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The Study on Designing Environmental Education With NGSS and STEAM on Elementary School Senior Grade Students—An Example of "Food and Agriculture Curriculum" Course Design

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This study aims to use the six self-developed teaching activities on "Food and Agriculture Curriculum". The Science, Technology, Engineering, Arts, and Mathematics (STEAM) and *Next Generation Science Standards (NGSS)* were used to design the *Environmental Education of Direction Governing for the 12-Year Basic Education Curricula*. In order to discuss the effects of these teaching activities on sixth-grade students, this study adopts single group pre-test and post-test design, which are both qualitative and quantitative studies. The subjects are 106 elementary school sixth-graders. Quantitative research tools include "Environmental Education Themes Scale for Elementary School Students", and qualitative methods include questionnaires, value clarification activities, activity logs, journals, semi-structural interviews, and teachers' reviews. The results indicated that the former "Environmental Education Themes Scale for Elementary School Students" is higher than the latter scale. Through the instructional activities of the "Food and Agriculture Curriculum", the overall environmental learning subjects were enhanced of elementary school senior grade students, and promoting environmentally conscious behaviors and their interests in environmental learning.

Keywords: Next Generation Science Standards (NGSS), Science, Technology, Engineering, Arts, and Mathematics (STEAM), Direction Governing for the 12-Year Basic Education Curricula, action research

Introduction

Faced with increased global warming and climate change, the authors designed the environmental education courses to help elementary school students realize the importance of practicing a low carbon lifestyle. *The Environmental Education Act*, implemented in June 5, 2011, required all primary and secondary schools to include four hours of environmental courses. The Act seeks to promote environmental education and to improve the understanding of the mutual relationship between individuals and society. Furthermore, the Act also helps the entire population of Taiwan understand environmental ethics and the responsibility to protect ecological balance, respect life, and advance social justice. This landmark legislation moves Taiwan's environmental education and protection policies in the right direction.

In 2004, the Ministry of Education issued the *Directions Governing for the 12-Year Basic Education Curricula*, which identified environmental education as one of the most important issues for future National

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New Education Curricula. In 2015, the Ministry of Education further developed the content of environmental education, including five themes: environmental ethics, sustainable development, climate change, disaster prevention and response, and sustainable use of energy (Ministry of Education, 2014). The development and application of renewable energy are both vital subjects for modern humans to pursue sustainable development.

The *Next Generation Science Standards (NGSS)*, published and implemented in America in 2014, created the “Educate to Innovate” program, announced by President Obama as a way to promote Science, Technology, Engineering, Arts, and Mathematics (STEAM) (STEM + Arts). The implementation of STEAM was combined with the 12-year basic education’s citizen core competencies, cultivating technology, the humanities, and culture. Facing the advent of the National New Education Curricula (Ministry of Education, 2014) and the era of AI (artificial intelligence), the authors applied the *New Era Science Courses Standards* that built on STEAM and the themes of environmental education, such as “Food and Agriculture Curriculum Teaching Activities”. Through the teaching activities, the authors expected to see student improvement in the environmental education core.

Literature Review

Environment Education

Directions Governing the 12-Year Basic Education Curricula will be implemented in August 2019. Environmental education is a process that allows individuals to explore environmental issues, engage in problem-solving, and take action to improve the environment. As a result, individuals develop a deeper understanding of environmental issues and have the skills to make informed and responsible decisions.

The components of environmental education are:

1. Awareness and sensitivity to the environment and environmental challenges;
2. Knowledge and understanding of the environment and environmental challenges;
3. Attitudes of concern for the environment and motivation to improve or maintain environmental quality;
4. Skills to identify and help resolve environmental challenges;
5. Participation in activities that lead to the resolution of environmental challenges.

STEAM

President Obama touted STEAM Education in 2017, and his administration’s push to elevate the importance of science and scientific research has provided a significant boost to those involved in STEAM education (Watson, 2016). STEAM education is a form of technical education that cultivates students’ STEAM literacy through interdisciplinary integration. This paper reviews the developmental history of STEAM education, analyzing the essence of STEAM education and explaining the connotation of STEAM education (The White House, 2013). STEAM teaching is an integrated interdisciplinary teaching that improved students’ abilities by cultivating student connections between theory and the real world. In addition, this paper proposed that the governmental and social support, high-level curriculum resources, transformation of teaching model, outstanding STEAM staff, and construction of teaching environment were the possible ways to promote the STEAM education.

The NGSS

Within the *NGSS*, there are three distinct and equally important dimensions to learning science. These dimensions are combined to form each standard—or performance expectation—and each dimension works with the other two to help students build a cohesive understanding of science over time.

Crosscutting concepts help students explore connections across the four domains of science, including physical science, life science, earth and space science, and engineering design (National Research Council, 2013). When these concepts, such as "cause and effect", are made explicit for students, they can help students develop a coherent and scientifically-based view of the world around them. The *NGSS* are K-12 science content standards. Standards set the expectations for what students should know and be able to do. The *NGSS* were developed by states to improve science education for all students. A goal for developing the *NGSS* was to create a set of research-based, up-to-date K-12 science standards. These standards give local educators the flexibility to design classroom learning experiences that stimulate students' interests in science and prepares them for college, careers, and citizenship (National Research Council, 2015).

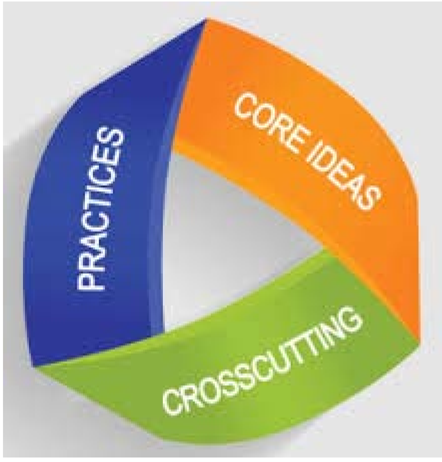

Figure 1. The thee dimension of science learning (Source: Pratt, 2013).

Method

Research Design

The STEAM education integration into the "Food and Agriculture Curriculum" courses was based on the five principles of "cross-domain, hands-on, life application, problem-solving, and sensory learning". The Ministry of Education indicated in *The 1-12 National Basic Education Curriculum General Guideline* that the "core competencies" refer to the knowledge, abilities, and attitude that people possess when facing the present and future challenges. These concepts that integrate STEAM education with "Food and Agriculture Curriculum" courses correspond to the advocated learning principles. Therefore, this study is based on STEAM education and its integration with *NGSS*, cross-domain, and core subject concepts in course design. Implementing self-edited "Food and Agriculture Curriculum" teaching activities, the researchers explore the effects of teaching activities to upper elementary students. This study quantifies results through pre-test and post-test in each group.

The design of the experiment in this study is shown in Table 1.

Table 1

Research Design

Group	Pre-test	Experimental processing	Post-test
Experimental groups (four classes)	O1	X	O2

Notes. O1: Pre-test of "Environmental Education Themes Scale for Elementary School Students";
O2: Post-test of "Environmental Education Themes Scale for Elementary School Students";
X: Showing the acceptance of "Food and Agriculture Curriculum" teaching activities of Experimental processing.

Tools

"Environmental Education Themes Scale for Elementary School Students" mainly investigates whether the understandings of environmental education themes change before and after the subjects receive the experimental instruction. The contents refer to the core competencies in *The 1-12 National Basic Education Curriculum Guideline*, regulated by the Ministry of Education (2014), and designed by the researchers.

Four categories were used in a Likert scale ("Strongly disagree", "Disagree", "Agree", and "Strongly agree"), and used a 4-point scale with this scoring: 1 = "Strongly disagree", 2 = "Disagree" 3 = "Agree", and 4 = "Strongly agree".

Expert Validity

The researchers compiled the first draft of the pilot test scale, and solicited the opinions of domestic scientific specialists and elementary science teachers regarding suggested amendments. After confirming the expert validity and the effectiveness of the content, the pilot test scale was finished with 45 questions in total. There are 40 questions in the formal scale, and the value of the Crobach's α in the scale is 0.87. The value of the Crobach's α in the formal scale in each dimensionality is suggested in the following Table 2. This study is mainly based on *The 1-12 National Basic Education Curriculum Guideline*, divided into five coefficients.

Table 2
Crobach α Coefficient in Each of Dimensionality of "Environmental Education Themes Scale for Elementary School Students"

The coefficients of "Environmental Education Themes Scale for Elementary School Students"	Crobach α coefficient	Questions
Environmental ethics	0.89	8
Sustainable development	0.78	10
Climate change	0.76	5
Disaster prevention and response	0.85	5
Sustainable energy resources usage	0.88	12
Quantity meter		

In order to design environmental education programs to achieve meaningful learning to students, the teachers must provide knowledge that is structured and organized, and preserve each student's capacity for critical thinking in order to master the content (Tyler, 1969; Ausubel, 2000). This study is designed to balance practice (skill) and cross-domain knowledge. It emphasizes three dimensions from *NGSS*: cross-domain, practice, and subject content (National Research Council, 2012), in order to integrate environmental education, and design STEAM courses based on the theme of the "Food and Agriculture Curriculum".

This study's sample comprises of 106 elementary school sixth-graders. Quantitative research tools include the "Environmental Education Themes Scale for Elementary School Students", while qualitative methods include questionnaires, value clarification activities, activity logs, journals, semi-structural interviews, and teacher reviews. The quantitative research is designed with a single group and a pre- and post- test. The test is given before and after instruction to acquire quantitative data using a paired *t*-test with a significance level of $\alpha = 0.05$, allowing for changes in the "abilities of environmental education learning themes for elementary school students" to be discussed.

Results and Discussion

Using the teaching activities of the "Food and Agriculture Curriculum", the effects of environmental education learning were used on upper grade elementary school students. Pre- and post- test of "Environmental Education Themes Scale on Elementary School Students" in descriptive statistics. The mean and standard deviation in the before and after tests of "Environmental Education Themes Scale for Elementary School Students" will be shown in the following Table 3.

Table 3

Test Describes the Results of the Before and After Tests of the "Environmental Education Themes Scale for Elementary School Students"

Item analysis	Pre-test			Post-test		
	Average	Standard deviation	Every question's point in average	Average	Standard deviation	Every question's point in average
Environmental ethics	21.85	4.04	2.73	22.68	3.90	2.83
Sustainable development	29.20	4.46	2.83	34.68	4.46	3.47
Climate change	12.55	2.15	2.51	14.38	2.27	2.88
Disaster prevention and response	11.80	1.65	2.36	13.60	1.86	2.72
Sustainable energy resources usage	34.98	5.95	2.84	36.98	5.92	3.03
Quantity meter	109.48	9.78	2.74	122.30	9.74	3.06

In the test, the average score of Quantity Meter (122.30) in the after test was higher than the before test (109.48), an improvement of 12.82 points. Each item's average in the after test scale also was higher than the before test. For example, 0.83 points higher in environmental ethics, 5.48 points higher in sustainable development, 1.83 points higher in climate change, 1.80 points higher in disaster prevention and response, and 2.00 points higher in sustainable energy resources usage. According to the average in Table 3, the points increase in each item, especially in sustainable development, environmental ethics, and climate change. In order to understand if there is a statistically significant difference between the before and after test of the "Environmental Education Themes Scale for Elementary School Students", a dependent sample *t*-test is conducted and the final results are shown in the following Table 4.

Table 4

The Points of "Environmental Education Themes Scale for Elementary School Students"

Item analysis	Difference between means	Standard deviation	95% in difference	Confidence interval	*T*	Significance
			Upper bound	Lower bound		
Environmental ethics	-0.82	1.34	-1.25	-0.40	-3.90	0.000*
Sustainable development	-5.48	5.24	-7.15	-3.80	-6.61	0.000*
Climate change	-1.83	1.50	-2.30	-1.35	-7.69	0.000*
Disaster prevention and response	-1.80	1.20	-2.18	-1.42	-9.47	0.000*
Sustainable energy resources usage	-2.00	2.25	-3.62	-2.18	-8.15	0.000*
Quantity meter	-12.83	5.73	-14.66	-10.99	-14.15	0.000*

Note. * $p = 0.0000 < 0.05$.

In Table 4, the dependent sample *t*-test shows that the difference between the before and after test points of quantity meter is statistically significant ($t = -14.15$, $p = 0.0000 < 0.05$). Therefore, the analysis shows that the teaching activities of "Food and Agriculture Curriculum", result in significant progress on student understanding of environmental issues in various themes.

The authors acknowledge the professional development from combining *NGSS* and STEAM through teaching activities and course design. Based on an analysis of the teaching notes, the design of "Food and Agriculture Curriculum" assists sixth-grade students utilize scientific principles and design a finished product that integrates STEAM. Students' feedback during the class also shows that the "Teaching Activities of Food and Agriculture Curriculum" piques students' interest in learning, which in turn furthers environmental education. The courses designed in this study offer an appealing and interesting teaching design.

Suggestions

1. In the "Food and Agriculture Curriculum", working sheets can be designed to extend and follow-up on in-class discussions, helping to advance dialogue more effectively. Students can respond and express their own thoughts by writing diaries, while instructors can effectively gauge student progress via working sheets and diaries, and provide guidance and recognition to the students.

2. In terms of the courses design, teachers can improve their instructional material through student experiment results and responses, class discussion and working sheets. Discussion among teachers can also improve instruction and further professional development.

Conclusions

Based on the principles of the new generation of scientific standards in the United States, the instructional activities of food and agriculture education were designed by using the interdisciplinary practical content. During the experiment, most of the students practiced the principles of science, experienced preliminary engineering, and exhibited high interest in learning. The instructional objectives of environmental education were achieved:

1. After implementing the teaching activities of "Food and Agriculture Curriculum", the sixth-grade students' learning abilities in the themes of "environmental ethics" was improved. The study's qualitative results revealed that the students now understand the importance of "environmental ethics" and display increased concern regarding humans and lives.

2. After implementing the teaching activities of "Food and Agriculture Curriculum", the sixth-grade students' learning abilities in the partial themes of "sustainable development" was improved. The study's qualitative results revealed that the students now reconsider humanity's future development plans, and pay attention to sustainable development of the earth.

3. After practicing the teaching activities of "Food and Agriculture Curriculum", the sixth-grade students' learning abilities in the partial themes of "climate change" was improved. The study's qualitative results suggested that the students now understand the impacts and influences on climate change to human beings.

4. After practicing the teaching activities of "Food and Agriculture Curriculum", the sixth-grade students' learning abilities in the partial themes of "disaster prevention and response" was improved. The study's qualitative results suggested that the students now understand how to prevent, avoid, and reduce disaster.

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