱讀教材、思考問題並提出問題 1-2 使學生能夠歸納問題 1-3 使學生能夠思考解決方法
2.Students can search the literature about the methods of producing hydrogen.	利用網際網路或從書籍、報章與雜誌搜集資料。	輔導學生蒐集資料，並與學生討論相關資料。	網際網路與各級圖書館	60分鐘	蒐集資料並與教師討論的狀況。	2-1 使學生能夠自行搜尋資料 2-2 使學生能夠進行資料討論 2-3 使學生能夠進行資料整理
3.Studentscan understand the methods of producing and saving hydrogen and explore the variables and the factors	1.學生綜合文獻內容，於課堂中提出發表及討論製氫與儲氫的原理與方法。 2.小組討論影響製氫的	1.觀察、記錄學生討論內容及適時引導建立學生正確概念。 2.審核學生設計實驗流程。 3.引導學生進行實驗	電腦、單槍投影機	60分鐘	1.學生報告文件內容及討論過程的記錄，變因的探討。 2.學生實驗設計報告內容	3-1 使學生能夠了解不同製氫與儲氫的原理 3-2 使學生能夠了解不同製氫與儲氫方法的操作

during the process.	變因。 3.學生設計製氫實驗的流程及方法。	操作及小組討論。				3-3 使學生能夠進行簡單的製氫實驗操作設計
4.培養學生能自行完成製氫實驗，並記錄、分析變因的影響情形	1.進行製氫實驗的流程，記錄實驗過程及實驗數據。 2.進行小組討論變因的影響與實驗報告。	1.設計實驗流　程及實驗準備單 2.引導學生進行實驗操作、實驗報告寫作及小組討論		60 分鐘	學生實驗的操作過程及記錄、報告寫作過程	4-1 使學生能夠依變因自行設計可行之製氫實驗 4-2 使學生能夠利用實驗操作來探討影響製氫的變因
5.培養學生提出問題、解決問題與探討實驗變因的能力	1.學生利用自行設計之實驗操作探究製氫的方法及變因的影響。 2.學生發表實驗結果、回答同學與老師提問。	引導學生進行實驗報告及小組討論		60 分鐘	1.實驗結果的報告呈現。 2.學生分組報告。	5-1 使學生能夠利用文獻來探討影響製氫的變因 5-2 使學生能夠收集實驗數據，並能整理、分析資料及發表。