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The Effects on Earth Science Concepts about Seasonal Changes by Generative Learning Strategy

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발생학습 전략의 적용이 계절변화 관련 지구과학개념 변화에 미친 효과

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Abstract: This study was designed to analyze the types of concepts about earth science related to seasonal changes, so as to develop a generative learning model focused on dissolving cognitive conflicts between the aforementioned concepts through debates and using said debates to find out how effectively the model works. There are 100 types of earth science concepts concering seasonal changes, 66 of which are unscientific in nature, including misconceptions. Through a second field trial and a research and development (R&D) process, a test on these concepts was developed, consisting of 14 items. For the experimental group, a four-phase generative learning strategy that reflects the types of earth science concepts and cognitive conflicts between such concepts was developed through pre-analysis and discussion, respectively. On the other hand, a traditional teaching and learning strategy was used for the control group. A meaningful statistic gap found between the two groups through a covariance analysis, the significance level of which was 0.05. This result may be interpreted to mean that the generative learning strategy is a possible alternative for correcting misconceptions about scientific concepts of seasonal changes.

Keywords: misconception, cognitive conflict, concept change, generative learning strategy, traditional learning strategy

요 약: 본 연구에서는 계절 변화에 관련된 개념 유형을 분석하고, 관련 개념들에 관한 토의에 의해 인지갈등을 해소하는 방법을 강조한 발생학습 전략의 적용 효과를 알아보고자 하였다. 계절변화 관련 지구과학 개념 유형은 100가지 였으며, 그 중에서 66가지는 오개념을 포함한 비과학적 개념 유형이었다. 계절변화에 관련된 개념 평가도구는 R&D과정과 2번의 현장검증을 거쳐 개발되었다. 실험집단에는 지구과학개념 유형과 인지갈등을 반영한 4단계의 발생학습 전략을 적용하였다. 한편 통제집단에는 전통적인 교수 학습 전략을 적용하였다. 유의수준 .05에서 공변량분석을 실시한 결과 두 집단 간에는 유의미한 차이가 있는 것으로 나타났다. 이러한 연구 결과는 계절변화와 관련된 오개념을 지구과학적 개념으로 변화시키는 데 발생학습전략이 하나의 가능한 대안이 될 수 있음을 의미하는 것으로 볼 수 있다.

주요어: 오개념, 인지갈등, 개념변화, 발생학습전략, 전통적학습전략

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Introduction

Most science education experts agree that there are two ways of studying scientific concepts: using science process skills, which involves procedural knowledge, and using declarative knowledge. Accordingly, it is but natural to understand science process skills and the characteristics of concepts, and to study alternatives theoretically and substantially so as to be able to teach science and evaluate science education most effectively.

In reality, science teachers and science education experts regard science teaching and learning methods as important and weighted, especially science concepts that are a basic and, in fact, the most important unit in the subject of science.

Traditionally, empiricists have insisted that experience is the only source of knowledge, and that new experiences erase old and existing ones that are carved on *tabula rasa*, and make new conceptions (Strike, 1983). The empiricists therefore thought learners could learn as instructors taught (Gilbert, *et al.*, 1982).

In this view, when we accept the empiricists' idea, there seems to be no problem if we apply a traditional teaching and learning method for the acquisition of scientific concepts of basic units comprising the science subject (Min, 1992).

According to previous researches on learning science concepts, however, despite instructors' good intentions, many learners develop misconceptions that are stable and thus, not likely to be changed by a traditional teaching and learning method and have negative effects on later learning (Min, 1992; Lee, 1998; Kwon, 2000; Hashweh, 1988). Thus, there is an increasing need for alternative teaching and learning strategies.

According to the results of a research on teaching and learning methods based on constructivism, such methods are the best ways to check preconceptions related to learning concepts that learners have and to help them correct their misconceptions, because learners today are regarded as active constructors of science concepts (Kwon, 2000).

It has been reported that one of the best ways to transform misconceptions into scientific concepts is through the cognitive conflict strategy (Kwon, 1989, 1992; Kim, 1991; Park, 1992; Oh, 1998; Niaz, 1995).

Kwon (1997), moreover, pointed out that the philosophical background of cognitive conflicts stems from Popper's falsification, which emphasizes discordant situations of cognitive conflicts; from Kuhn's science innovation theory, which emphasizes cognitive conflict situations; and from Lakatos' research program, which insists that cognitive conflicts alone cannot make change concepts. These suggest that meaningful learning of concepts is possible if learners are given a cognitive conflict situation related to the learning concepts.

Researches on ways to make a cognitive conflict are as follows: Dreyfus, Jungwirth and Eliovitch's (1990) strategy using logical reasoning; Stavy and Berkovits's (1980) strategy using response to quantitative and qualitative tasks; Hyund *et al.*,'s (1994) strategy using experimental observation, reading of materials refuting the theories, and small group debate; Druyan's (1997) strategy using experience, phenomenon observation, and discussion between colleagues; and Lim's (1996) and Park's (1996) strategy using phenomenon observation and logical reasoning.

These researches on misconceptions are divided into three parts: a research on misconceptions that learners have personally, a research on the types and origins of misconceptions, and a research on how to overcome misconceptions (Gil-Perez *et al.*, 1990). In earth science, however, there are few studies on teaching and learning strategies to correct misconceptions (Jeong *et al.*, 1995).

According to the science teaching and learning strategy, if instructors know learners' preconceptions that are related to learning tasks and teach them accordingly, they (i.e., the instructors) can get effective results from the learners (Doran, 1972; Fowler *et al.*, 1987).

Experimental Group	O_1	X	O_3	O_1, O_2 : Pre-test
Control Group	O_2		O_4	O_3, O_4 : Post-test
				X : Generative learning strategy treatment

Fig. 1. Experimental design.

Collection of basic earth science concepts on seasonal changes
↓
Drawing of a concept map
↓
Collection of earth science concepts for a survey
↓
Development of essay-type items
↓
Decision on an earth science concept test
↓ ←Modification and supplementation
Testing
↓
Development of two-tiered, two-to-four-option multiple choice items
↓
Testing

Fig. 2. Procedure for the development of an earth science concept test.

It is thus definitely important to find out what preconceptions learners already have before learning and what concepts they will have after learning (Watts, 1983; Hashweh, 1988).

The final aim of research on this topic, therefore, is to find out preconceptions related to the specific science concepts learners have and to transform misconceptions into correct scientific concepts (Gilbert *et al.*, 1985).

This study analyzes the types of, and reasons for, misconceptions on seasonal changes and finds out how a generative learning strategy focused on cognitive conflict through debates between colleagues affects changes in concepts about earth science.

Methodology

This study, which deals with science textbooks from middle school and science and earth science textbooks from high school, follows this procedure: experimental design and sampling, text analysis by analyzing units that describe the reasons for seasonal changes, development of an earth science concept test related to the reasons for seasonal changes, development and adoption of a generative learning strategy, and pre- and post-test and statistical analysis on concept changes. This methodology is illustrated in greater detail as follows:

Experimental Design and Sampling

To analyze the types of learners' concepts on seasonal changes and the effects of the application of a generative learning model on concept changes, a heterogeneous-group pre- and post-test experimental design was made, as shown in Fig. 1.

Chosen as subjects were 86 boys and girls, each attending high schools in large cities. Of these, 85 (43 boys and 42 girls) were in the experimental group and 87 (43 boys and 44 girls) were in the control group.

Text Analysis

The next procedure was to analyze middle school and high school textbooks that describe the reasons for the phenomena of seasonal changes and present teaching methods and teaching materials. Using text analysis, earth science concepts on seasonal changes were extracted and used as the criteria for an earth

Table 1. Summary of an earth science generative learning strategy.

Phase	Specific Contents
Learning Objectives	· Learners must be able to explain the reasons for seasonal changes in a concrete way. · Learners must be able to tell that changes in the sun's height at its zenith are related to the slope of the earth's rotation on its axis. · Learners must be able to tell that there may be other planets that have seasonal changes, like the earth's.
Preliminary Phase	When learners have preliminary knowledge before learning, learning is more effective. For example, before they learn the reasons for seasonal changes, their teacher must find out their preconceptions. · Which do you think is more related to the phenomenon of day and night: the earth's rotation or revolution? · Why is it cold in winter, and hot in summer in Korea? · Does the diurnal circle change because of the rotation of the earth? · Do you think the sun always rises at the same place?
Focus Phase	In this phase, teachers find out which phenomena appear to be explained with misconceptions. · The earth turns on its ecliptical orbit. With this fact, can you explain the phenomenon that summer comes when the sun is close to the earth and winter comes when the sun is far from the earth? · Can you explain the relationship between the annual parallax of stars with the revolution of the earth? **※Learners' misconceptions on the reasons for seasonal changes (C1)** Seasonal changes are due to the revolution of the earth.
Challenge Phase	*In this phase, learners realize that they cannot explain the expected results scientifically.* Their cognitive conflicts should be generalized into scientific concepts through debate. · Using the concept of the revolution of the earth, can you answer the questions below? - Why does the length of daytime change according to the season? - Why does the height of the sun change according to the season? - On the Northern Hemisphere, when the earth turns on its ecliptical orbit, winter comes when the earth's perihelion is closest to the sun, and summer comes when the earth's aphelion is farthest from the sun. Why? - Can you explain why summer is hotter than winter on the Northern Hemisphere using only the concept of the earth's revolution? **※New conception (C2)** Seasonal changes are phenomena caused by the revolution of the earth, which rotates on its axis at an angle of 23.5° as it revolves around the sun.
Application Phase	In this phase, learners' scientific concepts are reinforced onto their cognitive structure. · If the axis of rotation of the earth were to meet its plane of revolutionary orbit, would seasonal changes be possible on earth? · Do you think there are other planets in the solar system besides the earth that have seasonal changes? · If you there are, explain why, concretely.

science concept test and for the development of a generative learning strategy.

Development of an Earth Science Concepts Test

An earth science concept test was developed in this study using Borg and Gall's R&D (1983). Fig. 2 shows the procedure for such test.

The earth science concept test consists of 14 two-tiered, two-to-four-option multiple choice items. Learners had to choose one item and describe the reason for their choice.

Development and Adoption of the Generative Learning Strategy

The generative learning model presented by Osborne and Freyberg (1985) has four phases: the preliminary phase, the focus phase, the challenge phase and the application phase. This generative learning model was based on the information processing approach to the human cognitive process and focuses on the fact that a human being, as an active constructor, can transform an existing concept into a new concept spontaneously with the help of his experience and the information he possesses (Jeong *et al.*, 1998). Based on this model, a summary of an earth science generative learning strategy developed in this study is shown in Table 1.

Teaching and learning plans for the generative learning model were developed for four periods, each of which describes the teaching and learning activities appropriate to each phase, as Table 1 shows. The generative learning strategy was applied to the experimental group and the traditional learning strategy, to the control group.

Pre- and Post-tests

The earth science concept test developed in this study was administered to an experimental group and a control group. By analyzing the results, the types of and reasons for misconceptions were found. They were then used as the criteria for developing a generative learning strategy.

Later, the same type of concept test used in the pre-test was again administered to the experimental group and the control group. By analyzing the degree of concept change, the effect of the generative learning strategy was verified.

Statistical Analysis of Concept Changes

To determine how effectively the generative learning strategy works on earth science concept changes, a covariance analysis was performed using SPSS-WIN 10.0 (Windows Version), according to group, gender and total.

Results and Discussion

The types of earth science preconceptions on seasonal changes and the degree of concept changes determined from the test developed in this study are as follows:

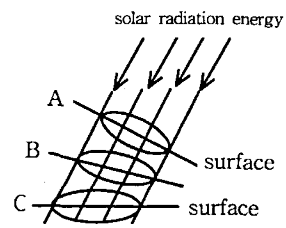
Development of an Earth Science Concept Test

This test was designed to extract earth science concepts about seasonal changes from learners. It consists of 14 items. Item 12 is shown below.

Item 12. Which point corresponds to summer in the picture?

① A
② B
③ C

∴ Why?



Earth science education experts and astronomers have verified the development of the test, and two field trials were performed to verify the conditions of such test. The reliability of the test (K-R 20) was found to be 0.70, its discrimination index, 0.38, and its answer ratio, 40.1.

Types of Learners' Preconceptions

Before the generative learning strategy is applied, the types of preconception that learners have must be known. As such, 43 boys and girls, each attending first year high school, were tested. Table 2 shows an analysis of the results of such tests.

Table 2 shows that there are 44 types of scientific understanding descriptions and that 66.2% of the learners had scientific concepts. Of the 100 types of earth science concept about seasonal changes to the 14 items, there were 56 types of unscientific understanding.

There are several reasons behind an unscientific understanding of seasonal changes. First, learners do not have a cognitive structure, which makes them judge and describe unstably according to the situation, as when they answered "It is continually day on half of the earth and continually night on the other half" in Item 4. This type of response can be found in other items. Second, learners tend to generalize unscientific concepts that they get through experience into scientific ones. For example, they answered "Because the sun comes closer to the

Table 2. Concept types per item.

Item No.	Stem	Degree of Understanding			
		Scientific Understanding	%	Unscientific Understanding	%
1	Why is summer hot?	· There is more solar radiation energy on a given area. · Because of the earth's revolution, there is more incidence energy. · Because of the slope of the axis of the earth's rotation · The sun is higher at its zenith.	69	· The sun is too close to the earth. · There is more radiation energy from the sun. · Due to the different amounts of incidence energy according to the rotation of the earth · Due to the effect of the North Pacific's high pressure	31
2	Why do seasons change?	· Because the sun's height at its zenith changes · The radiation energy that an area receives from the sun changes according to the area's latitude. · Because the earth's axis of rotation is sloped	67	· Because the distance between the sun and the earth changes · Because the amount of radiation energy from the sun changes due to the rotation of the earth · Because of the revolution of the sun	33
3	Will the length of days and nights change if the earth were to cease to rotate on a tilted angle on its axis?	· The length of days and nights will not change because the sun's height at its zenith will be the same all year round. · There will be no change because an area will receive the same amount of radiation energy according to its latitude. · If the earth were not to revolve, daytime would be fixed and the length of days and nights would not change.	75	· Days will be as long as nights. · The earth's rotation causes changes in the length of nights and days. · Days and nights will continue. · The slope of the earth's rotation on its axis determines the length of days and nights.	25
4	If the earth were to just revolve vertically on its axis, will the length of days and nights change?	· Days and nights will be longer. · The length of days and nights will be the same. · It will be day in half a year and night in the other half. · The slope of the earth on its axis as it rotates and revolves changes the length of days and nights.	52	· The revolution of the earth causes seasonal changes. · The length of days and nights is related to the earth's rotation. · Radiation energy from the sun will stay the same at any given area according to the area's latitude. · The height of the sun is fixed. · There will be no distinction between day and night. · Half of the earth will experience day, and the other half, night.	48
5	If the earth were to revolve and rotate just vertically on its axis, will seasons change?	· Radiation energy will be the same at any latitude. · The sun's height at its zenith will be the same. · Monthly average temperature will not change at any latitude. · There will still be climatic zones according to latitude.	59	· Only summer and winter will occur. · Seasons will change for as long as the earth revolves and rotates on its axis, regardless of the slope of its revolution and rotation. · Seasons will continue to change whenever the distance from the sun changes because of the revolution of the earth. · Seasons will still change because the amount of solar energy in an area will still differ according to the area's latitude.	41
6	Should the earth revolve and rotate on a vertical axis, will the tropics be different from the arctics?	· Climatic zones will be distinctive. · The latitudinal distribution of climatic zones will change slightly. · They will be different because the tropics and the arctics get different amounts of radiation energy per unit area according to their latitude. · The slope of earth's rotation on its axis is not related to climate.	71	· Since there will then be no seasonal changes, there will be no climatic zones. · Since they will get the same amount of solar radiation energy, there will be no difference in their climates. · Since there will be no seasonal changes, there will be no climatic zones. · Since there will be no slope in the earth's rotation on its axis, there will be no difference in the climates of the two areas.	29

Table 2. Continued.

Item No.	Stem	Degree of Understanding			
		Scientific Understanding	%	Unscientific Understanding	%
7	At what latitude on the earth does the sun give the most radiation energy?	· Low-latitude areas get more energy per unit area than do high-latitude areas. · The sun is highest at its zenith at low-latitude areas. · Radiation energy passes through the shortest atmospheric distance at low-latitude areas.	84	· High-latitude areas are hottest because bigger areas get energy. · The sun is high at its zenith and the amount of solar radiation energy is less in low-latitude areas.	16
8	When day is at its longest on the Northern Hemisphere, where is the earth on its revolutionary orbit?	· B gets the most radiation energy. · It is B, because the Northern Hemisphere is tilted towards the sun. · Day is long at B because the sun is at its highest there at its zenith. · Since B has more time to get radiation energy from the sun, day is long there.	70	· It is summer at D because it is the closest to the sun. · It is summer at C because it is the closest to the sun, such that sunlight is directly above the Northern Hemisphere. · It is summer at B because the distance between the earth and the sun is longest thereat and the sun shines on the largest surface thereat.	30
9	Does the place where the sun rises and sets cause changes in the sun's height when it is at its zenith?	· The place where the sun rises changes because of the slope of the earth's rotation on its axis and because of the earth's rotation and revolution. · The place where the sun rises causes changes in the sun's height at its zenith. · The place where the sun rises affects the length of day and night.	63	· The earth's revolution changes the height of the sun, so that the sun's height is related to the place where it rises. · The sun's height at its zenith changes only due to the earth's revolution and rotation. · The earth's rotation has an effect on the place where the sun rises. · The distance between the sun and the earth is related to the sun's height at its zenith. · The distance between the sun and the earth is not related to the sun's height at its zenith, but is due, rather, to the slope of the earth's rotation on its axis.	37
10	What happens to the temperature of the ground when the sun's height at its zenith increases?	· The area of the ground receiving solar radiation energy increases. · The energy per unit area increases. · The time when the area receives sunlight becomes longer and longer. · The sunlight's incidence angle becomes larger. · The distance through which sunlight passes through the atmosphere shortens.	68	· When the sun's height at its zenith increases, the amount of energy decreases, because the sun is far from the earth. · The ground's temperature is always the same due to radiation equilibrium. · The ground's temperature is regular, without any relation to the sun's height at its culmination. · When the sun's height at its zenith increases, the ground's temperature goes up since the sun is close to the earth.	32
11	Is a day longer the higher the sun is at its zenith?	· The rising time of the sun on the horizon becomes longer. · The diurnal circle becomes bigger. · Daytime is longer.	74	· Daytime becomes longer because the area widens due to the slanted light. · Whenever daytime is longer, the distance between the sun and the earth is closer. · The day is longer because the temperature of the sun goes up. · The sun's height at its zenith does not affect the length of daytime.	26

earth" in Item 1, "The earth's distance from the sun differs because of the earth's revolution" in Item 5, and "It is summer at C because it is the closest to the sun and the sun shines above the Northern Hemisphere" in Item 8, which are major types of unscientific concepts. Third, learners would not assimilate concepts that they get through experience into new knowledge, as when they answered

Table 2. Concept types per item.

Item No.	Stem	Degree of Understanding			
		Scientific Understanding	%	Unscientific Understanding	%
12	At what degree is an incidence angle in summer?	· A big incidence angle corresponds to a significant amount of energy per unit area.	71	· The answer is A, because it is closest to the sun. · Part C is the hottest because its width allows it to receive more sunlight. · It is summer at A because it receives solar radiation energy the most widely. · B and C are the hottest because they are almost perpendicular to the sun.	29
13	Is it possible to explain a constellation change only by means of the earth's rotation and revolution, without relating it to the earth's tilt on its axis during its revolution?	· A constellation change is an evidence of the earth's revolution and is not related to the earth's tilt on its axis when it rotates.	64	· A constellation change should be considered due to its peculiar motion. · Apart from the motion of the earth, there is another reason for a constellation change. · A constellation change can be explained only by the phenomenon of the earth's rotation. · A constellation change is impossible to explain without an assumption on the earth's tilt on the axis of its rotation.	36
14	Is there any planet in the solar system that has seasonal changes?	· There are some planets that are tilted on their axis as they rotate and revolve. · Planets that moves the same way the earth does have seasonal changes.	40	· Seasons change because the earth is tilted as it rotates on its axis. · Seasons change because the earth is tilted as it revolves on its orbit. · Seasons change because the earth rotates and revolves. · Where there are no living things, there are no changes in seasons. · Where there is air and water, seasons will change.	60

"Because of the effect of the North Pacific's high pressure" to the question "Why is summer hot?". Fourth, because of learners' lack of thinking ability, they cannot apply their knowledge scientifically, as when some students answered "When the sun revolves, seasons change" in Item 4 and "When the sun has just revolved, the length of days and nights doesn't change" in Item 5. This last happens because learners cannot connect seasonal changes with changes in the length of days and nights. Fifth, learners misunderstand the picture. Most types of unscientific understanding, as shown in Items 7 and 12, stem from intuitive thinking, a tendency of learners to interpret a picture as they see it.

Changes in the Concepts Ratio according to Group, Sex and Item after the Application of a Generative Learning Strategy. Table 3 shows the changes in the concepts ratio according to group, sex and item after the generative learning strategy was applied.

As in Table 3, there were no meaningful gaps in earth science concept changes according to sex ($p<.05$). Figures 3 and 4 show the differences between the groups and sexes before and after the generative learning strategy was applied.

Figures 3 and 4 show the gap in the scientific concepts ratio: the average of the experimental group is 16% (male, 18% and female, 14%) and of the control group, 11% (male and female, 11%). In addition, the scientific concepts ratio gap was almost similar before and after the generative learning strategy was applied: male, 13.9% and female, 13.1%. After the application, however, female achievement was higher by 3% than that of the males. In Item 2, "The reason for seasonal changes," female achievement was higher by 5.1%. In Item 10, "The

Table 3. Pre- and post-scientific concepts ratio according to group, sex and item.

ItemNo.	Content	Male				Female				p
		Exp. Group		Cont. Group		Exp. Group		Cont. Group		
		Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	
1	The reason for the heat of summer	57.5	72.5	52.0	65.2	52.3	72.7	57.1	66.7	
2	The reason for seasonal changes	47.5	62.5	65.2	67.4	47.8	65.9	62.0	71.5	*
3	The changes in the length of days and nights due to the earth's rotation and the slope of the axis of its rotation	55.0	70.0	60.9	69.6	68.2	77.3	76.2	83.3	
4	The changes in the length of days and nights due to the earth's vertical axis of rotation and revolution	45.0	52.5	32.6	43.5	50.0	61.4	42.9	50.0	
5	The changes in seasons due to the earth's vertical axis of rotation and revolution	47.5	65.0	45.7	54.3	36.4	56.8	54.8	61.9	
6	The earth's vertical axis of rotation and the distribution of climatic zones	45.0	67.5	60.9	71.7	54.5	72.7	66.7	73.8	
7	The amount of solar radiation energy according to latitude	77.5	87.5	78.3	82.6	68.2	81.8	76.2	83.3	
8	The position of the earth on its revolutionary orbit	52.5	75.0	52.2	67.4	50.0	70.5	52.4	69.1	
9	The position of the sun at its rise and its height at its zenith	27.5	67.5	28.3	56.5	43.2	72.7	26.2	54.8	
10	The sun's height at its zenith and the temperature of the ground	47.5	70.0	52.2	63.0	68.2	77.2	54.8	61.9	*
11	The sun's height at its zenith and the changes in the length of days and nights	60.0	72.5	63.0	67.4	68.2	79.6	69.0	76.2	
12	The latitude of the sun according to the season	70.0	77.5	54.3	65.2	54.5	75.0	54.8	64.8	*
13	The motion of the earth and constellation changes	55.0	67.5	47.8	54.3	63.6	68.2	57.1	64.3	
14	Seasonal changes on planets	17.5	40.0	21.7	34.8	27.3	45.5	26.2	38.1	
Total	50.4	67.7	51.1	61.6	53.7	69.8	55.4	65.6		

The number of each cell reveals the ratio of the scientific concepts of all the respondents. *$p < .05$

relationship between the sun's height at its culmination and the temperature of the ground," male achievement was higher by 8.5%. Finally, in Item 12, "The latitude of the sun according to the season," female achievement was higher than that of the men by 5.8%.

Changes in the Concepts Ratio after Treatment with a Generative Learning Strategy

Table 4 shows all the changes in the scientific concepts before and after the application of the generative learning strategy.

Table 4 and Figure 5 show that the ratio of scientific concept changes by treatment increased by 16.4% to 68.8%, in the experimental group, and by 10.5%, from 53.1% to 63.6% in the control group. Covariance analysis, which was used to test the difference between these two groups, proved that there was a meaningful difference.

These results can thus be interpreted to mean that the generative learning strategy is more effective than the traditional teaching and learning method on earth science concept changes in relation to seasonal changes.

Conclusion

This study developed a test of earth science con-

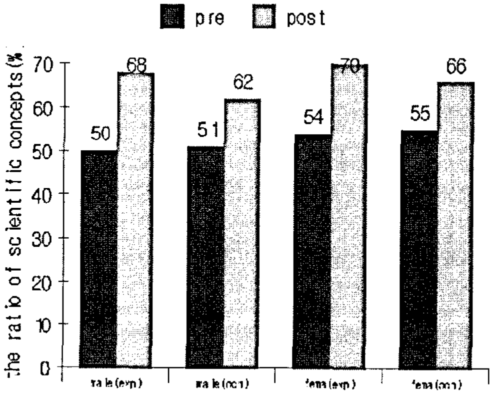


Fig. 3. the group gap by treat (total).

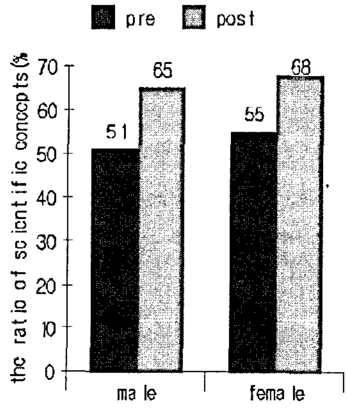


Fig. 4. the sexual gap by treat (total).

cepts on seasonal changes through an R&D process. The test was made up of 14 two-tiered, two-to-four-option multiple choice items. The test was applied to a first field trial to get learners' responses. On the basis of this first field trial, types of conceptions were analyzed and a generative learning strategy was developed. The effects of such generative learning strategy on changes in earth science concepts was analyzed, and the following conclusion is hereby made.

First, there are 100 types of earth science concept about seasonal changes, 44 of which, or in other words, 66.2% of the responsers, are scientific concepts and the rest, misconceptions.

Table 4. Total ratio of pre- and post-scientific concepts.

Item No.	Content	Exp. Group (N=85)		Cont. Group (N=87)		p
		Pre-	Post-	Pre-	Post-	
1	The reason for the heat of summer	54.8	72.6	54.5	65.9	*
2	The reason for seasonal changes	47.6	64.3	63.6	69.3	***
3	The changes in the length of days and nights due to the earth's rotation and the slope of the axis of its rotation	61.9	73.8	68.2	76.1	
4	The changes in the length of days and nights due to the earth's vertical axis of revolution and rotation	47.7	57.1	37.5	46.6	
5	The changes in seasons due to the earth's vertical axis of rotation and revolution	41.7	60.7	50.0	58.0	**
6	The earth's vertical axis of revolution and the distribution of climatic zones	50.0	70.2	63.6	72.7	**
7	The amount of solar radiation energy according to latitude	72.6	84.5	77.3	83.0	*
8	The position of the earth on its rotational orbit	51.2	72.6	52.3	68.2	*
9	The position of the sun when it is rising and its height at its zenith	35.7	70.2	27.3	55.7	*
10	The suns's height at its zenith and the temperature of the ground thereat	58.3	73.8	53.4	62.5	*
11	The sun's height at its zenith and the changes in the length of days and nights	64.3	76.2	65.9	71.6	*
12	The latitude of the sun according to the season	61.9	76.2	54.5	64.8	
13	The movement of the earth and constellation changes	59.5	67.9	52.3	59.1	
14	Seasonal changes on planets	22.6	42.9	23.9	36.4	*
	Total	52.4	68.8	53.1	63.6	*

The number of each cell reveals the ratio of the scientific concepts of all the respondents. *p<.05, **p<.01, ***p<.001.

Second, major types of misconceptions stem from learners' lack of structured cognition of spatial concepts, which makes their judgment unstable according to the situation; their tendency to generalize misconceptions that they get through experience into scientific concepts; their resistance to assimilating concepts that they get through experience into new knowledge; and their inability to analyze their own knowledge such that their intuitive thinking disturbs their interpretation of pictures.

Third, the test results on the treatment of the generative learning strategy showed a 16.4% increase in the experimental group and a 10.5% increase in the control group. Statistically, there was a meaningful difference, according to the covariance analysis, the significance level of which was 0.05. This suggests that the generative learning strategy developed herein can be a meaningful alternative to acquiring earth science concepts on seasonal changes.

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