Building Energy and Children: Theme-oriented and Experience-based Course Development and Educational Effects

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Abstract

To cope with the crisis of frequent occurrences of extreme weather, various sectors are striving to find a way to ease climate change. A common consensus indicates that to reverse this crisis, we should reduce fossil fuel consumption, rely more on renewable energy, conserve energy, improve energy efficiency, and protect the forests. To enable these measures to achieve full effect, the implementation of energy education is a topic that demands immediate attention. In Taiwan, the building energy sector is closely related to people's lives, and the energy consumption of building industries accounts for 12% of the total national energy consumption. Based on intuitive daily experiences, an energy-saving and carbon-reduction curriculum on the building sector (Green Building) is deemed a feasible approach for elementary school students to promote their capacities of energy cognition, attitude and practice. In this study, the “building sector (Green Building)” was used as a research topic for energy education to be integrated within the energy education context, experiential learning activities, and effective transformation into the curriculum. Participating university faculty and elementary school teachers engaged in collaborative action research concerning development of a curriculum, including identifying suitable study materials, course development (course planning, curricula, teaching module innovation, trial teaching), and assessments.

Keywords: energy education; environmental education; energy saving; Green Building

1. Introduction

Faced with frequent occurrences of extreme weather in recent years, various industries have devoted themselves to finding methods to ease climate change. To ensure that such methods can be implemented effectively, energy education becomes a key issue and is highly recommended. Energy education is a type of life education; it is interdisciplinary and multidisciplinary. The recipients of energy education should not only include students, but all citizens, because all citizens are expected to have a considerable level of "energy literacy." Energy education within schools mainly aims to establish habits, teach concepts, allow students to have the correct perceptions, and further establish correct energy attitudes and develop professional energy-related talents. (Owens and Driffill, 2008)

1.1 Energy cognition, energy attitudes and energy behaviors of elementary school students in Taiwan

‘Energy cognition’ refers to the understanding of energy content, which is also an integral part of energy education. ‘Energy attitudes’ refers to individuals' implicit and persistent evaluation of energy content. (Milfont, 2007) Education, in addition to allowing students to learn about energy, also affects students' daily lives and their interest in energy issues, and it actively establishes a positive attitude towards energy efficient behavior. The education authority generally considers that knowledge can influence a person's attitude and that attitudes influence behavior. In terms of 'energy behavior,' which refers to the ways in which students consume and conserve energy, the curriculum is designed to shape their attitudes toward energy and to influence their behaviors, thus reducing energy consumption and pollution. (Yin, 1999) (Kaiser, 2007) (Prokop et al., 2007)

In 1994-2009, Taiwanese scholars completed many energy-related surveys and analyses focusing on elementary school students (cognition: 11 literatures; attitude: 9 literatures). The authors have summarized the relationship between student background, energy cognition and attitude in Table 1. For factors that

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impact the energy cognition of elementary school students, grade, major source of energy knowledge, and the school's location show a significant correlation. For factors that impact energy attitudes, grade and the major source of energy knowledge show a significant correlation. An analysis of the results of 10 studies also shows that the relationships between energy cognition and energy behaviors, between energy cognition and energy behaviors, and between energy attitudes and energy behaviors of the research subjects all reached a significant level of \( p<0.01 \). This represents a positive correlation, which means that the higher a student's energy cognition, the more active and positive his attitude will be.

Therefore, the role of education in this context is to provide an appropriate amount of energy education (i.e., the source of energy knowledge), which, in turn, will effectively impact the students' energy cognition and energy attitudes. Furthermore, such education will also impact their energy behaviors and enhance their energy literacy.

1.2 Energy sector in buildings and energy-saving approach

Taiwan's dependence on imported energy has gradually increased every year, and recently, the country has almost completely depended on imported energy. In 2007, the industrial sector had the highest energy consumption (57.1%) among domestic sectors, followed by transportation (13.78%), residential (11.76%), service (10.55%), and agriculture (1.6%). The transportation, residential, and service sectors are closely related to people's lives, and these three sectors accounted for 36% of the national energy consumption.

In response to the sustainable development policy, and based on the subtropical climate of Taiwan, the assessment and labeling system for Green Building (GB) was established and put into practice in 1999. It includes seven GB assessment indicators: greenery, soil water content, water resources, energy saving, \( \text{CO}_2 \) emissions reduction, waste reduction, and sewage and garbage improvement. Starting in 2002, new public buildings worth over NT$50 million were required to obtain a GB candidate certificate before a construction license was issued. It was hoped that by requiring the public sector to take the initiative, the private sector would be encouraged to participate as well. In 2003 the GB assessment system was amended to incorporate a biodiversity indicator and an indoor environment indicator, for a total of nine assessment indicators. In 2004, some green building assessment indicators were included into the building code. Since 2000, more than 556 projects have received the Green Building Label, with a total floor area of \( 3.3\times10^7 \) (\( m^2 \)).

The life span of a building is 50-60 years, and much energy is consumed during the production of construction materials, the transportation of materials, construction, daily use, maintenance, and demolition, in which the energy consumption resulting from the long-term use of air conditioning, lighting, and elevators accounts for the largest part of energy consumed over the life cycle of the building. As air-conditioning and lighting energy consumption accounted for the largest part of a building's total energy consumption, the "daily energy conservation indicator" of the building energy category in the GB indicators uses air-conditioning and lighting consumption as the major assessment subject. The content of the daily energy conservation indicator refers to the total efficiency of the air-conditioning and lighting systems during the peak period in the summer; it also includes the use of renewable energies. A high performance of the building envelope, air-conditioning system, and lighting can result in a high score in the daily energy conservation category.

1.3 Contents related to building energy conservation in Taiwanese elementary school textbooks

In the curriculum for grades 1-9 since 2001, energy education is primarily placed in "Ecological Conservation" in the "Science and Life Technologies" field. The authors have summarized the competence indicators in the curricular fields that are related to energy education and have found that the related competence indicators are mainly in the science and life technologies field, followed by social studies, health and physical education, and integrative activities. This shows that energy education is distributed in a theme-based unit across various fields. Courses that are related to energy education mostly focus on types of energy and their applications.

The environmental education guidelines in the "2008 Grades 1-9 Curriculum Guidelines (implemented in 2011)," promulgated by the Ministry of Education in Taiwan in June 2008, also added GB as one of the learning themes in "environmental action experience." Thirteen of the 55 indicators of competency are related to GB concepts. Among those indicators, concepts related to water resources accounted for the largest number of indicators, although site water conservation was not mentioned at all.

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Table 1. The Background Variables that Impact Elementary School Students' Energy Cognition and Attitudes in Taiwan
(Source: Domestic Literature Analyzed by the Authors)

| Gender | Grade | The relationship between parents' work and energy | The major source of energy knowledge | School location | Family socioeconomic status |
|--------|-------|--------------------------------------------------|-------------------------------------|----------------|---------------------------|
| Cognition | N.A. | Significant (+) | No significant difference | Significant | Significant | N.A. |
| Attitude | No significant difference* | Significant (+) | No significant difference | Significant | N.A. | N.A. |

N.A.: The research result has divergent views and is inconsistent; *the statistical data remains weak.
Domestic elementary school textbooks have three major versions: K, N, and H, in which, the social studies textbook of N has fewer pages introducing the GB concept than the other textbooks. The GB concepts that appear most frequently are "biodiversity" and "sewage waste improvement." However, "waste reduction," "indoor environment," "water resources", and "disaster prevention" are not mentioned in this textbook edition. The H social studies textbook had the largest number of pages regarding GB concepts. The most frequently appearing GB concepts are "biodiversity" and "sewage waste improvement." There is also a lesson in the "New World of Humanity and Technology" unit in the 2nd semester of grade 6 that specifically introduces "sustainable and energy conservation green building." Therefore, the H version has a more detailed introduction to GB concepts, in comparison to the other textbooks, and it includes every GB assessment indicator. When considering the daily energy conservation indicators of Green Building Labeling, the authors found that the "envelope energy conservation" concept in the current elementary school social studies textbooks occurs most frequently and that "air-conditioning energy conservation" and "lighting energy conservation" occur least often.

1.4 Integrated energy education curriculum

An integrated curriculum integrates related content and learning experiences to closely connect curricular knowledge and practical experience. In light of the fact that (1) the knowledge of domestic energy education is spread throughout the theme unit of various fields; (2) the knowledge of building energy crosses more than one field; and (3) building energy is one of the GB issues and is closely related to other GB issues, the elementary school building energy curriculum is suitable for integrating GB topics through the theme-oriented course methods. This will enable students to learn the GB design element in a comprehensive and multi-dimensional approach and to further develop their building energy knowledge base.

1.5 Research theme in this study

The sectors in Taiwan that consume the most energy are as follows, in descending order: industrial transportation, construction, service and agriculture. Starting from the construction sector, which has the most direct living experience, is a feasible elementary school energy-education approach. Therefore, this study will focus on students in grades 5 and 6 and apply the collaborative action research method of inquiry carried out by 2 elementary school teachers and 3 university professors to develop a GB and building energy curriculum. Learning materials development, curriculum research and development (e.g., curriculum planning, teaching material and teaching module research and development, and teaching experiments) and curriculum efficacy assessment were included. It hopes to use theme-oriented and experience-based courses to integrate the related building energy knowledge into the formal education content areas.

2. Research Method

The research method mainly applies a quantified questionnaire survey, coupled with qualitative, semi-structured interview, teaching, and curriculum development meeting records, in addition to student work and activity work sheets. Different assessment methods are applied to students who take the course, the curriculum designer, and the administrators who participate in the curriculum to achieve a comprehensive and multi-dimensional assessment.

2.1 Research object

Shin-Dong Elementary School is a small rural school located in Hou-Bi District in Tainan City. There are 6 grades in the elementary school, and each grade has 1 class. There is also an affiliated kindergarten class. There are 128 students, and 17 teachers. Tian-Zi Elementary School is a small school located in Gaoshu Township, Pingtung County. There are 12 classes in the elementary school, and one class in the kindergarten, totaling 301 students and teachers.

2.2 Energy cognition, attitude and behavior survey

The pre-test questionnaire assessing energy cognition, attitudes, and behaviors was issued to fifth and sixth grade students at Shin-Dong and Tian-Zi Elementary Schools to test their knowledge before teaching. The post-test questionnaire is issued to the grade 6 class A students of Tian-Zi Elementary School, who participated in the complete curriculum teaching experiment and the grade 6 class B students who did not participate in the curriculum teaching experiment; it was also issued to the grade 6 class C students of Shin-Dong Elementary School, who participated in the curriculum teaching experiment, and the grade 5 class D students, who did not participate in the curriculum teaching experiment. The cognition pre-test questionnaire has 12 "Yes or No" questions and the post-test has 12 multiple-choice questions. Each correct answer earned one point, and incorrect answers earned zero points. The results will eliminate the questions that have poor discrimination and difficulty.

Fifty-nine boys, accounting for 48.4% of the total sample, and 63 girls, accounting for 51.6% of the total sample were tested. Thirty-nine Shin-Dong Elementary School students were tested; accounting for 32.0% of the total sample, and 83 Tian-Zi Elementary School students were tested, accounting for 68% of the total sample. The level of education attained by the tested students’ parents varied: 46.7% had a senior high school education, 22.1% had less than a junior high school education, 18% attended college or university, and 2.5% completed advanced education beyond graduate school. Sixty-two people were tested in grade 6, accounting for 50.8% of the total sample, and 60 people were tested in grade 5, accounting for 49.2% of
the total sample. Eighty students who were tested did not participate in the curriculum teaching experiment, accounting for 65.6% of the total sample, and 42 students who were tested participated in the curriculum teaching experiment, accounting for 34.4% of the total sample.

2.3 Green Building learning achievement test
The questionnaire was designed by referring to literature and technology related to energy conservation and carbon reduction and GB design and regarding curriculum activities and learning objectives. The questionnaire content was validated by experts. The pre-test of the GB cognition test has 14 "Yes or No" questions and was issued to the test subjects before teaching; the post-test has 13 multiple choice questions and was issued to the test subjects one week after they completed the taught unit. The delay-test randomly takes 8 "Yes or No" questions from the pre-test questions, and 8 multiple choice questions from the post-test questions; it is issued to the test subjects four weeks after the end of teaching. One point was awarded for each correct answer, and no points were given for incorrect answers. After eliminating the questions that have poor discrimination and high difficulty, the scores of the remaining questions are calculated.

2.4 Teaching experiment implementation
Regarding team cooperation and division, elementary school teachers designed the curriculum, and university teachers provided support for technology integrated within the curriculum. A teaching curriculum is designed according to the teaching goals and basic competence indicators (developed according to Taiwanese elementary school "science and technology" learning competence indicators) set by Shin-Dong Elementary School teachers. The curriculum designer taught the unit in his school, Shin-Dong Elementary School. After teaching the unit at Shin-Dong, the curriculum was revised according to the teaching condition and content. The revised curriculum was given to the teachers of Tian-Zi Elementary School for implementation to inspect the feasibility and appropriateness of the curriculum. Finally, the advantages and disadvantages were assessed, and the curriculum and the supporting activities were revised to be used as references for future research and teaching. The implementation subjects are students in grades 5 and 6, and there were 6 lessons (a total of 240 minutes). The implementation is explained in the next section.

3. Teaching Activity
The participating teachers' school has been involved in the "Sustainable Campus Project" of the Ministry of Education in Taiwan, and the school has implemented a basic curriculum focusing on the old school building renovation. Therefore, the teachers have rich ideas and creativity regarding the curriculum planning of "Green Building." The curriculum's main theme is "global warming," coupled with building features, GB photos, and factual videos to guide the children to understand the meaning and method of energy conservation and carbon reduction, GB design elements, and the relationship between the two.

3.1 Lesson 1: "Warming treatment room"
Activity 1: Warming phenomenon and earth crisis.
(1) Video sharing: the global warming crisis.
(2) Discussion: Ask the students: (a) What is global warming? (b) What are the factors that cause global warming? (c) What are energy conservation and carbon reduction approaches? For example: Recycling (resource reuse), try not to ride motorcycles and scooters (reduce air pollution, and reduce the use of gasoline), use less electricity, use more natural ventilation and less air conditioning, and use renewable energy.

Activity 2: Introduce the basic concept of GB through the results of Activity 1 and describe the connection between GB and energy conservation and carbon reduction.
(1) Photo appreciation: (a) Share photographs showing the features of actual buildings. (b) Describe the impact of construction materials or design on comfort and energy consumption by making reference to the photos.
(2) Video discussion (Initial exploration of GB): (a) Play GB introduction video. (2:28) (b) Discuss the video content, and introduce the GB elements in the video.

3.2 Lesson 2: "Green-pill to relax Warming"
Activity 1: Create motivation: Ask the students about the contents from the last lesson and the related GB concepts.

Activity 2: Develop activities: Discuss various GB elements through multimedia, such as photos and video.
(1) Video appreciation: (a) German GB video (3:29); (b) Da Ai Television "Spread the wind of green energy" news (6:47); (c) Rainwater re-use video (2:37).
(2) Discussion: Video content focus and teacher's additional information.
(3) Photo appreciation (authentic GB design case studies): green curtains, green environment, solar energy, wind power, and tap water conservation.

Activity 3: Discussion: The teacher will summarize the focus of this lesson and ask the students whether there are GB elements at/near their home or on the campus?

3.3 Lesson 3: "Green Building expert-1"
The teacher requests the students to use different panels to hand-assemble them into a simple model house and to then apply halogen light to simulate the sun and allow the light to shine in the house. This activity will allow students to observe and compare
temperature changes in model houses made of different materials. In addition, this activity helps students to understand the effects of ventilation on indoor air-cooling through opening and closing windows. To simplify the assembly process of the model house, the panels were cut into connectable pieces, as shown in Fig.1.

Activity 1: Create motivation: Review the last lesson. The heat transfer features are different for different construction materials; therefore, in the same sunlight conditions, the construction material temperature will also be different. Furthermore, natural ventilation is effective for indoor air-cooling.

Activity 2: Develop activities:
1) DIY (Do It Yourself) teaching aids: Each group will receive materials and instructions for assembling a model house. The students will complete the assembly by themselves.
2) Describe the content of the experiment content and begin the work.
3) Experiment 1: Compare the air temperature within the model houses (windows are closed): (a) each group will apply a different material: Group 1: aluminum; Group 2: transparent acrylic; Group 3: wood; Group 4: foam board; (b) pre-test the temperature in each model house; and (c) shine the light (heat) on the model house with the halogen light according to the same directions and the same experiment time (approximately 5-7 minutes; the teacher will provide instructions) and from the same distance. Measure the interior temperature with the thermometer and observe and record the temperature changes.
4) Experiment 2: Compare the air temperature within the model houses (windows are opened). The steps and methods are the same as Experiment 1, except that the windows in the experimental house are opened.
5) Teachers will summarize the information of every group.
6) Discuss the results collected by the various groups, such as the internal temperature increase of various model houses and why different model houses have different temperature increases. Is the internal temperature related to airflow in the house?

3.4 Lesson 4: "Green Building expert-2"
1) Metal, wood, foam board, cement, and transparent acrylic were cut into sample panels, and the two ends of the thermocouple were connected to the sample panels and the thermometer with the electronic display board, as shown in Fig.2., to allow the students to easily observe the inside (non-lighted side) surface temperature.

Fig.1. Simple Model House (Wood Sheet)
Fig.2. Panel Surface Temperature Measurement

Students measured the sample panel's surface temperature (lighted side) with a thermometer.

Activity 1: Create motivation: Review the results of the experiment discussed in the last lesson and introduce and describe the experimental content of this lesson.

Activity 2: Develop activities:
1) Experiment 1: Measure the inside and outside (lighted) surface temperature of different material panels that have been exposed to the halogen light.
2) Experiment 2: Water mist cooling: Follow the steps outlined in experiment 1: apply the halogen light for approximately 5-7 minutes; spray water mist on the sample panels; and then measure the inside and outside surface temperatures of the panels.
3) Experiment 3: The importance of greenery (teachers' operation): (a) teachers will shine the halogen light on the cement and grass at the same time for 5-7 minutes when the students are doing the experiment 2; (b) compare the temperature change between cement and grass. Explain the importance of greenery for micro-environment cooling (reduce the urban heat island effect).

Activity 3: Integrative activities: Collect each group's notes from the experiment and present them to the class. The teacher will summarize the results.

3.5 Lesson 5: "Explore Green Building"
The teacher will display GB design elements through GB model-house teaching aids and will allow students to look for these design elements, as shown in Fig.3.

Activity 1: Develop activities:
1) GB photo appreciation: Show the GB photos prepared by the teacher and explain the design elements.
2) Explore the GB model: (a) every group will observe the GB model house and discuss the applied GB design elements; (b) present the GB elements
is 86%. Therefore, the result of “there is a significant
correlation, and the statistical power = .866 shows that
= .128 indicates that the two variables have a moderate
students without the teaching intervention (M=4.78).
(M=6.80) is significantly higher than the score of
of students with the complete teaching intervention
interventions in the post-test of energy cognition. The
difference for students with different teaching
interventions in the post-test of energy cognition is
higher (M=6.81) than students without the teaching
intervention (M=4.77).

(2) Energy attitude
The attitude scale scoring method is the following: 5
points for “Strongly agree,” and 1 point for “Strongly
disagree” in the positively worded items; 1 point for
“Strongly agree,” and 5 points for “Strongly disagree”
in the negatively worded items. The top score for the
attitude scale is 60 points, and the higher the score is, the
more positive energy attitude there is. Energy
attitude scaling includes three sub-variables as the
factor content; they are 4 "resource-use attitude" items,
6 "energy crisis and global warming awareness" items,
and 2 "energy conservation and CO₂ reduction" items.

According to the results, the average score of the
tested subject in the energy attitude pre-test is 50.1
points (4.17 points on the five point scale), which
shows that the tested subjects have a positive attitude
regarding energy conservation and CO₂ reduction. If observed with the sub-variables, the average five-
point scale score of "resource-use attitude" items,
"energy crisis and global warming awareness" items,
and "energy conservation and CO₂ reduction" is more
than 4, which shows that the test subjects pay attention
to energy conservation and CO₂ reduction and have a
positive value and attitude.

The average score for the energy attitude post-test
is 49.02 (4.08 points in the five point scale). After
teaching, it shows that the test subjects still have a
positive attitude regarding energy conservation
and CO₂ reduction. However, there is no significant
difference between the energy attitude pre-test and
post-test attitude scale, and also no difference in
attitudes across all student backgrounds.

(3) Energy conservation and CO₂ reduction
behaviors
There are 12 behavior scale questions; five points
will be given for "Always," and one point will be
given for "Never." The higher the score, the more
positive environmental behaviors there are. Energy
conservation and CO₂ reduction behaviors includes two

found by every group, such as the ventilation strategy,
shading devices, green curtain, green roof, solar
energy, wind power, and rainwater recycling.

Activity 2: Integrative activities:
(1) The teacher will summarize the lesson.
(2) Have every group look for GB materials on the
campus and record them with a digital camera.

3.6 Lesson 6: "Seeing campus GB"
Activity 1: Develop activities: Load the photos
taken by students into the computer and have the group
leader make a presentation. The teacher will propose
questions, such as "What is the function of the GB
design element shown in this picture?" "What needs
to be addressed while designing?" "Is it easy to break
during application?" and "Is it expensive to maintain?"

Activity 2: Integrative activities: The teacher will
summarize the overall curriculum and will describe the
GB concepts again.

4. Results and Discussion
4.1 Energy cognition, attitudes and behaviors of the
tested students
School and the Internet accounted for the most
(82.8% and 74.6%, respectively) energy information
retrieval sources for the tested students, followed by
television and broadcasting (66.4%), books (55.7%),
parents and family (49.2%), newspapers and magazines
(48.4%), friends or classmates (37.7%), government
propaganda posters (36.1%), and others (4.9%). It
can be seen that there is no difference between the
students from the two schools in regard to their energy
information retrieval sources; the three major channels
are school, television, broadcasting, and the Internet.

(1) Energy cognition
It can be seen from Table 2 that there is a significant
difference for students with different teaching
interventions in the post-test of energy cognition. The
t value = 3.115 (p<.01), which shows that the score
of students with the complete teaching intervention
(M=6.80) is significantly higher than the score of
students without the teaching intervention (M=4.78). η²
= .128 indicates that the two variables have a moderate
correlation, and the statistical power = .866 shows that
the accuracy rate of the above-mentioned inference
is 86%. Therefore, the result of "there is a significant
difference for students with different teaching
interventions in the post-test of energy cognition" is
supported.

There is no significant difference in the energy
cognition pre-test for students with different
background variables (including gender, school,
grade, teaching intervention, and parents’ education
background). There is no significant difference in the
energy cognition post-test for students with different
genders, schools, and parents’ education background.
However, there is a significant difference in the
energy cognition post-test for students in different
grades and for the teaching intervention. The grade
6 students scored significantly higher (M=6.44) than
the grade 5 students (M=3.11); the students with the
complete teaching intervention scored significantly
higher (M=6.81) than students without the teaching
intervention (M=4.77).

(2) Energy attitude
The attitude scale scoring method is the following: 5
points for “Strongly agree,” and 1 point for “Strongly
disagree” in the positively worded items; 1 point for
“Strongly agree,” and 5 points for “Strongly disagree”
in the negatively worded items. The top score for the
attitude scale is 60 points, and the higher the score is, the
more positive energy attitude there is. Energy
attitude scaling includes three sub-variables as the
factor content; they are 4 "resource-use attitude" items,
6 "energy crisis and global warming awareness" items,
and 2 "energy conservation and CO₂ reduction" items.

According to the results, the average score of the
tested subject in the energy attitude pre-test is 50.1
points (4.17 points on the five point scale), which
shows that the tested subjects have a positive attitude
regarding energy conservation and CO₂ reduction. If observed with the sub-variables, the average five-
point scale score of "resource-use attitude" items,
"energy crisis and global warming awareness" items,
and "energy conservation and CO₂ reduction" is more
than 4, which shows that the test subjects pay attention
to energy conservation and CO₂ reduction and have a
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The average score for the energy attitude post-test
is 49.02 (4.08 points in the five point scale). After
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and CO₂ reduction. However, there is no significant
difference between the energy attitude pre-test and
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(3) Energy conservation and CO₂ reduction
behaviors
There are 12 behavior scale questions; five points
will be given for "Always," and one point will be
given for "Never." The higher the score, the more
positive environmental behaviors there are. Energy
conservation and CO₂ reduction behaviors includes two

Fig.3. GB Model House
sub-variables as the factor content; there are 6 "energy conservation action" items and 7 "CO₂ reduction action" items.

The average score of the energy conservation and carbon reduction behavior pre-test is 42.65 (3.55 points in the five point scale), which shows that the tested students already have specific practices regarding energy conservation and carbon reduction behavior before teaching. The sub-variable observation shows that the score of "energy conservation actions" is higher than "CO₂ reduction actions."

The average score for the energy behavior post-test is 43.46 (3.62 points in the five point scale), which is slightly higher than the average score for the pre-test, which shows that after teaching, the tested students have adopted additional practices regarding energy conservation and CO₂ reduction behavior. The sub-variable observation shows that the score of "energy conservation actions" is higher than "CO₂ reduction actions."

The energy cognition, attitudes and behaviors of students who have participated in this GB teaching do not have a significant difference before and after teaching. The possible reason may be that the levels related to students' energy cognition, attitudes and behaviors are very wide, and GB teaching material content can only include a small part of it. Therefore, the curriculum participation cannot respond to the large improvement of students' energy cognition, attitudes and behaviors.

4.2 The impact of GB teaching on students' GB cognition

It can be seen from Table 3, that there is no significant difference in the pre-test score between the teaching intervention and no teaching intervention conditions. The t value=.982 (p>.05), which does not reach a significant level, and the null hypothesis is accepted. There is a significant difference in the students' post-test score between the teaching intervention and no teaching intervention conditions. The t value =2.310 (p<.05), which is significant, and it indicates that the post-test score with teaching intervention (M=7.45) is significantly higher than the score without teaching intervention (M=5.60). η²=.123 shows that the teaching intervention variable can explain 12.3% of the variance of the GB cognition post-test score. There is a significant difference in the students' delay-test between the teaching intervention and no teaching intervention conditions. The t value=3.680 (***p<.001), which is significant, and it indicates that the delay-test score with teaching intervention (M=12.10) is significantly higher than the score without teaching intervention (M=8.50). η²=.273 shows that the teaching intervention variable can explain 27.3% of the variance of the GB cognition delay-test score.

Table 3. The Impact of Teaching Intervention on the Test Result of GB Cognition

| Variable                  | Teaching intervention | Amount | Mean   | Standard deviation | t value | η²     | p value |
|---------------------------|-----------------------|--------|--------|--------------------|---------|--------|---------|
| Pre-test                  | Yes                   | 19     | 8.68   | 2.212              | -.292   | .123   | .022    |
|                          | No                    | 62     | 8.06   | 2.462              |         |        |         |
| Delay-test                | Yes                   | 20     | 12.10  | 3.680***           | .273    | .947   | .001    |
|                          | No                    | 18     | 8.50   | 3.57               |         |        |         |

n.s. p>.05   **p<.01 ***p<.001

5. Conclusion

This study focused on students in grades 5 and 6 and applied the collaborative action research method of inquiry carried out by 2 elementary school teachers and 3 university teachers to develop a GB and building energy curriculum, including learning material development, curriculum research and development (curriculum planning, teaching material and teaching module research and development, and teaching experiments) and curriculum efficacy assessment. The pre-test questionnaire of energy cognition, attitudes, and behaviors is issued to the fifth and sixth grade students who are involved in the teaching experiment to test their basic concepts before GB teaching. After teaching, post-test questionnaires are issued to a class that has participated in the curriculum and to a class that has not participated in the curriculum. The
GB cognition pre-test is issued to the tested subjects before GB teaching; the post-test is issued to the same subjects a week after teaching; the delay-test randomly takes 8 "Yes or No" questions from the pre-test questions, and 8 multiple choice questions from the post-test questions and is issued to the test subjects in the 4th week after teaching.

The results show that there is no significant difference between the students from the two schools regarding their energy knowledge retrieval sources; the three major channels are school, television, broadcasting, and the Internet. The tested subjects have positive attitudes regarding energy conservation and CO$_2$ reduction. There is no significant difference between the energy attitude pre-test and post-test, regardless of the tested subjects' background variables. The tested students have specific practices regarding the energy behavior before and after teaching, and the score of "energy conservation actions" is higher than "CO$_2$ reduction actions". There is a significant difference between the "energy conservation and carbon reduction behavior" pre-test and post-test. After teaching, the energy conservation and CO$_2$ reduction behavior performance increased.

The energy conservation and CO$_2$ reduction cognition score of students with the GB teaching intervention is significantly higher than the students without the teaching intervention. GB teaching has no significant difference regarding the students' GB cognition pre-test. However, the teaching intervention does result in a significant difference regarding the GB post-test and delay-test, which verified that teaching GB has a positive impact on improving students' energy conservation, CO$_2$ reduction cognition and GB cognition.

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