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Article

Multi-Timescale Education Program for Temporal Expansion in Ecocentric Education: Using Fixed-Point Time-Lapse Images for Phenology Observation

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Abstract: Ecocentric education programs should include a method for the in-depth understanding of multi-scale ecological time concepts. To accomplish this, the common restriction that ecocentric education should pertain only to realistic nature may have to be removed. The purpose of this research was to confirm the validity of a program featuring phenology observation, employing fixed-point time-lapse images as climate change learning, and to obtain suggestions on the influence of the program on the multi-timescale concepts of the learners. An observation sheet listing images of cherry flowering from 16 April to 15 March each year from 1996 to 2017 was created, and the 50-min educational program using the observation sheet was conducted with 189 third year junior high school students. The tendencies among students' answers to the two questions before and after the program suggest that the program contributed to the students acquiring the hundreds-year timescale concept based on the short-term timescale concept of dynamic nature. The contribution of this research is to visualize long-term and multi-scale ecological time concepts. By combining long-term time-lapse images with everyday nature experiences, the possibility of expanding such emotions as wonder and attachment to nature towards a long-term ecological timescale is achieved.

Keywords: multi-timescale education; phenology observation; environmental education; time-lapse imagery; Cyberforest

1. Introduction

In order for environmental education to express its ecological value, it is necessary for educational programs to include a method for the in-depth understanding of ecological time that contains multi-scale concepts. This is important because some natural resources, such as trees, can be regenerated within time spans of some ten years, while such global-scale issues as climate change, which have a considerable influence on the circulation of natural resources, need to be understood within time spans of some hundred years or more. Unless more people can properly comprehend these multi-timescale concepts, society tends to include "ecological time-scale violations" [1] that make it difficult to create a sustainable society.

Conventional ecocentric educational programs share the potential to contribute to such complex concepts as those described above, using sensitive and emotional approaches. Specifically, there are environmental education approaches that foster wonder [2,3] or empathy [4,5] towards nature. These approaches do not restrict human well-being to economic aspects; rather, they can make the conventional sustainability education richer and profound [6–8]. Such ecocentric education aims to recognize the limits of human understanding by positioning human beings as part of nature [9]. The concrete method of ecocentric education, however, has not been sufficiently examined.

In order to seriously consider how to learn multi-timescale concepts, the restriction that ecocentric education pertains only to realistic nature may need to be altered or removed. This is because it is almost impossible for people to directly experience the multi-timescale phenomenon of real nature. However, it is not enough to simply present the phenomena to students with visual media. Instead, it is considered necessary to link multi-timescale concepts closely to the short-term pragmatic agenda close to students' daily lives [6]. Presenting in visual media an event that people have already encountered as a natural phenomenon is desirable to aid students' comprehension.

Plant phenology, which means seasonal biological phenomena, is a phenomenon that many people observe in their daily life and can be presented as multi-timescale phenomenon in visual media. Time-lapse images of plants from a fixed point leads us to an improved understanding of tree phenology on a time-scale of decades [10–15]. Although the possibility of employing time-lapse images as environmental education materials has been previously highlighted, there have been only a few studies that aim to verify its validity [16,17]. If the observation of phenology with fixed-point time-lapse images can be implemented as an environmental education program, and if its educational effects are confirmed, it will increase the value of arguments for extending the subject of ecocentric education to include learning multi-timescale concepts through the use of visual media.

The observation of phenology with these fixed-point time-lapse images might provide, in particular, a methodology that solves conventional problems in climate change learning. Taking action towards resolution of climate change problems is considered to be difficult owing to the uncertainty surrounding these issues [18–20]. Nevertheless, it is desirable not to hide the uncertainty but to face it because there is a concern that many students have misconceptions regarding climate change [21–24]. In such situations, selecting events such as phenology that have already been encountered by students as teaching materials is deemed effective. Although the possibility of using time-lapse images as materials in teaching climate change has been previously highlighted, prior research using phenology as a teaching material has been limited in the extent to which its possible application has been highlighted in this context [25–27].

In this research, an environmental education program, including phenology observation, by employing fixed-point time-lapse images was conducted. The purpose of this research was to confirm the validity of the program as climate change learning and to obtain suggestions on the influence of the program on the multi-timescale concepts of the learners.

2. Materials and Methods

2.1. Time-Lapse Images and Observation of Flowering Phenology

Time-lapse images taken in the University of Tokyo Chichibu Forest (Ohtaki, Chichibu-shi, Saitama, Japan) each year since 1995 were used. The images were taken automatically at approximately 11:30 a.m. on each day throughout the year, as part of a research project conducted by the Cyberforest Project [28]. These time-lapse images allowed us to observe the flowering phenology of a cherry tree (*Prunus verecunda*) [29]. Cherry blossoms are familiar to many Japanese people and close to their daily lives, which is in line with the requirements of this research.

In order to use these time-lapse images in an educational program, an observation sheet that lists images of cherry flowering periods (between 16 April to 15 March each year from 1996 to 2017) was created. Daily changes were recorded in the horizontal direction and annual changes were recorded in the vertical direction in the sheet. A PDF file of the observation sheet has been published on the Internet (http://www.cf4ee.jp/chichibu_1996-2017.pdf) so that it can be printed at maximum B0 size (Figure 1).

Figure 1. A large-sized (B0 size is shown in this picture) sheet for observation of cherry flowering allowed teachers and learners to observe flowering phenology together.

This observation sheet enabled learners to comprehend the annual changes of the flowering phenology by setting observation criteria to determine the distinguishing date of each year. In order to implement such phenology observation as an educational program, it was required to set observational criteria that could be clearly explained by a teacher and could be discerned easily in a short time by learners. The following two criteria were set in this research as "full bloom date" that satisfied these requirements: the day when white flowers of the cherry blossom appear to be most abundant is full bloom date; if there are multiple days when the cherry blossom appear to be most abundant, the earliest day is the full bloom date (cf. a specific observation example in Figure 2).

25 April 26 April 27 April 28 April 29 April 30 April 1 May

Figure 2. These are excerpts of the cherry flowering period in 2016 from the observation sheet. 28 April cannot see the cherry blossoms due to bad weather. The white flowers of cherry blossoms peak from 27 to 29 April. If it is judged that the 27th and the 29th do not change, for example, the 27th is determined to be a full bloom date.

2.2. Target and Educational Program

This study targeted 189 third year junior high school students who were 14 or 15 years old in one school that is located close to the sea in Japan, and a program using the observation sheet was conducted in 2017 (for 54 female students and 50 male students) and 2018 (for 43 female students and 42 male students). As with many schools in Japan, most students have relatively little experience of forest because there is no large forest in the region. School-based education offers an important opportunity for environmental learning for many students [30], and education through junior high school is compulsory in Japan. Furthermore, there is also an example of leafing phenology observation using fixed-point time-lapse images by junior high school students [17]. One of the authors of this paper served as an instructor of the program.

At both the beginning and end of the program, the instructor asked the students the following two questions: (1) Do you think nature is changing from day to day? (2) Do you think that taking pictures of the same place in nature will lead to a solution for global warming? The first question aimed at acquiring a relatively short-term time concept through understanding nature as dynamic. The second question aimed at acquiring a relatively long-term time concept through thinking about global warming, which is a hundred-year issue. It was assumed that the change in answers to these two questions would reflect the influence on the students' multi-timescale concepts.

As an approach based on climate change learning to the above multi-time scale concept, flowering phenology observation of the cherry blossom was carried out in this program. Using the observation sheet printed on an A3-size paper, the students attached a red sticker on the day they judged as "full bloom date," according to the above-mentioned observation criteria (Figure 3). This observation work took approximately 15 min out of the 50 min allotted for the entire program. Students were able to grasp the annual change of flowering phenology by perceiving the red seal similar to a graph point. At the time, only these 50 min could be secured; thus, the students themselves did not analyze or consider the relationship between the full bloom date and the annual temperature. Instead, the instructor explained that the full bloom date of cherry blossoms was related to global warming in that it is affected by the temperature conditions of each year.

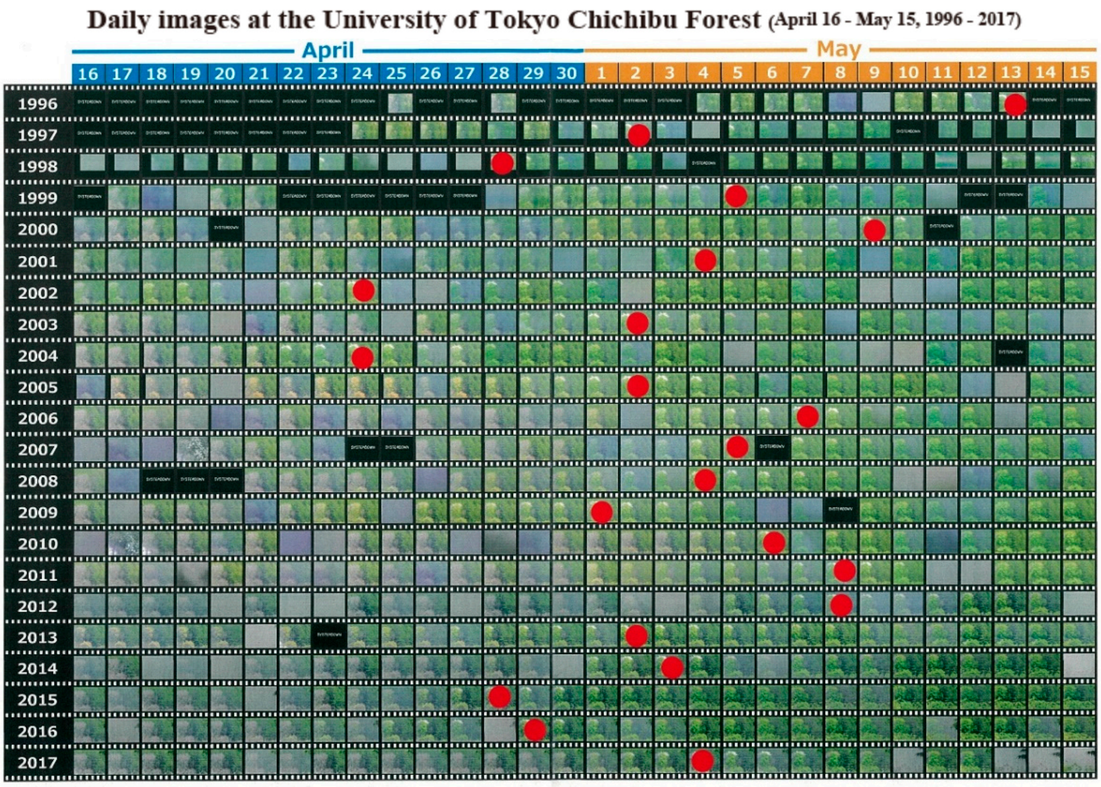

Figure 3. The phenology observation sheet with red stickers attached on the "full bloom date" of each year according to the following observation criteria: the day when white flowers of the cherry blossom appear to be most abundant is considered the full bloom date; if there are multiple days when the cherry blossom appear to be most abundant, the earliest day is the full bloom date.

2.3. Data Analysis

2.3.1. Validity of the "Full Bloom Date" Determined by the Students

The mean of all the students' determinations of full bloom day with a red sticker was calculated. In addition, sample variance and sample standard deviation were calculated in order to understand how much variation existed among the students. Furthermore, Pearson's product-moment correlation coefficient was calculated with the air temperature data of the "Koakasawa" site (1.84 km direct distance from the cherry blossoms) from 2001 to 2017 [31–47] in order to confirm the validity of the mean full bloom date. Taking into consideration the convenience of employing the learning materials with students in the future, the mean temperature of three months, from February to April, was used based on the assumption that the dormancy breaking of cherry blossom occurs in February [48]. If the correlation with the three-month mean temperature, which can be calculated easily even by junior high school students, is confirmed, the validity and usefulness of having students analyze and consider the relationship between full bloom date and temperature has been found.

2.3.2. Effects of the Educational Program Using the Phenology Observation Sheet

As answers to the two questions (1) "Do you think nature is changing from day to day?" and (2) "Do you think that taking pictures of the same place in nature will lead to a solution for global warming?", the students selected one of the following four options at both the beginning and the end of the educational program: agree, somewhat agree, somewhat disagree, disagree. Regarding the answers to these two questions, the effects of the program were examined from comparisons before and after the program and from the answer patterns classified by cluster analysis. The comparison was analyzed using Fisher's exact test and the Benjamini and Hochberg method [49] as a multiple comparison, and the cluster analysis was conducted by the Ward method with the Jaccard distance through converting the answers into dummy variables.

3. Results

3.1. The "Full Bloom Date" Observed by the Students

The results of observations were obtained from all 189 students although some inappropriate aspects, such as multiple stickers applied in the same year, which were excluded from the analysis, were also included in the observations. Looking at the variance and standard deviation (Table 1) for the full bloom dates observed by the students for each year, the values were prominent only in 1998, which was a result of the fact that many students mistakenly recognized the white noise included in a portion of the 1998 images as a cherry blossom. Furthermore, the observation difficulty was considered to be relatively high in 2002, when the second largest value was found, due to the long flowering period and the many days of bad weather. In particular, students who participated in the 2018 program had more variation in their 2002 observations than did participants in 2017. Students in the 2017 program observed using the table, while students did not use the table in the 2018 program, and this may have reduced the observation accuracy of the students in 2018. The standard deviation of the other years fell below two days.

Table 1. Results of flowering phenology observation by students.

Year	Mean of Full Bloom Date [1]	Sample Variance	Sample Standard Deviation	Mean Temperature of Three Month from February to April
1996	42.2	2.79	1.67	
1997	32.6	2.06	1.44	
1998	29.6	29.02	5.39	
1999	34.9	0.76	0.87	
2000	39.6	3.92	1.98	
2001	36.4	1.26	1.12	2.3
2002	24.9	4.77	2.18	3.8
2003	31.6	0.83	0.91	1.8
2004	23.5	1.35	1.16	3.7
2005	31.9	0.86	0.93	2.1
2006	36.8	1.09	1.04	1.9
2007	34.9	2.02	1.42	2.7
2008	34.1	1.25	1.12	1.7
2009	30.9	1.07	1.04	3.1
2010	35.6	2.18	1.48	1.6
2011	38.3	0.55	0.74	1.6
2012	37.6	0.84	0.92	1.2
2013	31.7	3.60	1.90	2.6
2014	32.5	0.92	0.96	1.8
2015	28.4	0.51	0.71	2.9
2016	28.4	1.90	1.38	3.3
2017	34.5	0.80	0.89	2.0

[1] The mean values for leafing date are represented as the number of days since April 1 in each year.

A strong negative correlation (correlation coefficient −0.85) was identified (Figure 4) between the mean temperature of three months from February to April and the mean full bloom dates observed by the students (Table 1).

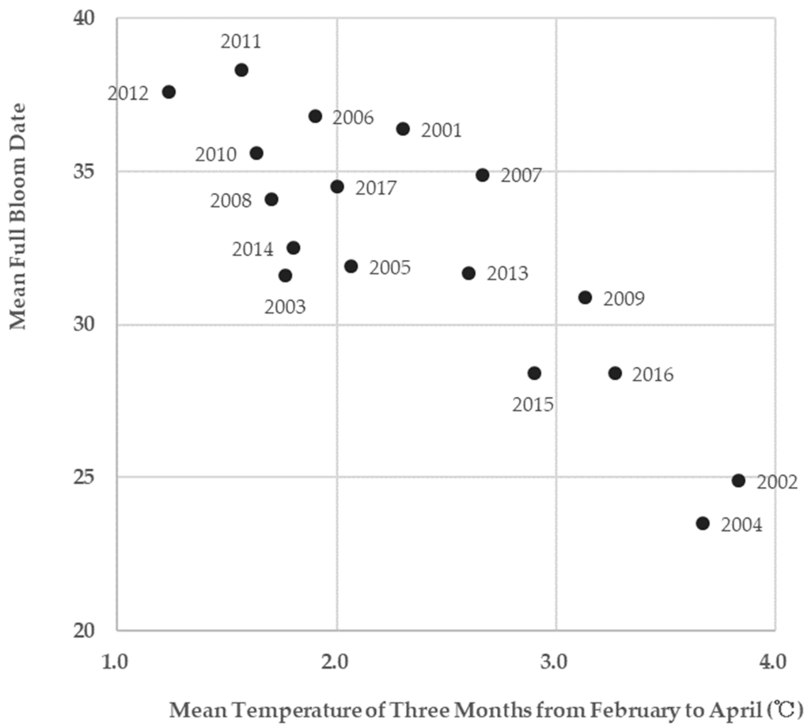

Figure 4. The relationship between mean temperature of a three-month period (from February to April) and mean of full-bloom dates. The correlation coefficient was −0.85.

3.2. Effects of the Educational Program

Of the two questions at the beginning and the end of the educational program, Question 1 (hereafter Q1) had many "agree" responses and few "disagree" responses before the program; nevertheless, the number of "agree" responses increased significantly relative to "somewhat agree" after the program (Table 2), which was met the significance level of 1%. On the other hand, Question 2 (hereafter, Q2) had the highest number of "somewhat agree" responses before the program, and "disagree" was also higher than that of Q1 responses before the program. After the program, however, "agree" responses increased significantly relative to all of "somewhat agree," "somewhat disagree" responses, and "disagree" responses (Table 2), which met the significance level of 1%.

Table 2. The answer to the questions before and after the educational program.

	Question 1 "Do You Think Nature Is Changing from Day to Day?" [1]				Question 2 "Do You Think That Taking Pictures of the Same Place in Nature Will Lead to a Solution of Global Warming?" [1]			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Before	129	45	3	3	48	84	33	15
After	161	16	2	1	109	57	11	3

[1] Numbers refer to the following responses: (1) agree, (2) somewhat agree, (3) somewhat disagree, (4) disagree.

As a result of cluster analysis using answers to Q1 and Q2 both before and after the program, findings could be divided into 6 clusters (Table 3): the students in Cluster 1 answered "agree" in Q1 and "somewhat agree" in Q2 before and after the program, Cluster 2 includes many students whose answers to Q2 have changed from "somewhat disagree" to "agree" or "somewhat agree," and answers to Q1 have changed to "agree" as well, Cluster 3 contains many students whose answers to both Q1 and Q2 have changed from "somewhat agree" to "agree," Cluster 4 contains many students whose answers to Q1 were "agree" before and after the program, and answers to Q2 have changed from "disagree" to "somewhat agree." The students in Cluster 5 answered "agree" in Q1 both before and after the program, and their answer to Q2 changed from "somewhat agree" to "agree." The students in Cluster 1 answered "agree" in Q1 and Q2 before and after the program.

Table 3. The answers to questions by cluster.

Cluster	Question 1—Before [1]				Question 2—Before [1]				Question 1—After [1]				Question 2—After [1]			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
1	23	0	0	0	0	23	0	0	22	0	1	0	0	23	0	0
2	14	20	0	0	1	0	33	0	28	6	0	0	6	18	9	1
3	0	21	0	1	4	18	0	0	18	4	0	0	16	6	0	0
4	11	4	3	2	3	2	0	15	12	6	1	1	6	10	2	2
5	41	0	0	0	0	41	0	0	41	0	0	0	41	0	0	0
6	40	0	0	0	40	0	0	0	40	0	0	0	40	0	0	0

[1] Numbers refer to the following responses: (1) agree, (2) somewhat agree, (3) somewhat disagree, (4) disagree.

The features of the six clusters can be roughly divided into three patterns: a pattern in which answers to both Q1 and Q2 have changed to the "agree" side; a pattern in which the answer to Q1 was originally "agree," and the answer to Q2 changed to the "agree" side; a pattern in which answers to both Q1 and Q2 did not changed. However, it should be noted that the answers on the "agree" side do not guarantee the holding of the relevant-timescale concepts, since the answers were solely the student's self-evaluation.

4. Discussion and Conclusions

Regarding the influence of the educational program on multi-timescale concepts, the tendency of the students' answers to the two questions about the time concept suggested that the program, including phenology observation, using fixed-point time-lapse images, contributed in particular to the students acquiring the hundreds-year timescale concept based on the short-term timescale concept of dynamic nature. Regarding the time scale of the phenology observation sheet in this research, although the students might be able to observe daily changes and differences among the years from 1996 to 2017, they were not able to directly observe the ecological effects of long-term climate change, such as global warming. Nevertheless, some students responded to the link between fixed-point photography and global warming (Question 2). The observation sheet is considered to have introduced the multi-timescale concept to the students by clarifying the limitations of timescale. It is desirable to conduct empirical studies hypothesized for this process; these may clarify what kinds of processes form students' multi-timescale concepts.

The 50-min educational program that includes a 15-min plant phenology observation activity by third-year junior high school students has provided ecologically appropriate phenology observation results, as well as the potential for important educational effects regarding timescale, as described above. Compared with the past cases of leafing phenology observation using fixed-point time-lapse images [17], each student observed all years of a 21 year period instead of sharing a single year, and the variation in results was smaller. This suggests that it is better for students to observe flowering than leafing as the basis of an educational program. The ecologically valid phenology observation conducted by students in a short time frame, using fixed-point time-lapse images of this research, provided a path for realizing the possibility that phenology observation could contribute to improved environmental education on the theme of such long-term timescale events as climate change [25–27]. With additional lesson time, it would not be very difficult for students to work with temperature data and examine relationships between the temperature and tree phenology, although this was not a focus of the educational program in this research.

The contribution of this research is to provide students with the tools to visualize long-term and multi-scale ecological time concepts, which are regarded as a method to introduce ecological elements into environmental education in a sensory form. However, it should be noted that this method is not a realistic natural experience. In particular, replacing short-term ecological events that can be experienced directly, such as daily changes, with time-lapse images should be avoided. On the other hand, it is important to consider the fact that few people are able to observe plants frequently on a daily basis [50]. Rather than replacing natural experiences with time-lapse images, by combining long-term time-lapse images with everyday experiences of nature, the possibility is found of expanding emotions such as wonder and attachment to nature, which are considered to be the core of ecocentric education, towards a long-term ecological timescale.

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