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Action Research of the STEAM Educational Program on Climate Change Using Leaf Fossils

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Abstract

In this study, we used the STEAM education program on climate change as a high-school science club activity and analyzed its effectiveness. Ten rounds of lessons and a 1-day field trip for collecting fossil leaves were carried out. The overall satisfaction of students with the STEAM program was highly positive (the mean score of 4.76 on a 5-point Likert scale). Additionally, the score was high when combined with the optimized level of difficulty, as it gave a sense of challenge and originality to the students' tasks (the score of 4.53). The students liked the process and direct experience of the STEAM educational factors and convergence thinking across various academic fields with the common subject, namely, that of climate change, and fossil analysis. It is worth noting that, prior to participation in the program, the students did not previously encounter academic learning of this type based on hands-on experience. Furthermore, the students experienced enjoyed creativity, character education, and planning ways to reduce climate change during the program.

Keywords: *STEAM education program, climate change, science club, fossils*

1. Introduction

As climate changes have recently started to occur worldwide, concerns and discussions about climate change have become more critical [1]. Following the global trend, South Korea is also increasing its efforts to mitigate climate change with the national development strategies of low carbon green growth. Implementation of these strategies has led to an increasing need of climate change education [2]. In response to the urgent need of education on climate change, a revised national curriculum, assistant materials and teachers' references for climate change education were developed and distributed in 2007. Although UNESCO (2012) provides relevant guidelines with regard to climate change education, the practical field of education still lacks comprehensive understanding of climate change and educational programs for students in South Korea [3-4].

In order to cultivate democratic citizens with the sense of responsibility for sustainable growth in the future, education on climate change should pursue relevant concepts, including climate literacy and civil practice, *i.e.*, concepts that go beyond plain knowledge about climate change. Also, since climate change is a complicated issue that involves various perspectives, it should be approached not only with standard strategies of conventional education, but also include the appeal to values, morals, and behaviors suing the integrated STEAM education [5-6]. In the present

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study, we applied the STEAM education program on climate change as an inquiry activity for a science club and analyzed its effectiveness.

2. Methodology

2.1. The STEAM Education Program on Climate Change

In this study, the STEAM program was used to encourage high-school students in science clubs to learn more about climate change through small group projects. In order to learn the STEAM factor of creativity character education, this program was designed for the students to investigate paleotemperature using the leaf margin analysis of leaf fossil. The process was completed through the Delphi method and the validity was assessed by educational expert panels. Table 1 shows the program that consisted of 10 round lessons and a 1-day field trip for collecting leaf fossils.

2.2. Subject of Study and Data Collection

A total of 18 students from 3 high school science clubs in the Jeonbook area participated in the study. Three groups were formed (N=6 in each group) that were assisted by 6 college students majoring in science education. A pilot test was carried out from July 21 to July 30, 2014 with 10 rounds of lessons, each lesson lasted 2 hours. Additionally, a 1-day field trip for collecting leaf fossil samples was scheduled. Quantitative data were collected to assess the satisfaction level of the students; and experiment reports, open questions, class observation, and interviews were also conducted. Data analysis was conducted with 17 students after the data cleaning that filtered out one unreliable response.

2.3. Testing Tool

The STEAM program testing tool developed by Yoon & Hong (2012) was used for the analysis of the effectiveness of the program application [7]. A questionnaire consisted of 4 different areas with 17 questions. Eleven of these questions were developed for measuring satisfaction level using a 5-point Likert scale. The remaining questions (6 open-ended questions) were designed to ask the participants would whether or not they would recommend the program to others and why/why not. The participants were also asked about what part they were most satisfied with, and whether they would recommend any changes to the program.

3. Results and Discussion

3.1. Program Application Lessons

• Presentation of the Situation Stage (Round 1)

We introduced the science club investigation activity subject, induced interest to it among the students, and then encouraged them to form goals of study regarding the interaction between climate and human activities, as well as possible threats posed by climate change. The students discussed whether they would be able to figure out past climatic conditions by analyzing fossils remaining in the Earth's strata. Also, they proposed other ways to infer past climatic conditions.

• Creative Design Stage (Rounds 2-3)

This round involved discussion and creative design of the ways to collect fossil leaves. In addition, the groups discussed how to investigate paleotemperature data by analyzing

the collected leaf fossils. Broad leaf tree species were collected around the school, classified by the leaf margins, and documented as expressed in the drawings.

The students drew graphs based on the data of annual temperature and the percentage of leaf fossils with smooth edges. They elaborated creative designs to investigate high temperatures of the geographical era by using the research method of Wolfe (1971) [8-9]. Through data research and discussion, the Pohang basin was selected with the most similar flora to the present site. The Miocene Janggi and Yeonil groups, corresponding to the middle Neo-tertiary Period as classified by Kim (1970), were selected as the places to collect the fossils [10].

Table 1. Contents of the STEAM Education Program on Climate Change

Instruction num.	Teaching and learning process	STEAM educational factors	Contents	Learning method
1	Presentation of situation	Communication, inquisitiveness, high concept	Introduction and team formation, investigation of previous studies and motivation, investigation methods of studying paleoclimate	Orientation Discussion
2 - 3	Creative design	Exploration, designing, analysis, discussion	Ways to explore paleotemperature using leaf fossils	Discussion
			Identification of the Cenozoic strata	Investigation
4 - 7	Emotional experience	Creative experience, identification of leaf fossils (arts), empathy	Leaf-margin analysis and collection of a fossil leaf	Field trip
			Analysis of the Cenozoic paleoclimate in Korea, analytical ability (critical thinking & data analysis)	Investigation
8 - 9	New challenge	Expansion of exploration, proposal of values and plans	Discussions of climate change of the northern hemisphere, efforts to prevent climate change	Discussion STS learning
10	Presentation and assessment	Presentation	Presentation and evaluation of a product of learning	Presentation Evaluation

• Emotional Experience Stage (Rounds 4-7)

The students visited the selected Cenezoic fossil site and collected leaf fossils. Through mentoring and group activities with experts and historical geology studies during the site visit, the students underwent emotional experiences through communication and cooperation skills. They visited 9 fossil sites, collected 23 leaf fossils, and used 179 fossil samples for the analysis (Figure 1). Also, they received advice from experts on classifying leaf fossil species and genus. In addition, the students separately classified the smooth and non-smooth edges of the fossils, which were later used for calculating the percentage of leaf fossils with smooth edges. They were also able to quantitatively investigate paleotemperature in the Janggi and Yeonil groups (see Figure 2).

• New Challenge and Assessment (Rounds 8-10)

The students challenged themselves to discuss climate change in the northern hemisphere through examining previous research on Miocene paleotemperate and climate change. They formed groups to organize and present the process and results of their investigation.

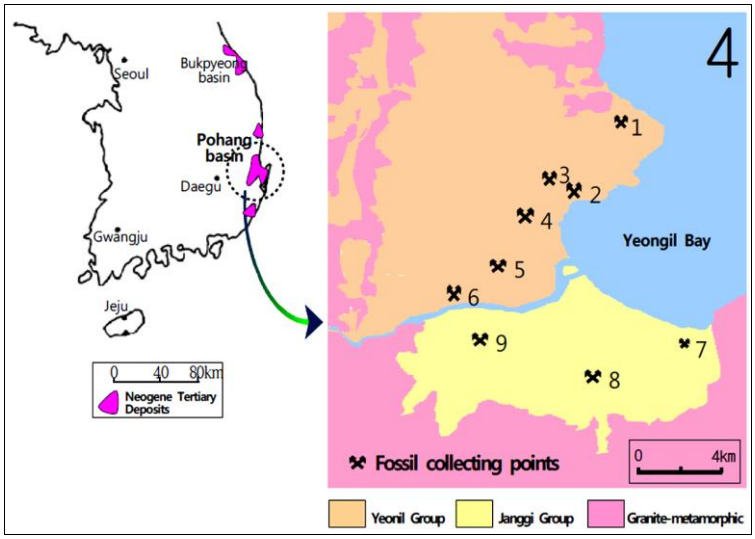

Figure 1. Map of Fossil Collection Sites from the Neogene Tertiary in the Pohang Basin

3.2. Effectiveness of Lessons

The results of the satisfaction level survey of the student participants yielded the scores of 3.35 or higher (on a 5-point Likert scale) on all the questions. The mean score of 4.33 was also very high (see Table 2). High scores were obtained for the overall satisfaction level with the STEAM program (4.76), level of understanding of the STEAM program (4.71), self-directed lessons (4.65), and novel and original subject of investigation (4.53). The scores on the sufficient investigation time span (3.35) and level of textbook and material understanding (3.88) were relatively lower than the overall mean. These results were due to time constraints of science club activities and a large amount of time needed for fossil collection and classification. To enhance the understanding of the textbook, the number of previous studies and academic papers to consult was minimized and relevant works were structured for easier understanding. If sufficient time can be allocated as a creative experience activity in school, this material can definitely be an appealing subject of investigation for student club activities.

The answers to the open questions in the survey were also interesting. For example, when asked about the subject that the students were most satisfied with in the STEAM program and the corresponding reasons, all students responded they were satisfied with the field trip and the associated mentoring during the leaf fossil collection and classification (see Table 3). This self-directed and expert scientific way of studying fossils, as well as analyzing and participating in experience-oriented lessons on 29- million-year-old paleotemperature data, was reported to be highly satisfactory and motivating by 15 students. Also, discussions and presentations on the Cenozoic climate change were reported to be satisfactory by 11 students. The reasons provided by the students were that the students were able to be involved in a direct scientific experience, which was very different from what they usually encountered in conventional classroom environment. In addition, the students' scientific experiences were combined with their emotional experiences of actually collecting and analyzing fossils in the natural environment. They also said that they were able to learn from each other during the discussion process, collaboration, and presentations on the Cenozoic climate change. This collaboration made them feel as if they were professional scientists.

After selecting the observed interested subjects and tabulating the data from teachers' interviews conducted throughout the course, we analyzed the students' cognitive processes by means of anecdote observation. The following questions (a-b) were asked:

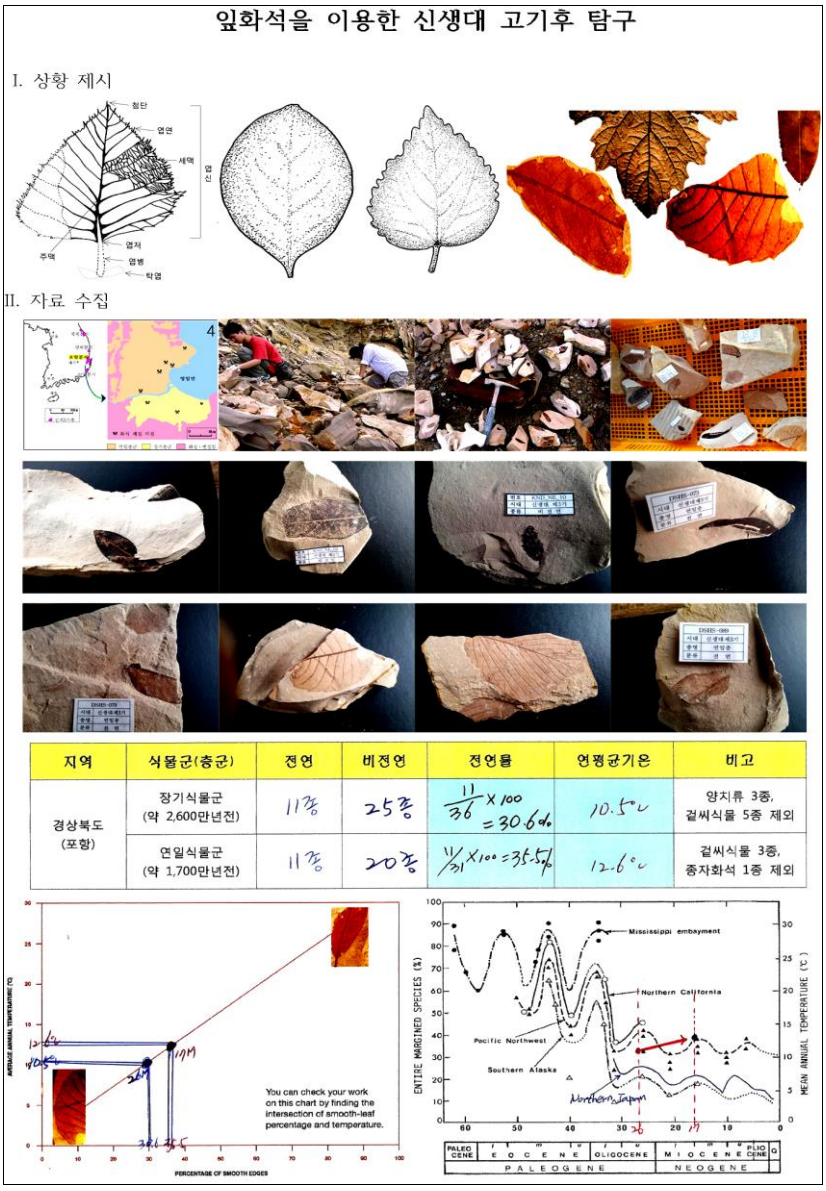

Figure 2. Student Worksheet

a. As a result of the STEAM program on climate change, were we able to find evidence of student change in terms of their ability for creative design and application?

Through provision of conditions, research on academic papers, group research, and the process of discussion, we observed how students designed and constructed the ways to investigate paleotemperature climatic indicators using leaf fossils. To establish the hypotheses and initiate active discussions, we looked at the questions such as "*Where would students collect fossils*?" "*How would they figure out the geographical area?"* and "*How would they classify the collected leaf fossils*?". Notably, we observed that the students' ability for creative design was improved and used during the process of discussion.

Table 2. Result on Survey for the Satisfaction Level of the Participants (N=17)

Question	Mean	Std.
・Overall, the STEAM education program was beneficial	4.76	0.44
・Club investigation activities helped understand the STEAM education program	4.71	0.47
・Textbooks and materials were easy to read and understand	3.88	0.70
・I actively participated in the class and understood the materials well	4.29	0.59
・There was enough time for investigation activities (experiment–practice–research–discussion)	3.35	0.61
・The subject of investigation was novel and original	4.53	0.62
・The STEAM educational factors were helpful in class	4.47	0.51
・It was a self-directed way of studying	4.65	0.49
・Sufficient understanding and satisfaction was helpful in terms of career exploration	4.29	0.59
Mean	4.33	0.20

Table 3. Open Questions on the Most Satisfactory Experience-Practice (N=17, repeated answers included)

Questions	Num. of respondents	Percentage (%)
・Mentoring on collecting and classifying leaf fossils (emotional experience)	17	100.0
・Discussion and investigation on paleotemperature using leaf fossils (emotional experience)	15	88.3
・Discussion on climate change in the northern hemisphere (new challenge)	11	64.7
・Contest on output evaluation (new challenge)	10	58.9
・Presentation of previous studies on the ways to investigate paleotemperature (creative design)	5	29.5
Main reasons for satisfaction in the program (Number of respondents) ◦ It was novel and interesting (16) ◦ They liked field trip for collecting leaf fossils (15) ◦ They felt as if they were scientists (11) ◦ It was a creative experience activity that they had never experienced in school (10) ◦ They could learn from each other in the process of research, discussion, and cooperation (8) ◦ The students bonded and liked discussing the subject material (5)		

b. Were we able to find evidence of student change in the students' willingness to take new challenges or emotional experience as a result of the STEAM program on climate change?

During the fossil collection field trip and as a part of visual-spatial experience, the students could identify their location on the geographical map. They also encountered "hearts-on" experience of inquisitive and intellectual joy in the process of hands-on experience of collecting 29-million-year-old leaf fossils. Through communication with group members in the process of sketching and classifying the leaf fossils by their shapes and kinds, the students' experienced artistic emotions.

Through applying the percentage of leaf fossils with smooth edges, the students' ability

for convergence thinking and creative integration of biology, earth science, mathematics, and arts were also enhanced. When comparing their own results with those of previous studies, the students demonstrated their appreciation of the new challenge and discussed climate change of the given geographical era through self-directed research. Moreover, they showed willingness to conceive of the ways to practice projects for reducing climate change.

4. Conclusions and Suggestions

In this study, we applied the STEAM education program on climate change to high-school science club activities and analyzed its effectiveness. Ten rounds of lessons and a 1-day field trip for collecting leaf fossils were carried out. The results of our analysis allow for drawing the following conclusions.

First, the overall level of satisfaction of the students was very high (4.76), which was largely due to the novel and original subject of the investigation (4.53). These scores indicate that the students enjoyed cooperative learning and scientific investigation. In addition, the students experienced interesting aspects of various STEAM educational factors for convergence teaching while investigating climate change and collecting the fossils. Prior to participation in this study, the students had rarely experienced this type of hands-on activity in conventional classroom environment. Also, from the students' perspectives, the program succeeded in relating the subject of investigation to the recent trend of global warming research and relevant issues. Just-in-time learning of extending the visual-spatial concept of the geographical era and climate change in the northern hemisphere was thus accomplished. If this program can be generalized and extended to creative experience activities on climate change, it can liberate students from the academic boredom of conventional classroom learning, which can further contribute to active practicing of the STEAM educational program in school curriculums.

Second, the most satisfactory part of the STEAM program for the students was the emotional experience that emerged throughout fossil collection and classification during the field trip. The students said they liked this aspect of the program the most. With expert-aided self-directed studying, the students showed a high level of satisfaction during the process of fossil collection. The students were more motivated, because they actually felt as if they were professional scientists (15 students). Also, through participating in storytelling, discussion, and presenting the results (10 students) about climate change (11 students), the students' satisfaction level seemed to increase.

This increase suggests that students should actively participate in experiment-practice in the STEAM education program. This practice can be done by forming small groups and assigning specific roles to each of the groups in designing and preparing the experiment.

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