Effectiveness of Applying Inquiry Learning Approach to Bio-Energy Curriculum

Meng-Yu Lin[1] Ying-Yi Chen[2] Wei-Ying Lin[3]
Miao-Li Agricultural & Industrial Vocational High School

Abstract

This study aims at investigating the effectiveness of implementing innovative bio-energy curriculum through Inquiry learning approach. A wide variety of data are collected from the teaching field and statistical analysis has been done afterwards. Qualitative data, including video of classroom activities, students' interviews, teachers' interviews, students' learning logs, etc., are transcribed and coded so that they can be easily analyzed and used to support the research findings. Quantitative data include performance evaluation made before and after each learning unit, peer assessment, SIAC (Teachers Assess students to explore the Ability of the Checklist), SIASS (Students Explore the Ability of Self-rating Scale) and so on. Based on the comprehensive qualitative and quantitative analyses, the research findings are as follows: (1) Bio-energy curriculum adopting guided inquiry learning approach helps enhance students' knowledge learning, scientific capacity and learning attitudes; (2) With appropriate guidance in the learning activities, students will take the initiative in designing their own experiments and the attitude of inquiry learning will be cultivated.

Keywords: inquiry learning, Bio-energy

I. Introduction

Traditional experimental courses are mostly based on the school curriculum and schedule with pre-determined content and detailed guidance on experimental procedure and methods so that they ensure students achieve the expected results which verify the answers in the textbooks. However, in this mode, students often lack space to think, and just follow the instructions in experimental procedures and activities. Most students will not ask questions, doubt, and even think back to the experimental purposes and significance. In other words, doing experiments is nothing more than memorization of scientific knowledge.

In the rankings in PISA 2006, our students ranked first for mathematical literacy and ranked fourth for scientific literacy in the world. However, the ranking of teaching content indicated that there is still much room for our students to improve their ability of science investigation into raising scientific issues and the ability to justify their arguments based on scientific evidence. This shows that science education in our country still focuses on the transfer of knowledge and lacks scientific inquiry activities. As Sutman (1996) points out that even if there are inquiry activities in class such as doing experiments, their purpose is mainly to verify the phenomena described by teachers or in textbooks. They neither stimulate student's logical thinking nor foster their creativity.

What is the appropriate teaching method in science education? Ministry of Education (2000) points out that science education should focus on creating an inspiring environment for inquiry learning and enhancing students' willingness to do science investigation. Wing Mui (2000) indicates that science is not only about facts, theorems and methods of collection, but also about the access to knowledge and problem-solving. When this system is used as teaching content and learning tools, it becomes a key to open the treasure house of science and technology. In addition, it is a prerequisite for understanding scientific knowledge and doing scientific investigation. Scientific inquiry emphasizes student-centered learning. Therefore, students experience "learning by doing" by taking part in designing and implementing their own experiments. Inquiry ability originated in the field of science and it is also called science process skills (science process skills), or scientific inquiry (science investigation). Yang Xiu-ting and Wang Guo-hua (2007) also suggest that the process of finding problems and then trying to solve them can be seen as the process of inquiry. Therefore, when learning science, we should understand not only what science is, but also how it develops, how to study it and how to apply it in our daily life.

II, Research Design

Our school started the experimental project called "Bio-mass Energy Curriculum Design and Development" in the beginning of the school year 2007. The project has been supported by the grants from National Science Council as part of "High Scope Plan." This study aims at investigating how to implement the Biomass Energy Curriculum in a school and the students in the second grade in our school were chosen as participants. The courses were designed according to the research purposes, and in the end of the curriculum, an evaluation was made. The research design includes participants, research context, research procedure, research tools, data collection and analysis.

(I) Research Object and Context

1. Subjects

The subjects were vocational high school students in grade 2 and the experimental courses were carried out during extracurricular classes. 22 boys and 18 girls were randomly divided into class A and class B. Each class had 20 students and they were asked to work in groups. Generally speaking, 4-5 people formed a group and they could choose their own group members.

2. Research Context

(1). School Situation: Our school is the only agricultural and industrial vocational school in Miaoli area. It is a large-sized school with 12 departments and 54 classes. The faculty and staff members are more than two hundred and the students are about eighteen hundred people. As a vocational high school, it puts emphasis on students' skill training; therefore, the school is well equipped with all training facilities, experimental equipment, software and hardware.

(2). Classroom Situation: Because the courses were carried out in groups and much time would be spent on experiments, a lab was more suitable than a normal classroom. Therefore, most of the teachers ran their courses in a laboratory or a factory. If the experiments couldn't be completely done in class or the experimental data should be collected and recorded every day, sometimes, students were required to stay after school or come to school during holidays to continue their unfinished work.

(3). Course Situation: The experimental courses lasted for one year and they were implemented in extracurricular classes every week. There were about 12 sessions in the first semester and every session was about 2 hours. The experimental curriculum consisted of five courses and each course lasted for about four weeks (totally about eight hours). The themes of these courses are as follows: (1) bio-diesel (2) Bio-ethanol (3) bio-gas (4) bio-hydrogen (5) bio- fuel cells.

(II) Research procedure

It was considered that the students' prior knowledge might not be enough and the students had been accustomed to the traditional teaching approach with lectures in class, and therefore guided inquiry teaching was adopted instead of open inquiry teaching. The guided inquiry teaching was designed to help teachers and students to explore a topic under the guidance. First, teachers selected research questions, and then they discussed the way of running the course with their students. Meanwhile, students developed their own research methods to solve research problems.

Guided inquiry learning started with research questions and followed the principles of inquiry teaching approach. Various activities were designed according to different features of each unit. They included scenario investigation, data collection, experiments, presentation, and problem-solving activities. In order to enhance students' learning interest and motivation, group and individual competitions were held and learning passports were used. Besides, the students were instructed to make learning portfolios which help them keep a record of their learning process. Things such as worksheets, related data, papers, photos, experimental records, and so on can be put in a portfolio.

.

(III) Research Tools

Both qualitative data and quantitative data were collected. Qualitative data included video of classroom activities, students' interviews and teachers' interviews; quantitative data were collected from pre-teat and post-test of learning achievement, SIAC(Student Inquiry Ability Checklist), SIASS(Student Inquiry Ability Self-assessment Scale) and so on. SIAC and SIASS were developed by Yang Xiu-ting and Wang Guo-hua (2007) and the internal consistency reliability of SIAC was 0.84. There are five dimensions of the checklist and their internal consistency reliability are as follows: 0.78 for understanding of questions, 0.67 for observation and recording, 0.74 for data collection, 0.72 for data transformation, and 0.69 for knowledge claim. SIAC was used to evaluate the performance of students' inquiry ability after they had received guided inquiry teaching.

1. SICA(Student Inquiry Ability Checklist)

In a guided inquiry curriculum, teachers raise research questions, and then co-design experiments with their students. First, they have to discuss and find out possible variables and then conduct experiments based on these variables. Students' inquiry ability is assessed by SICA, which stands for Student Inquiry Ability Checklist. This checklist, which makes an important reference to Gowin's Vee diagram, contains five dimensions of inquiry ability and they are understanding of questions, observation and recording, data collection, data transformation, and knowledge claim.

2. Student Inquiry Ability Self-Assessment Scale (SIASS)

Like SICA, in this scale, students' inquiry ability is divided into five dimensions and they are understanding of problems, observation and recording, data collection, data transformation, and knowledge claim. This study uses Likert five-point scale and the five ordered response levels are viewed as interval variables. For each dimension, there are two to five questions. Totally, there are fifteen questions in this scale.

(IV) Data Collection and Analysis

1. Data collection

The data collected were mainly qualitative data and were supplemented by quantitative data. Qualitative data included video of classroom activities, students' interviews, teachers' interviews, and learners' diaries; quantitative data were collected from pre-test and post-test of learning achievement, peer evaluation, SIAC (Student Inquiry Ability Checklist), and SIASS (Student Inquiry Ability Self-assessment Scale).

(1) Video of Classroom Activities

Two experimental classes were fully videoed. By doing this, the interaction between the learners and the instructors as well as students' participation could be better understood. At the same time, one teacher would come into the classroom and acted as an observer. He or she had to take notes of things happening in class, such as students' participation, teacher-student interaction, peer interaction, experimental manipulation, and so on. Then, he or she e-mailed the notes that pointed out the pros and cons of the class to the teacher who ran the course for future improvement.

(2) Students' Interviews

At the end of each course, the teachers randomly selected students from different groups for interview. The interview had several purposes: (1) to see how students change their understanding of knowledge and ability of observation ;(2) to see if students' ability of designing experiments, predicting, and interpreting data have been enhanced;(3) to see if students' learning attitudes have been changed; (4) to provide ready assistance when students counter difficulties in the learning process.

(3) Student Learning Diary

The teachers designed worksheets for students to keep a record of their learning. On the one hand, it helped the teachers find out the learning difficulties the students encountered and how well they had learned, and on the other hand, it helped the students reflect on their own learning.

(4) Achievement Test

At the start of a course, a pre-test of learning achievement was administered and the test questions were made by the course teacher. After the course was completed, a post-test of learning achievement was conducted. The test questions included multiple choice ones and short essay questions. The tests of achievement were used to assess how well the students understood the main concepts taught in the course and the process to manipulate an experiment. The reliability and validity were reviewed by the related teachers, and content of the test papers, including wording, was adjusted and corrected by doing a polite study.

(5) Peer Evaluation

One week before a class started, the teacher sent learning materials which included related literature and possible research issues to the students by e-mail and asked them to study and get prepared for discussion and presentation in the coming class. In class, the students were divided into several groups to do presentations in turn. At the same time, they had to score the following aspects of his/her classmates' presentations: content, clarity, teamwork, familiarity, special records and question raising. This kind of peer evaluation helped understand if the students previewed the learning materials on the initiative. In the peer evaluation form, there was a column for the students to take notes so that they might be more concentrated when listening to others' reports and this also promoted interaction among the students.

(6) SIAC(Student Inquiry Ability Checklist)

Before the end of each course, the teacher used SIAC to evaluate students' inquiry ability. In SIAC, inquiry ability was divided into the following dimensions: understanding of problems, observation and recording, data collection, data transformation, and knowledge claim. Points from 0 to 3 were given to each evaluation item.

(7) SIASS (Student Inquiry Ability Self-Assessment Scale)

Both at the start and end of a course, SIASS was administered. The same as SICA, students' inquiry ability was divided into five dimensions and they were understanding of problems, observation and recording, data collection, data transformation, and knowledge claim. It adopted Likert five-point scale and there were two to five questions in each dimension. Totally, there were fifteen questions in the scale. By conducting SIASS before and after the implementation of the experimental course, we could see how students changed their inquiry ability.

2. Data Analysis

The data collected were mainly qualitative data and were supplemented by quantitative data. Qualitative data included video of classroom activities, students' interviews, teachers' interviews, and learning diaries. The interview questions for students were designed by the teachers who acted as classroom observer and modified by the teachers who actually ran the courses. Five students from each class were selected randomly for interview, which would be recorded and then transcribed afterwards. Teachers' interview questions were also designed by the teachers who were responsible for classroom observation and then reviewed by professionals. The classroom observers interviewed the course teachers and the audio data then transcribed for further analysis.

Quantitative data were collected from SIAC and SIASS. Students' inquiry ability was assessed by SIAC and the mean score for each dimension of inquiry ability was calculated and then expressed as a percentage to better illustrate how much the students achieve the goal. Statistics from SIASS were also presented in percentage and the comparison between the pre-test and post-post was made by conducting paired t-test using SPSS 12.0 version. The statistical analysis could be used to support and explain the findings in the students' interview,

Ⅲ. Results and Discussion

Based on the comprehensive qualitative and quantitative analyses, it was found that the students who received bio-energy curriculum improved their knowledge learning, scientific capacity and learning attitudes. The finding corresponds to what have indicated in the literature review.

(I) Knowledge Learning

Many researches have indicated that inquiry-based teaching can help students learn knowledge and that is echoed by this study. After receiving the guided inquiry teaching, the students increased their understanding of knowledge, and refine and clarify the original concepts.

1. Increase Understanding of knowledge

The increase of knowledge after each course can be seen in Table 4-1 and 4-2.

.

Table 4-1 **Significance Test on Learning Achievement of the Students in Class A**

T-test Results of Achievement Assessment (Multiple Choice Test) of Class A (N=16)				
	Bio-Diesel		Ethanol Conversion	
	Pre-test	Post-test	Pre-test	Post-test
Mean	3.88	5.38	3.38	4.69
T-Test	2.951(***)		2.594(**)	

NOTE：***p<.01

Table 4-2 **Significance Test on Learning Achievement of the Students in Class B**

T-test Results of Achievement Assessment(Multiple Choice Test) of Class B (N=13)						
	Bio-Hydrogen		Bio-Gas		Bio-fuel cell	
	Pretest	posttest	Pretest	posttest	Pretest	posttest
Mean	6.15	6.38	4.54	5.23	4.38	6.38
T-Test	.562		1.264		4.416(***)	

NOTE：***p<.01

Overall, after the students in Class A finished two courses(bio-diesel and ethanal conversion), their mean score for overall learning achievement increased from 7.25 (pre-test) to 10.06 (post-test) with 3.337 for T-Test, which was statistically significant. Meanwhile, for the students in class B, who had completed three couses (bio-hydrogen , biogas, and bio- fuel cell), their mean score for overall learning achievement went up from 15.08 (pretest) to 18.00(post-test) with t-test value of 4.009, which alse reached statistical significance.

Supported by the interviews, it was found that students made progress in knowledge learning after they completed a course. Take bio-hydrogen course as an example. The results showed that because of taking this course, the students got a general idea about the process of producing bio-hydrogen and could evaluate the effectiveness of the experiment by measuring how much bio-hydrogen was collected. Finally, they also gave some suggestions for future improvement. The following was from the students' interview.

T: After taking the bio-hydrogen course, do you have some new thoughts and findings?

SB19: I found there is infinite vitality in the stinky ditch. In fact, a lot of things around us remain undiscovered because of our neglect and that's a kind of waste.

SB12: I didn't know that bacteria could help produce hydrogen before and I only know the electrolysis of water. (Cited from Interviews of students – bio-hydrogen production 2009/03/18)

2. Refine and Clarify the Original Concepts

There were some short essay questions in the achievement tests, and they helped observe how the students changed their concepts in the process of learning. Let's take bio-hydrogen course for example. Before the course, the students knew little about bio-hydrogen, but they could clearly explain the ways of producing bio-hydrogen and their advantages and disadvantages after they received the course. The following are some examples of students' answers:

T: Please tell me some microorganisms that help produce hydrogen, and give a brief description of their principles, advantages and disadvantages.

SB11: (1) anaerobic bacteria: advantages- not aerobic, metabolites can be use; disadvantages- improper disposal of metabolites may cause pollution.

(2) aerobic bacteria: advantages- high efficiency of hydrogen production and it can be mixed with anaerobic bacteria. (2009/03/18 Short essay questions in the achievement test SB11-bio-hydrogen production)

(II). Ability Performance

Statistical analysis of SIAC and SIASS found that all of the five dimensions of inquiry ability had significantly changed.

1. Understanding of Problems

The results of the pre-test and post-test of SIASS showed that the mean for the ability of understanding problems rose from 6.37 to 7.67 with T-Test value of 5.635, which was statistically significant. It indicated that the studnets had significantly improved their inquiry ability in this dimension. The following feedback, which could support the finding, was from the students' interview:

T: When you encountered a problem, how did you handle it?
SB19: I will face the problems, and try to find solutions.
T: Then how do you know which answer is right?
How did you retrieve information? How did you judge if it is right?
SB19: I will try to check the accuracy of the information through various ways, such as Google or related books. (2009/03/18 Interviews of students SB19 bio-hydrogen production)

2. Observation and Recording

To provide the students with more chances to think actively and do experiments by themselves, the teachers guided the students to find possible variables. By controlling independent variables, the students observed and recorded the changes of dependent variables. The results of the pre-test and post-test of SIASS showed that the mean for the ability of recording increased from 9.57 to 11.47 with T-Test value of 5.279, which was statistically significant. The statistics suggested that the students' ability of recording changed significantly. The following data from the students' interview could support the finding.

T: On the table, there are experiments you conducted last time. What are you going to observe then?

SB11: Changes of the bacteria, color, bubbles, hydrogen production, etc.

SB12: Hydrogen production, the color and amount of the cultivation liquid

SB19: I would like to see if there are bubbles in the fermentation tank. Is there any H2 collected? (2009/03/18 Interviews of students – Bio-Hydrogen Production)

3. Data Collection

The results of the pre-test and post-test of SIASS showed that the mean for the ability of collecting data increased from 15.43 to 18.67 with T-Test value of 6.353, which was statistically significant. The statistics suggested that the students' ability of collecting data significantly improved.

4. Data Conversion

The results of the pre-test and post-test of SIASS showed that the mean score for the ability of transforming data increased from 9.37 to 11.47 with T-Test value of 5.941, which was statistically significant. The following was quatitative data that could suspport the statistics mentioned here.

(4-1) Designing Experiments on Ethanol Conversion

In the record of classroom observation, the classroom observer mentioned that with proper guidance from the course teacher, the students could design experiments on their own to solve the problems that interested them. In the course focusing on ethanol conversion, the teacher guided the students to brainstorm the possible oils that could be used in experiments instead of giving them direct advice on which oil to use. The following description of the classroom activities was from the record of classroom observation.

The first group:

After the teacher gave a short lecture on the topic, the students were required to design the experimental process of producing bio-diesel on their own. This group decided to use methanol as fuel, and the teacher asked why ethanol not was chosen. The students answered properly.

The second group:

This group wanted to use olive oil as a reactant. The teacher asked why they chose such expensive oil and suggested that they use soybean oil instead. Then, the teacher asked what kind of oil was used as fuel in Taiwan and the students' answers were *sunflower oil and peanut oil. Finally, the teachers asked them how to know the reaction was completed, and the students said, "color and concentration".*

The third group:
This group would like to choose peanut oil as fuel. The teacher asked what should be used as fuel to cause nuetralisation of acid and alkali and the students answered that it was acetic acid because of its price and safety.

The fourth group:
This group planned to use palm oil 150g, methonal 15g, and Sodium 1.5g in their experiment. The time for was reaction 40 minutes.

After discussing the experimental designs with the teacher, the students would actuaally do the experiments in the next class. (2008/11/05 Classroom Observation – Ethonal Conversion)

(4-2) Prediction and Interpretation of Results

T: Can you predict if there is hydrogen produced by the cultured bacteria ? How much will be it? How to collect?
SB19: We can use fire to burn it and try to get hydrogen by draining the gas. (2009/03/18 Interviews of Students SB19-Hydrogen Production)

5. Knowledge Claim

The results of the pre-test and post-test of SIASS showed that the mean for the ability of claiming knowledge increased from 7.30 to 8.10 with T-Test value of 3.449, which was statistically significant. The statistics suggested that this aspect of students' inquiry ability was significantly improved. An example from the records of classroom observation illustrated this.

T: What can be proved in this experiment?
SB11: As long as anaerobic bacteria can be got by purification, and the right environment and nutrients can be provided, hydrogen can be produced. (2009/03/18 Interviews of Students SB11-Hydrogen Production)

Table 4-3 shows the comparison between pre-test and post-test of SIASS. We can see that all of the five dimensions of the students' inquiry ability reach significant difference.

Table 4-3 T-Test on Pre-test and Post-test of SIASS

	Mean (Pre-test)	Mean (Post-test)	T
Understanding of problems	6.37	7.67	5.635(***)
Observation and Redording	9.57	11.47	5.279(***)
Data Collection	15.43	18.67	6.353(***)
Data Conversion	9.37	11.47	5.941(***)
Knowledge Claim	7.30	8.10	3.449(***)
Total	48.03	57.37	8.592(***)

Note：***p<.01

In the academic year 2008, we evaluated ststudents'inquiry ability by using SIASS and the statistics from the pre-test and post-test showed that the five dimensions of the students' inquiry ability were changed significantly. In conclusion, the effectiveness of applying inquiry teaching approach to a bio-energy experimental curriculum on the students' inquiry ability reached significant difference.

III. Attitude Cultivation

In addition to the investigation of knowledge learning and inquiry skill improvement, the study also put emphasis on the change of learning attitudes. Qualitative information, such as the students' interviews, found that the students improved not only their knowledge and inquiry skills, but also the ability of communication, teamwork, and understanding of environmental protection. The following data from the students' interviews illustrated this finding.

T: What have you learned in the process?
SB12: Presentation skills.
SB16: A better understanding of hydrogen production and hydrogen energy.
SB11: The equipment needed for cultivating microorganisms and their functions.

T: In addition to knowledge, what else have you learned?
SB12: Teamwork, science fairs, motivation, future R & S, information search, Internet search.
SB16: How to operate different kinds of the machines, and cooperation.
SB11: There is an urgent need to save the Earth.
(2009/03/18 Interviews of students - Hydrogen Production)

In summary, besides knowledge learning and inquiry skills, cultivation of students' learning attitudes could be seen as part of effectiveness of inquiry teaching.

IV. Conclusion and Recommendations

For different subjects, there are different teaching methods that would best suit them and the teaching processes may vary due to the complex believes and content of the knowledge fields. Therefore, a single theory or action is neither enough to represent the whole process of teaching and learning nor easy to achieve expected teaching goals (Ouyang Jiao, 1987). The purpose of science education doesn't actually lie in the development of scientific knowledge, but in equipped students with enough ability and right attitudes to adapt to the ever-changing world in the future. This study found that the students taking the experimental bio-energy curriculum with inquiry teaching made progress in knowledge, research skills and learning attitudes. However both the teachers and the students interviewed mentioned that they felt more pressured and carried more burdens, especially for the students who had not experienced inquiry-based teaching before. Those students needed more guidance from the teachers, and thus it was important that the teachers themselves had enough inquiry ability. Therefore, it is suggested that well-planned and comprehensive training programs focusing on inquiry learning should be provided to teachers who will run such courses so that the inquiry-based curriculum can be better implemented.

IV References

中文部分

教育部(2000)。國民中小學九年一貫課程暫行綱要。臺北市:作者。

楊秀停、王國華(2007)。實施引導式探究教學對於國小學童學習成效之影響。科學教育學刊，15(4)，439-459。

歐陽教(1987)。教學的哲學分析。教學研究專集，21-31。

蘇詠梅(2006)。小學科學探究學習的探討。亞太科學教育論壇，7(1)，文章 3。

西文部分

Sutman, F. X. (1996). Seeking more effective outcomes from science laboratory experiences (Grade 7-14): Six companion studies. Paper present at the annual meeting of the National Association for Research in Science Teaching.