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Learning Progression for Japanese Elementary Students' Reasoning about Ecosystems

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Abstract

The purpose of this study is to elucidate how the Japanese students' reasoning about ecosystems of first through sixth grade students differs across grades using learning progressions (LPs) approach. This study was conducted through oral interviews. Structured interviews were conducted with 12 students from first through sixth grade. The results of this study suggested that the first through sixth grade students' reasoning of differs by their grade level, specifically, that their reasoning about ecosystems improves as they move to upper grades.

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1. Theoretical background

1.1. Understanding ecosystems as complex systems

The ecosystems are complex systems of interactions among biological communities or between biological communities and the environments leading to inflow-outflow and circulation of materials and energy. We find that even though the ecosystems are made up of various elements that interact with each other, the system as a whole has properties and behaviors that cannot be reduced to individual elements. It is believed that understanding ecosystems

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as complex systems serve as the essential foundation for students to learn about global environmental issues such as global warming, biodiversity, and water pollution (Leach, Driver, Scott, & Wood-Robinson, 1995; NGSS Lead States, 2013).

Research has been conducted to probe students' reasoning about ecosystems, in order to gain basic insights on how to introduce content knowledge about ecosystems into the science education curriculum, as well as how to teach such content knowledge (Leach, Driver, Scott, & Wood-Robinson, 1996a, 1996b). For example, a conceptual framework to understand natural events as complex systems has been proposed. Chandler and Boutilier (1992) point out that the understanding natural events as complex systems comprises reasoning of the following four properties: (a) Systemic synthesis: a change or disturbance in one element of the system affects all the other elements, (b) Systemic analysis: there are critical elements that are essential for the system to work, and they are different from incidental elements, (c) Dynamic recycling: the materials and energy in the system do not leave it but instead keep circulating inside it, and (d) Circular connectivity: every element sends materials and energy to other elements in the system and receives materials and energy from them. Chandler and Boutilier (1992) conducted interviews with students 8 to 18 years of age and demonstrated that while such systemic reasoning is related to Piaget's stages of formal operation, it is an independent cognitive domain. Furthermore, other studies have investigated the reasoning in students of different ages. The results of these studies illustrate that students in junior high schools, high schools, and universities do not understand ecosystems as complex systems (Smith & Anderson, 1986).

However, reasoning and its progression in elementary school students, that is to say, the extent to which elementary school students understand ecosystems as complex systems and whether their understanding changes as they progress to upper grades, have yet to be elucidated fully. Given that content knowledge related to ecosystems is important for science education, it can be said that there is a need to incorporate such content knowledge beginning at the elementary school level. This requires building up research focused on the reasoning and its progression in elementary school students. In this study, we will adopt the learning progressions approach discussed below to elucidate elementary schools students' reasoning about ecosystems.

1.2. Learning progressions approach

Learning progressions (LPs) is research-based cognitive models of how learning of scientific concepts and practices unfolds over time (Duncan & Rivet, 2013; National Research Council, 2007). These models start from the prior knowledge learners already have. Research on LPs varies from attempts to find teaching methods that facilitate the progress of learning of scientific concepts and practices using design research methodology to studies that include interviews and surveys to identify the process by which learning of scientific concepts and practices progress in the existing curriculum. Furthermore, the studies cover a wide range of disciplinary areas and concepts like physics (force and motion), chemistry (atoms and molecules), biology (genetics and evolution), astronomy (motion of celestial bodies), and environmental problems (carbon cycle, water cycle, biodiversity) (Alonzo & Gotwals, 2012; Duschl, Maeng, & Sezen, 2011). The common feature among LPs research in all these diverse areas is the attempt to identify 'intermediate steps' in the learning path from the least sophisticated reasoning to the most complex (Duncan & Rivet, 2013). In most cases, these intermediate steps are qualitatively different from the scientific theory that marks the end goal, and they are still incorrect. However, it is more of a productive state that retains ideas related to the steps necessary to understand scientific theories, rather than an unproductive state that retains incorrect ideas. Thus, identifying the intermediate steps is expected to provide valuable suggestions for curriculum and instruction.

Songer, Kelcey, and Gotwals (2009) fuse argumentation and ecosystem content for fourth through sixth grade, and Lehrer and Schauble (2012) developed LPs of ecology and evolution using the modeling practice. However, we only find Hokayem (2012) and Hokayem and Gotwals (2013) who developed a LP for lower elementary students using systemic reasoning. Moreover, there are many LPs research on American and European learners (Alonzo & Gotwals, 2012; Duschl, Maeng, & Sezen, 2011) but hardly any on learners from Asia or other regions (Fulmer, 2014). As it is for the conceptual change research from international perspectives (e.g. Clark, Menekse, Ozdemir, D'angelo, & Schleigh, 2013), we can demonstrate the possibilities for generalization and local endemism for the cognitive model of progress in scientific concepts and practices proposed up till now. This could contribute to the advancement of LPs research in science education on a global scale.

2. Purpose of the study

Our final goal is to build a cognitive model of how reasoning about ecosystems progress using the LPs approach. As the first step towards this goal, the purpose of this study is to elucidate, how the reasoning of students from first through sixth grade at an elementary school in Japan differs across grades. This study is driven by the following research question: How are Japanese first through sixth grade students' reasoning about ecosystems similar or different across grades?

3. Methodology

3.1. Participants

Participants in this study were 12 students, 2 from each grade (1 boy and 1 girl), in first through sixth grade at a Japanese elementary school. The sample consisted of students who had average scores in science or science-related subjects. The students' parents came from the average middle class, which is the most common socioeconomic class in Japan. The elementary school curriculum was based on national curriculum of Japan. The school and students lived in a provincial town surrounded by a relatively rich natural environment.

3.2. Assessment tasks

Following Hokayem (2012) and Hokayem and Gotwals (2013), we used the assessment tasks composed by 13 questions related to four properties: systemic interdependency[†], systemic analysis, dynamic recycling, and circular connectivity. Of the 13 questions, 6 were about systemic interdependency, 2 about systemic analysis, 4 about dynamic recycling, and 1 about circular connectivity.

Table 1 lists the representative questions for each of the four properties. In the question related to systemic interdependency, we asked the students what would happen if a particular living thing (e.g. fox, fish, black bird, grass and tree), with showing a picture of the living things. In the question related to systemic analysis, we asked what the most important thing to save all the living things shown in the picture from extinction was. In the question related to dynamic recycling, we asked how the dead body would change as time passed after the death of a particular living thing (fox, grass, fish, mouse) shown in the picture. In the question related to circular connectivity, we showed the diagram of community probe (Leach, Driver, Scott, & Wood-Robinson, 1995). Afterwards, we asked the students to choose as many living things as they thought could inhabit the environment and to tell us about the relationships among them as well as their relationships with the environment. The students were interviewed individually in science classroom after school hours. The first author was the interviewer, and it took about 30 minutes to conduct each interview. All the responses were recorded using a video camera and IC recorder.

3.3. Analysis

For the analysis, the hypothetical LP proposed by Hokayem and Gotwals (2013) were used as the analytical framework. As shown in Table 2, Hokayem and Gotwals (2013) set five levels of the LP. Level 1, anthropomorphic reasoning, and Level 2, concrete or practical reasoning based on everyday experiences, form the lower levels. Level 3, simple causal reasoning, and Level 4, semi-complex causal reasoning, form the middle levels. The top level, Level 5, deals with complex causal reasoning.

[†] Hokayem (2012) and Hokayem and Gotwals (2013) use the term 'Systemic Interdependence' instead of 'Systemic Synthesis' for the following reason. "Note that the original name by Chandler and Boutilier (1992) for this category was systemic synthesis, but the idea of 'synthesis' may be confused semantically with creating something rather than analyzing the effect of the changing one population of the ecosystem. For this reason I substituted the word synthesis for 'interdependency'" (Hokayem, 2012, p. 6). In this study, the authors use the term 'Systemic Interdependency' based on Hokayem (2012) and Hokayem and Gotwals (2013).

Table 1. The representative questions of each four properties.

Properties	The representative questions
Systemic interdependency	What do you think will happen if all the foxes disappeared?
Systemic analysis	Which organisms or parts of the environment are the most important in keeping this system working?
Dynamic recycling	If the fish died, what do you think will happen to it with time?
Circular connectivity	Imagine an environment in nature and then pick as many of the other pictures as you think is necessary that can be in this environment? Why did you choose the ones you did? Tell me the relations among the pictures or between the pictures and the environment.

Note. Adapted from “Learning progression of ecological system reasoning for lower elementary (G1-4) students,” by H. A. Hokayem, 2012, pp. 131-134. Copyright 2012 by the author.

Table 2. LP levels.

Levels	Explanation of the levels
Level 1	Anthropo-morphic or aesthetic reasoning (Relating reasoning about populations to human feelings or to beauty of nature).
Level 2	Concrete or practical reasoning (Reasoning based on everyday experiences and observations).
Level 3	Simple causal reasoning (Beginning to identify an external mechanism that is related to phenomena).
Level 4	Semi-complex causal reasoning (Reasoning that takes into account more than one external factor affecting phenomena).
Level 5	Complex causal reasoning (Reasoning that considers a network of relations which recognizes the complexity in an ecosystem).

Note. Adapted from “Learning progression of ecological system reasoning for lower elementary (G1-4) students,” by H. A. Hokayem, 2012, pp.48-51. Copyright 2012 by the author.

Table 3. LP levels of the Circular connectivity.

Levels	Explanation of the levels
Level 1	Relating their choice of populations human relations or personal liking of those populations.
Level 2	Relating their choice of populations to being part the nature they see in their everyday life.
Level 3	Relating their choice to the habitat that the populations live in. Relating their choice to a ONE way eating relationship like squirrel eats nuts.
Level 4	Relating their choice to the habitat they live in AND the organisms they feed on.
Level 5	Relating their choice to the network of feeding relationships of populations of the organisms that constitute a food web in the ecosystem.

Note. Adapted from “Learning progression of ecological system reasoning for lower elementary (G1-4) students,” by H. A. Hokayem, 2012, pp.48-51. Copyright 2012 by the author.

All five levels are set for each of the four properties. Out of the four properties, the levels for circular connectivity are shown in Table 3. Level 1 involves deductive reasoning based on anthropomorphism, where the students were required to relate their choice to human relations. Level 2 involves deductive reasoning based on daily experiences and observations of things we see around us every day. Level 3 involves simple causal reasoning, where the students had to relate their choice to either the habitat or predation. Level 4 involves slightly complex causal reasoning, where they had to relate their choice to both the habitat and predation. However, Level 5 involves complex reasoning, where the students had to relate their choice to multiple predator-prey interactions. The transcripts of all interviews were used as the data for analysis. They were analyzed by going back and forth iteratively between the analytical framework and the data, using the qualitative analysis method (Erickson, 1986) to find out whether the ‘interviewees’ responses to each of the 13 questions could be coded into one of the five levels that it matched.

Iterative analysis of this kind is the standard method of analysis used in many LPs studies (Alonzo & Gotwals, 2012). After all coding was complete, descriptive statistics were used to clarify the students’ levels for each of the four properties.

4. Results

Table 4 shows the results regarding 12 interviewees for each of the four properties. Based on the median values, we investigated the grades of the students whose mean values were higher than the median as well as the grades of those whose mean values were lower than the median, for each of the four properties. Then, we divided the students into two groups, a lower grade group comprising students in grades first through third, and an upper grade group comprising students in grades fourth through sixth. After that, we calculated the number of students who had mean values higher, equal to, and lower than the median, respectively, for each level (Table 5). Although there are slight differences between the four properties, the trend this result suggests that the first through sixth grade students’

reasoning differs by grade level; specifically, their reasoning about ecosystems improves as they move to upper grades.

Table 4. Results regarding interviewees for each of the four properties.

Students	Gender	Grade	Mean value of the level			
			SI	SA	DR	CC
a	Male	first	2.5	2.0	2.0	4.0
b	Female	first	3.2	3.5	2.5	4.0
c	Male	second	2.5	1.0	2.8	3.0
d	Female	second	1.8	4.0	2.3	3.0
e	Male	third	3.7	3.0	2.8	4.0
f	Female	third	3.0	1.5	2.8	4.0
g	Male	fourth	4.2	4.0	2.5	4.0
h	Female	fourth	3.7	3.0	2.5	4.0
i	Male	fifth	2.3	3.5	3.0	4.0
j	Female	fifth	2.8	3.5	3.5	4.0
k	Male	sixth	3.2	3.0	2.8	4.0
l	Female	sixth	3.7	3.0	3.3	5.0
Median			3.1	3.0	2.8	4.0

Table 5. Distribution of the results of the early grade and the late grade.

Group	Comparisons with median	SI	SA	DR	CC
Lower grade	Higher	2	2	0	0
	Equal	0	1	3	4
	Lower	4	3	3	2
Upper grade	Higher	4	3	3	1
	Equal	0	3	1	5
	Lower	2	0	2	0

5. Discussion

The results of this study suggested that the first through sixth grade students' reasoning differs by their grade level, specifically, and that their reasoning about ecosystems improves as they move to upper grades.

This result differs from the findings of Hokayem (2012) and Hokayem and Gotwals (2013). Both these studies conducted interviews using the same assessment tasks used in this research, with elementary school students in first through fourth grade at a school in the American Midwest. An analysis of the relationship between grade and level of reasoning revealed that out of the four properties, a relationship could be seen in systemic interdependency but not in the other three properties. These results show that the LP regarding reasoning about ecosystems that Hokayem (2012) and Hokayem and Gotwals (2013) proposed apply not only to American students, but also to Japanese students; and since it can help reveal the country-by-country difference of how reasoning progresses in grades. We can conclude that this LP has the potential to identify students at different levels. We are currently working on analyzing a larger sample to determine the specificities of this LP.

Furthermore, this study also suggests that elementary school students in Japan are capable of reasoning about ecosystems even at a younger age. Although there were differences among the four properties, overall, the elementary school students' reasoning ability increased as they moved from lower to higher ones. This finding suggests that the current learning environment inside and outside schools in Japan has basic functions that help in reasoning about ecosystems, and these will serve as the foundations for future development through changes in the curriculum or other sources of learning.

The next step in the research will be to increase the number of interviewees to strengthen the credibility of the results obtained in this study. Furthermore, as attempted by earlier studies, it is also important to carry out detailed analyses on how the reasoning of each of the four properties is interrelated and how the background of the learners, including their personal experiences and school curriculum, is related to their reasoning.

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