Development of an Effective Strategy to Teach Evolution

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Abstract: This study proposes a new instructional strategy and corresponding materials designed from various alternative frameworks to help students understand evolution as a biologically acceptable theory. Biology teachers have normally taught the evolutionary mechanism by means of comparing Lamarckism with natural selection. In this study, a new instructional strategy in which the Lamarckian explanation is first excluded because Lamarckism is known to be subsumed in a learner's cognitive structure as a strong preconception of evolution is suggested for teaching evolution. After mutation theory is introduced, Darwinism including natural selection is explained separately during the next class hour. Corresponding instructional materials that aid student understanding of the evolutionary mechanism were developed using recently published articles on human genetic traits as scientific evolutionary evidence instead of the traditional evolutionary subject matter, giraffe neck. Evolutionary evidence from human genetic traits allows students to exclude anthropocentric thoughts effectively and raise concern for the phenomenon of evolution positively. The administered instructional strategy and materials in this research improved student conception, concern, and belief of evolution and it is believed that they helped students understand the evolutionary mechanism effectively.

Key words: biology education, evolution, Darwinism, Lamarckism, instructional strategy, 5E learning cycle model

Ⅰ. Introduction

Evolution has been used to explain the diversity of life and the ultimate cause of life phenomena (Mayr, 1997) and is recognized as a central concept in biology education (Kennedy *et al.*, 1998; Rutledge & Mitchell, 2002). NSTA has emphasized its necessity in the biology curriculum (NSTA, 2003), and it is also recognized as an important concept emphasized in the biology section of NSES (NRC, 1996). These reasons have compelled the biology curriculums in most countries to set evolutionary theory as a fundamental concept in biology (Swarts *et al.*, 1994).

In addition to the importance of teaching evolution according to a biological view, it is essential to recognize that students' conceptions of evolution are diverse and strong. Many studies on students' conceptions of evolution have shown that students did not explain the evolutionary mechanism as natural selection after mutation but as creationism, teleology, or Lamarckism (Bishop & Anderson, 1990; Brumby, 1984; Settlage, 1994; Sinclair *et al.*, 1997; Ha *et al.*, 2006). Present day scientific view recognizes the evolutionary mechanism as natural selection after mutation (Mayr, 1997).

Many science teachers have utilized various instructional strategies and developed instructional materials to help students replace their alternative conceptions of evolution with scientific ones. Among them, there are the constructivist strategies which focused on the conceptual change theory (Bishop & Anderson, 1990; Demastes *et al.*, 1996; Jensen & Finley, 1995; Jimenez-Aleixandre, 1992; Smith, 1994), instruction based on inquiry (Demastes *et al.*, 1995; Settlage, 1994) and instruction based on the history of science (Jensen & Finley, 1996). To change students' concepts of evolution, those instructional strategies were focused on a change from Lamarckism - a typical alternative conception - into Darwinism. Some studies provided successful outputs (Bishop & Anderson, 1990; Jensen & Finley, 1995). However, unlike conceptual change strategies, Demastes *et al.* (1996) maintained that inquiry was more

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efficient for student comprehension of evolution than use of a conceptual change strategy. Research on instruction based on inquiry focused on role-play (Duveen & Solomon, 1994) or inquiry skills (Hilbish & Goodwin, 1994). Because awareness of the change process pattern of the evolution concept as learnt from the history of science was similar to the change procedure of individual conceptions, research also found teaching strategy based on the history of science to be effective (Jensen & Finley, 1995). Hence, each strategy for teaching evolution has unique merit, and generally, the common aim of these strategies for teaching evolution has been to ease student understanding of evolution.

Instructional material for teaching evolution, on the other hand, has not been researched as much as instructional strategy. Few studies consider the effects of teaching evolution via the usage of special material. Ha *et al.* (2006) claimed that student conceptualization patterns regarding evolution differed according to instruction on three kinds of subjects: humans, animals, and plants. Additionally, Thanukos (1999) found that students differed on beliefs in and truths on evolution according to instruction using teaching materials for the same three subjects.

Evolution, the core concept of life science, has many alternative conceptions posited in students' conceptual structure, and as such, effective instruction for evolution is needed. The main purpose of this paper is to present instructional strategy and corresponding teaching materials that can apply the idea of evolution efficiently.

The rationales of teaching strategies for evolution

Research on the teaching of the evolution theory to students has shown that students have difficulty learning the scientifically proper concept of evolution (Demastes *et al.*, 1995) because teachings have failed to change students' alternative conceptions of evolution into the present-day accepted scientific concept. As Ha *et al.* (2006) reported, it is possible to change student conceptions of evolution from teleology into Lamarckism (the theory of use and disuse). The study was based on a sample of 1,540 elementary, junior high and high school students. This research, as a result, proposed the necessity for a proper strategy to teach evolution. Although the Korean science curriculum emphasizes that a belief in Lamarckism is incorrect and students have surely absorbed the idea, many Korean students still posses other alternative conceptions of which include Lamarckism. Ha *et al.* (2006) analyzed this phenomenon as being a result of that their alternative conceptions of evolution were removed perfectly by preexistent instruction of evolution. Consequently, previous research has emphasized that effective instruction of evolution should focus on the removal of students' alternative conceptions of evolution such as Lamarckism before actual classes on evolution. Once the alternatives are removed perfectly, teachers should then focus on 'the theory of natural selection after mutation'. Ha & Cha (2007) also found a regression phenomenon in evolution conceptions when they researched the evolution conceptions of biology teachers and college students who were learning biology according to the college curriculum. Unlike the conceptions of college students, many biology teachers had alternative conceptions of evolution. Biology teachers who should have expressed a scientifically proper evolution conception regressed to alternative conceptions. Brumby (1979) suggested that Lamarckism obstructed students' proper learning of Darwin's evolution theory. The common interpretations of this and other research is that Lamarckism presents a stumbling block to the correct learning of the scientific concept of evolution. This study suggests a new instructional strategy of evolution that focuses on an exclusion of Lamarckism from students' cognitive structure in concurrence with a focus on teaching the scientifically proper conception of evolution. An important thing is containing processes to remove successfully students' alternative conceptions of evolution before teaching the scientific concept of evolution in the curriculum. As a new instructional strategy for evolution, its key lies in the exclusion of Lamarckism from the cognitive conflict. A cognitive conflict strategy which is effective at conception change has been shown to be useful for learning the scientific concept of evolution (Bishop & Anderson, 1990; Jensen & Finley, 1995).

The evolution content of biology textbooks in many countries usually compares Lamarckism and Darwinism (Swart *et al.*, 1994). However, the instructional strategy of comparing Lamarckism and Darwinism centre on the teaching of Darwinism rather than on strengthening cognitively the learning of Lamarckism. Ha & Cha (2007) assert that Lamarckism and Darwinism are not adopted as opposing concepts. The results of their research, which investigated the evolution conceptions of college students and biology teachers, showed an alternative conception: 'natural selection after individual variation' after an analysis of interviews. A number of research subjects expressed the thought: 'are developed living things, which have used particular organs, not repeatedly selected?' This alternative conception combines both Lamarckism and Darwinism. Research subjects did not comprehend that if Lamarckism was correct, Darwinism was wrong, and vice versa. Although the desired outcome for instruction of evolution via a comparison of Lamarckism and Darwinism was for students to learn Darwinism and remove Lamarckism, the comparison assisted students in formation of the new alternative conception, 'natural selection after individual variation'.

On the contrary, other interview analysis research has shown subjects form a relationship between mutation and Lamarckism. In these studies, a number of research subjects said to the researchers, 'if phenotype is changed as an organ is used repeatedly, does it influence the organ's gene?' Researchers, upon discovery of this relationship have strongly suggested that the Lamarckism conception, 'changed character after repeated usage', and the mutation conception, 'sudden gene change' must not be mixed. According to modern science, if an organ is frequently used and its phenotype is changed, genes should not change; that is, evolution does not occur. This finding suggests students have cognitive conflict about whether only using repeatedly can evolve or changed gene need to evolve. Therefore, the theory of mutation is more useful as an opposing concept to Lamarckism than Darwinism from the natural selection theory. Settlage (1994) proposed that the conception of mutation should exist in conceptions held by students who gave up Lamarckism. Contra positively, it is possible to purport that if one did not understand mutation, one did not give up Lamarckism. Settlage (1994) also claimed that teachers should be continuous of strengthening students' alternative conceptions by adamant introduction of mutation; in other words, teachers must only introduce the concept. Based on discussion from these prior studies, Lamarckism was only considered in the teaching of the evolutionary hypothesis because of the history of science. Thus, it should be excluded, which will enable the concept of mutation to be used as an important factor in the teaching of evolution.

To exclude Lamarckism, teachings need to compare Lamarckism and the theory of mutation and present discordant cases about Lamarckism rather than compare Lamarckism and Darwinism. To explain, take instruction related to the human brain evolution. Assume that the teacher plans to teach about human brain evolution by starting with the question, "Why does the human brain develop faster than the brain of other primates?" The teacher might follow this with the following two questions: 'Does the human brain develop when it is used often?' or 'Is human who have big brain selected?' If students generate the conception of 'humans who use their brain repeatedly were selected', Lamarckism is known to be active in students' cognition. On the contrary, if the teacher had started the class with 'Does the human brain develop when it is used repeatedly?' or 'Can humans who have a well-developed brain suddenly appear?' students would not have confused the two questions and sided with one of the two ideas. These two different scenarios can be inferred because they are related to different character generation. Lamarckism is related to an acquired character and mutation is related to an inherited character.

In this regard, new instruction for evolution which takes into consideration students' comprehension will not involve traditional instruction concerning evolution; i.e., the comparison of Lamarckism and Darwinism but compare Lamarckism and mutation. Once students comprehend inherited character, teachers should discuss Darwinism, a concept of natural selection. To prevent students from solidifying the Lamarckism conception in their cognitive structure and to aid in effective generation of cognitive conflict, teachers should illustrate evolutionary cases to students by explaining mutation not by explaining Lamarckism continuously.

Human materials or human evolution materials are presumed by this study to be the best instructional materials for teaching evolution. Moreover, among them, articles on human evolution based on mutation published in famous science journals recently are considered the best. It is presumed that this material originates with anthropocentric thoughts of, interests in, and beliefs of evolution. Additionally, humans are also living things which developed through the process of evolution alike other living things such as animals and plants. That is to say, humans never developed through a mechanism that differed from other living things (Mayr, 1997). However, students' concerns about, opinions of, and conceptions of human evolution differ from other living things. Thanukos (1999) suggests that it is likely student evolutionary belief and thought differ in terms of subject matter – humans, animals, and plants. For the case of explaining evolutionary mechanism as it relates to human evolution, it is possible for students to conflict creationism with the evolution theory. Actually, according to Thanukos' results, acceptance of the evolutionary explanation by students differed in terms of subject matter.

Bizzo (1994) researched the sources of evolution conceptions held by several students. According to the results, students typically replied with 'the process of becoming human from an anthropoid...' to the question 'What is evolution?' because 'human' is at the center of students' evolution conception. Bizzo conjectured that this finding was the direct result of anthropocentric thoughts and presented plants as examples. The alternative conception "evolution can occur if there is driving will", is deduced more often when plants are used as explanatory subjects than when humans or animals are used. In other words, when plants are used as explanatory subjects of evolution, students formulate an alternative conception ? 'plants do not have internal will and as such are passive', which results in the generation of a different student point of view about evolution change from that of humans and animals. Students explain plant evolution differently from humans and animal evolution.

Ha *et al.* (2006) researched student explanation of evolution and found there were numerous connections to Lamarckism in students' explanations of human evolution and students were more concerned with human evolution than animal or plant evolution. The results of Ha & Cha (2007) showed that most students' evolution conceptions were constructed by incorporating the human evolution theory. They pointed to student anthropocentric thoughts as the cause of these constructions. It is abnormal for students' anthropocentric thoughts to have special conceptions and opinions about the evolution theory. Misconceptions about human evolution influence students' evolution conceptions of other living things. For these reasons, it is crucial to teach the notion that humans evolve according to the same mechanism as other living things. In order to do this, it is necessary to use human evolution as the material for evolution instruction. It is hypothesized that if human evolution materials are used in evolution lessons, anthropocentric thoughts of evolution would disappear and students would formulate a similar conception of evolution for humans, animals, and plants.

Another advantage of the usage of appropriate human evolution materials is that teachers could spark more interest from students in the evolution theory. Interest in human evolution is higher than others because human evolution is published in famous science journals (Besterman & La velle, 2007). In fact, articles on the evolution of the human brain and jaw, which students normally explain via Lamarckism, are published in *SCIENCE* (Mekel-Bobrov *et al*., 2005) and NATURE (Steadman *et al*., 2004). The articles establish the origin of present primates' brains and jaws based on mutation, not an acquired character. Because formulation of an evolutionary conception is correlated with faith (Sinatra, 2003), when teachers show students recently published evolutionary materials based on molecular biology, students will be more likely to trust the evolution theory. This additional merit will be beneficial for students who harbor a strong mistrust of the evolution theory. Grose & Simpson (1982) found that about 24% of American college students did not believe the evolution theory. Similarly, research related to the nature of the evolution theory by Dagher & Boujaoude (2005) who interviewed 15 college students showed that a number of the students did not have any strong conviction about the evolution theory. Evolution instruction which revolves around inappropriate unconcerned material and unreliable data cannot raise students' cognition conflict, change conceptions, and develop concern and opinion about the evolution theory.

Accordingly, human evolution materials are very appropriate for the instruction of evolution. Human evolution materials used in the instruction of evolution would ease teachers struggle to overcome anthropocentric thoughts which prohibit students from formulating correct conceptions of evolution and increase student interest in the evolution theory.

The development of evolution instruction

The new instruction for teaching evolution effectively requires a total of four lesson hours, and the lessons focus on cognitive conflict strategy by excluding Lamarckism and applying recently published human evolution materials (Table 1). The reason why this new instruction is composed of 4 lesson hours is that evolution is generally taught over a 4 hour lesson plan period in Korea. These evolution lessons are outlined in the table below. The present teaching modules were discussed and modified by a Ph. D student in biology education degree and an inservice biology teacher.

The first class hour is taught with activities aimed at helping students understand the evolution concept generally by addressing typical student misconceptions of evolution. Moreover, with special regard to research conducted by Ha & Cha (2006) concerning the influence of television animation programs on student evolution conceptions; i.e., the misunderstanding of 'metamorphosis' to be evolution, activities directed at correcting the influence were included. In the second class hour, a cognitive conflict strategy is implemented, which excludes Lamarckism and directs students towards learning a scientifically proper evolution concept. This hour strengthens students' cognitive conflict through activities that are not explained by Lamarckism, but by activities involving a picture of Arnold Schwarzenegger's sons, a picture of the result of a double eyelid operation,

Table 1
Goals, teaching strategies and materials to teach about evolution organized in modules

Class hours \ Content	Goals	Teaching Strategies	Materials
First hour: What is evolution?	General understanding of evolution	Presenting the scientific evolution concept after confirming students' preconceptions to be typical evolution misconceptions	– Picture of human skulls – Picture of human jawbones – TV animation characters – Picture of various human species – Picture of Scala Natura
Second hour: Development of the human brain; sudden mutation?	Understanding that a new appearance characteristic is caused by sudden mutation	Presenting discord examples and mutation examples of human evolution to exclude Lamarckism	– Human brain evolution (Mekel-Bobrov *et al.*, 2005) – Human jaw evolution (Steadman *et al.*, 2004) – Arnold Schwarzenegger's physique and his sons – Picture of the result of a double eyelid operation – Weismann's rattail experiment
Third hour: Gene selected by nature	Understanding that only a fitted individual in an environment is alive	Presenting three examples of natural selection	– Industrial melanism – Saussurea laniceps' evolution (Law & Salick, 2005) – Antibiotic-resistance bacteria appearance
Fourth hour: Viewing living things via present-day evolution theory	Explaining the characteristic of living things via the principle of natural selection after mutation	Explaining the various characteristics of living things by applying present-day evolution theory	

and a presentation of Weismann's rattail experiment. Also included in this hour are recent research articles related to mutation; especially, the study about the origin of the human brain by Mekel-Bobrov *et al.* (2005) published in *SCIENCE*, the study about the origin of the human jaw by Steadman *et al.* (2004) published in *NATURE*. These publications will stimulate students' cognitive conflict.

Natural selection is evolutionary explanation by Darwin is included in the third class hour. Instead of the typical comparison of Lamarckism with Darwinism, evolutionary examples as seen from the natural selection phenomena, based on Darwinism, are presented independently in this class. Since research has shown students to have difficulty understanding Darwinism as a reasonable explanation for evolution, for instance the well-known studies of black moth by Kettlewell, additional supplementary research materials from recent biology studies were collected to provide proof of Darwinism. Evolution of *Saussurea laniceps*, published in PNAS by Law & Salick in 2005, and exemplary antibiotic-resistance bacteria photos were selected as these supplementary instructional materials.

In the fourth and last class hour, students are required to explain the diverse characteristics of living things by natural selection after mutation. Activities contained in this last lesson raise students awareness for the reason why teleology and the internal will of living organisms cannot explain evolution. Each class hour follows the 5Es learning cycle model which is an effective model for implementing the constructive concept change instructional strategy (Llewellyn, 2002).

Ⅱ. Method

Subjects

The aforementioned evolution instruction strategy was applied to eighth grade junior high school students and tenth grade high school students who consented to become research subjects. The total subjects were forty-six students from junior high and high school. The junior high school students attended K middle school located in metropolitan Seoul, Korea. It is a general level school of average academic achievement and the 17 students who took part in this study were active members of an 'environment preservation' club at school. Because the 'Environment Preservation Club' is composed of students who do not have exceptional achievements in science or high interest in science, their overall academic achievement was evenly distributed. The high school students participating in the study were twenty-nine tenth graders from the same science class at W general high school, Gyeonggido province in Korea. The academic level of the school is average and the 29 students' science achievements were evenly distributed.

Instruments

Two questionnaires were used to identify students' conceptions of, concerns about, opinions of and beliefs in the evolution both before and after implementation of the instruction strategy. One questionnaire instrument consisted of eighteen questions on the evolution concept and the other questionnaire contained nine questions on concerns about, opinions of, and beliefs in evolution and degree of interest and belief in the evolution of humans, animals, and plants. Both instruments were specially designed by Ha *et al.* (2006). The questions for identifying evolution conceptions were multiple-choice. There were eighteen questions and each question had five answers which were based on creationism, teleology, internal will, Lamarckism and natural selection after mutation (Table 2). The questions uncovering concerns about and opinions of evolution were also multiple-choice and each answer differed in level. The questions on the belief level of evolution were measured by the five-step likert scale (Table 3).

Students were inspected via a pre-test before implementation of new instructional strategy, then a post-test was given to students ten days after completion of the last lesson. To investigate conviction firmness regarding students' conceptions of, concerns about, opinions of, and beliefs in evolution, a follow-up test was given fifty days after the post-test. The interval between post-test and follow-up test was judged an adequate period of time for students to have forgotten instruction content due to events such as school festivals and final examinations. Data collected was analyzed by means of a paired-sample t-test, cross tabulation (chi-square test), and ANOVA by the SPSS WIN 12.0 program. Also, to analyze percentage similarity, the MVSP program was utilized.

Table 2

Structure of the questionnaire developed to identify students' conception about evolution (Ha et al., 2006)

Subjects	Humans	Animals	Plants
Aspect	- Human vertebras - Erect posture - Human hands - Human brain - Anti-cholesterol - Human vocal cords	- Giraffe's neck - Hawk's eyes - Fatty tissue of a polar bear - Body color of a chameleon - Insecticide resistance of Leafhopper - Running speed of a cheetah	- Fragrance of a rose - Thorns of a cactus - Stomatal pores of a water lily - Wide leaves - Seed of a cocklebur - Tracheid of a fern

Table 3

Structure of the questionnaire to identify students' perception of evolution (Ha et al., 2006)

Categories of questionnaire	Choices of questionnaire
Concerns about evolution theory	Concern A : I have heard about evolution and I am appalled by the idea. Concern B : I have never heard about evolution. Concern C : I have heard about evolution but I do not have any interest in it. Concern D : I have heard about evolution and I am a little interested in it. Concern E : I have heard about evolution and I want to learn about it in more detail.
Opinions about evolution theory	Opinion A : It is fake. Opinion B : It is a scientific hypothesis which has no validity. Opinion C : It is a scientific hypothesis for which there is little evidence. Opinion D: It is a scientific theory for which there is much evidence. Opinion E : It is a fact that cannot be denied.
Beliefs about evolution evidence	Five-step Likert scale
Degree of interest in the evolution of humans, animals, and plants	Five-step likert scale
Degree of belief in the evolution of humans, animals, and plants	Five-step Likert scale

Ⅲ. Results and Discussions

To improve understanding of the evolutionary mechanism, this study developed lessons on evolution based on the cognition conflict strategy as well as human evolution materials. With these created items, this study investigated changes in students' conceptions of, concerns about, opinions of, and beliefs in evolution from pre-study instruction to post-study instruction.

Changing the conceptions of evolution

To inspect changes in students' conceptions of evolution, a paired-sample t-test method was used. Table 4 illustrates the results of junior high school students' conception change after instruction by comparing pre- and post-test results and post- and follow-up test results. The test scores clearly show that students' conceptions changed. In particular, upon instruction completion, the answers of teleology, internal will, and Lamarckism were reduced significantly ($p<0.01$), while answers for natural selection after mutation, which is the scientifically proper answer, increased significantly ($p<0.05$). Because responses for creationism did not change significantly ($p<0.05$), it was surmised that the conception of creationism was related to innate beliefs. The instruction focused on cognition conflict strategy to exclude Lamarckism, which is strongly established in students' cognitive structure. Investigation of Lamarckism discovered that 43.1% of students held this conception on the pre-test, but only 21.2% of students chose this answer on the post-test. Moreover, the post-test result was repeated with only 21.9% of students choosing this answer on the follow-up test. Similarly, investigation of the scientific concept, natural selection after mutation, found only 4.6% of students held this answer the pre-test, but this percentage changed to 56.9% on the post-test and was preserved with 54.9% of students selecting this answer on the follow-up test. Therefore, it is possible to surmise from these results that students' conceptions of evolution changed.

Table 5 shows the results of a paired-sample

Table 4

Paired-sample t-test results between the pre- and post-test, and between the post- and follow-up test for junior high school students' conceptions of evolution

Explanation patterns for evolution	Pre-Post					Post-Follow-up				
	test	M*	SD	t	*sig.*	test	M*	SD	t	sig.
Creationism	pre	2.0	3.4	−0.61	0.548	post	2.9	5.2	−0.64	0.529
	post	2.9	5.2			follow-up	3.9	6.7		
Teleology	pre	32.7	11.1	4.54	0.000	post	13.1	18.0	−0.10	0.921
	post	13.1	18.0			follow-up	13.4	18.4		
Internal will	pre	17.6	13.9	3.14	0.006	post	5.9	6.9	0.00	1.000
	post	5.9	6.9			follow-up	5.9	11.2		
Lamarckism	pre	43.1	12.2	3.66	0.002	post	21.2	20.7	−0.15	0.886
	post	21.2	20.7			follow-up	21.9	29.3		
Natural selection after mutation	pre	4.6	4.5	−5.43	0.000	post	56.9	39.2	0.43	0.675
	post	56.9	39.2			follow-up	54.9	44.7		

* Unit is % and relative rate about total explanation.

t-test which analyzed high school students' pre- post- follow-up test scores. Changes to students' conception of evolution after instruction produced clearer results in high school students than junior high school students. Evolution lessons in the formal Korean curriculum are taught in the ninth grade. Therefore, junior high school students who took part in this study had not learnt about evolution before partaking in this study because they were only in the eighth grade. However, the high school students were in the tenth grade, so they had knowledge of evolution. According to constructivism, the understanding of something is related to former knowledge and experience (Ausubel *et al.*, 1978), so it is possible to conjecture that high school students who had learnt about evolution had more evolution experience than junior high school students, and as a result, could understand more effectively. It is surmised that this difference caused the difference in conception change between the two groups of students.

If there is appropriate harmony between new conceptions and former conceptions learning will be accomplished, if not, learning can be accomplished when former conceptions are changed (Hewson & Hewson, 1984). Posner *et al.* (1982) said that conflict steps caused by a dissatisfaction in former conceptions and the discovery of new concepts are useful in the process of conception change. The new instructional strategy for evolution was effective in terms of the constructionists' viewpoint. That is to say, cognition conflict strategy used to compare Lamarckism and mutation can be conflicted well students' conception.

Cross tabulation analysis was done to inspect how each answer changed from the pre-test to the follow-up test. Table 6 shows the cross tabulation results for the inquiry into changes in the patterns of students' conceptions of evolution before and sixty days after the instruction. The total number of possible answers to the questionnaire instrument that consisted of eighteen questions examining forty-six students' ideas was 828. 71.3% of the students who selected creationism, teleology, internal will, and Lamarckism on the pre-test selected natural selection after mutation on the follow-up test. In 77.3% of these cases, students who had answered Lamarckism changed their response to natural selection after mutation. The table also shows how students who selected creationism on

Table 5

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Explanation patterns for evolution	Pre-Post					Post- Follow-up				
	test	M*	SD	t	*sig.*	test	M*	SD	t	*sig.*
Creationism	pre	7.9	20.5	1.31	0.202	post	6.9	21.2	−2.09	0.046
	post	6.9	21.2			follow-up	9.0	25.1		
Teleology	pre	29.1	17.0	7.15	0.000	post	4.2	10.7	0.41	0.682
	post	4.2	10.7			follow-up	3.6	8.3		
Internal will	pre	9.4	13.2	2.98	0.006	post	1.5	4.7	−1.80	0.083
	post	1.5	4.7			follow-up	2.7	5.7		
Lamarckism	pre	48.9	23.8	8.83	0.000	post	5.4	9.0	1.31	0.200
	post	5.4	9.0			follow-up	3.8	10.2		
Natural selection after mutation	pre	4.8	12.1	−12.35	0.000	post	82.0	31.2	0.53	0.602
	post	82.0	31.2			follow-up	80.8	33.0		

* Unit is % and relative rate about total explanation.

the pre-test did not shift from the idea of creationism to an evolutionary view regarding the diversity of life even though they were taught about evolution for four class hours. This finding suggests that it is difficult to change misunderstandings based on inherent strong beliefs such as creationism into correct scientific concepts.

Assimilation of the evolution conception in terms of humans, animals, and plants

After instruction, the hypothesis that if human evolution materials were used, students would construct similar conceptions of evolution in terms of humans, animals, and plants was investigated. Fig 1 is the graph of an ANOVA test on the results of five evolution conceptions in terms of humans, animals, and plants. As shown from the pre-test in Fig. 1, there were significant differences ($p<0.05$) for the answers of teleology and Lamarckism. As Bizzo (1994) and Ha *et al.* (2006) reported, there were more teleological explanations and less Lamarckism explanations for plant evolution. Some studies have suggested that this result gives rise to anthropocentric thoughts of evolution and

Table 6

Changes in answers to each question from the pre-test to the follow-up test

Pre- \ Follow-up	CR	TE	IW	LH	NM	Total
Creationism	30* (63.8)	3 (6.4)	1 (2.1)	1 (2.1)	12 (25.5)	47 (100.0)
Teleology	12 (4.8)	27 (10.7)	9 (3.6)	28 (11.1)	176 (69.8)	252 (100.0)
Internal will	6 (5.8)	4 (3.9)	8 (7.8)	10 (9.7)	75 (72.8)	103 (100.0)
Lamarckism	10 (2.6)	20 (5.2)	12 (3.1)	46 (11.9)	299 (77.3)	387 (100.0)
Natural selection after mutation	1 (2.6)	6 (15.4)	2 (5.1)	2 (5.1)	28 (71.8)	39 (100.0)
Total	59 (7.1)	60 (7.2)	32 (3.9)	87 (10.5)	590 (71.3)	828 (100.0)

*Number of questions (rate)

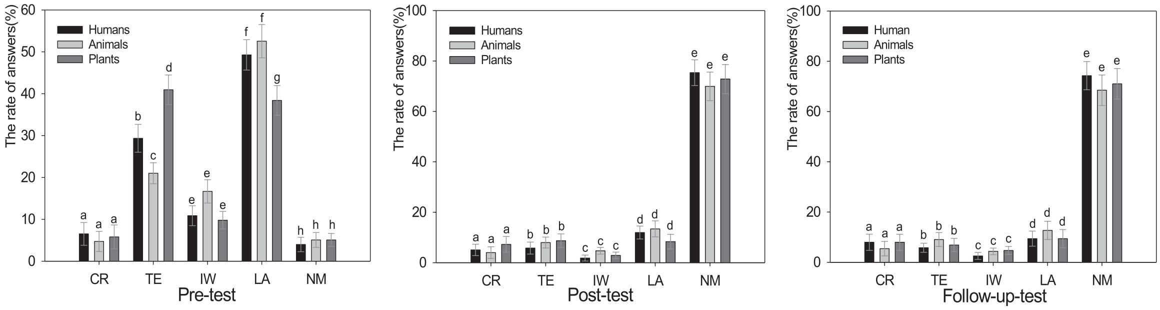

Fig. 1 *ndependent t-test results of five evolution conceptions in terms of humans, animals, and plants*

human evolution is at the center of anthropocentric thought. After the instruction, which incorporate numerous cases of human evolution, significant differences disappeared in terms of humans, animals, and plants. Human evolution helped students exclude anthropocentric thought and arrive at the same evolution conception for all living things.

Percentage similarity was analyzed using the MVSP program and then graphed. Fig. 2 is a graph of percentage similarity of evolution in terms of humans, animals, and plants. The graph shows how evolution conceptions in terms of the three categories become increasingly similar after instruction. The percentage similarity among humans, animals, and plants was about 83% in the pre-test, but it increased to 93% in the post-test. This percentage similarity increase implies the assimilation of the evolution conception by students.

Fig. 3 and Fig. 4 show the percentage similarity of interests in and beliefs in evolution, as graphed by the MVSP program. Although there was scarcely any difference in the percentage similarity of interest in evolution between the pre-test and post-test, percentage similarity of beliefs in evolution showed a 6% difference between the pre-test and post-test. This analysis of percentage similarity implies that the instruction helped students decrease

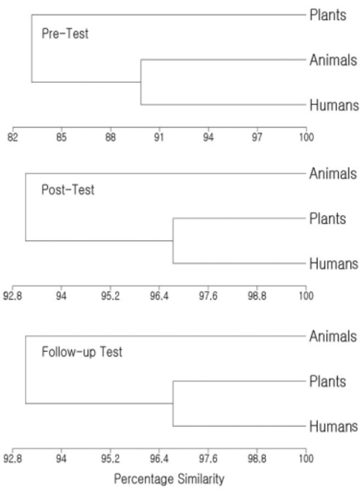

Fig. 2 *Percentage similarity of evolution conceptions in terms of humans, animals, and plants*

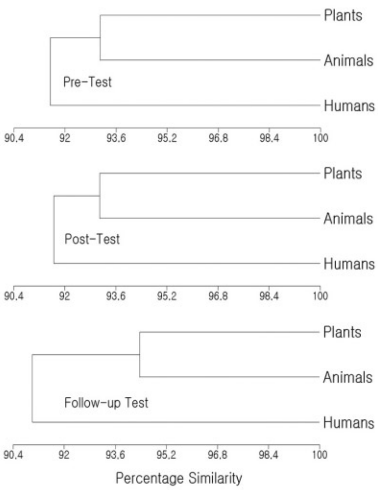

Fig. 3 *Percentage similarity of interest in evolution in terms of humans, animals, and plants*

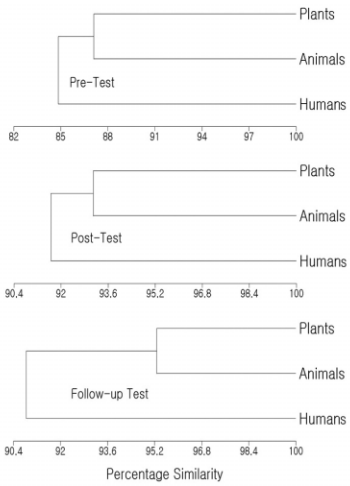

Fig. 4 *Percentage similarity of beliefs in evolution in terms of humans, animals, and plants*

differences in viewpoints of evolution.

Changes of students' concerns about evolution

Students' concerns about evolution after the program were examined to determine if they had changed (Table 7). According to cross tabulation analysis, students' concerns of evolution changed significantly ($p<0.05$) between the pre-test and the follow-up test. Students who responded to cA with 'I have heard about evolution and I am appalled by the idea.' totaled 17.4% for the pre-test; however, this option was never selected on the follow-up test. Students who chose cC, 'I have heard about evolution, but I do not have any interest in it' totaled 47.8% on the pre-test; however, selection of this option was reduced to 19.6% on the follow-up test. These results suggest the new approach for teaching evolution with respect to constructivism was effective for increasing students' concerns about evolution.

Changes in students' opinions of evolution

Table 8 shows the change pattern in students' opinions of evolution before and after the instruction. Cross tabulation analysis indicates that students' opinions of evolution did not change significantly ($p<0.05$) between the pre-test and follow-up test. However, looking at the

Table 7

Cross tabulation analysis on changes in students' concern (p=0.024)

pre \ Follow-up	cA	cB	cC	cD	cE	Total
Concern A	0 (0.0)	3 (6.5)	1 (2.2)	4 (8.7)	0 (0.0)	8 (17.4)
Concern B	0 (0.0)	1 (2.2)	5 (10.9)	5 (10.9)	1 (2.2)	12 (26.1)
Concern C	0 (0.0)	4 (8.7)	1 (2.2)	14 (30.4)	3 (6.5)	22 (47.8)
Concern D	0 (0.0)	0 (0.0)	1 (2.2)	0 (0.0)	2 (4.3)	3 (6.5)
Concern E	0 (0.0)	0 (0.0)	1 (2.2)	0 (0.0)	0 (0.0)	1 (2.2)
Total	0 (0.0)	8 (17.4)	9 (19.6)	23 (50.0)	6 (13.0)	46 (100.0)

Concern A : I have heard about evolution and I am appalled by the idea.
Concern B : I have never heard about evolution.
Concern C : I have heard about evolution but I do not have any interest in it.
Concern D : I have heard about evolution and I am a little interested in it.
Concern E : I have heard about evolution and I want to learn about it in more detail.

Table 8

Cross tabulation analysis on changes in students' opinion (p=0.419)

pre \ Follow-up	oA	oB	oC	oD	oE	Total
Opinion A	0 (0.0)	0 (0.0)	3 (6.5)	1 (2.2)	0 (0.0)	4 (8.7)
Opinion B	0 (0.0)	3 (6.5)	5 (10.9)	1 (2.2)	0 (0.0)	9 (19.6)
Opinion C	2 (4.3)	2 (4.3)	16 (34.8)	2 (4.3)	0 (0.0)	22 (47.8)
Opinion D	0 (0.0)	0 (0.0)	5 (10.9)	3 (6.5)	1 (2.2)	9 (19.6)
Opinion E	0 (0.0)	0 (0.0)	1 (2.2)	1 (2.2)	0 (0.0)	2 (4.3)
Total	2 (4.3)	5 (10.9)	30 (65.2)	8 (17.4)	1 (2.2)	46 (100.0)

Opinion A : It is fake.
Opinion B : It is a scientific hypothesis which has no validity.
Opinion C : It is a scientific hypothesis for which there is little evidence.
Opinion D: It is a scientific theory for which there is much evidence.
Opinion E : It is a fact that cannot be denied.

data qualitatively, response selections of oA, 'It is fake' and oB, 'It is a scientific hypothesis which has no validity', two negative opinions of evolution, totaled 28.3% on the pre-test; however, only 15.2% of students retained their negative opinions on the follow-up test. oC, one of the positive opinions, 'It is a scientific hypothesis for which there is little evidence' was selected as an answer by 47.8% of the students on the pre-test and 65.2% of the students on the follow-up test. On the other hand, oE, 'It is a fact that cannot be denied' was rarely chosen as an answer on either the pre- or the follow-up test.

Changes in students' beliefs of evolution

Table 9 highlights changes to students' degree of belief in evolution before and after the instruction. Using a five likert scale, students responded to statements that examined the degree of belief in evolution. Cross tabulation analysis found that students' beliefs in evolution did not change significantly ($p<0.05$) between the pre-test and the follow-up test. A qualitative discussion of data indicated that students who did not believe in evolution totaled 26.1% on the pre-test; however, on the follow-up test, the percentage was remarkably reduced to 4.3%. Moreover, the percentage of students who believed in evolution before the instruction rose from 26.1% to 54.4% after instruction. Instruction using evidence of human evolution published recently in science journals helped students strengthen beliefs in evolution.

Ⅳ. Conclusions and limitations

A new strategy to teach about evolution was constructed and applied to secondary school students and its effectiveness analyzed in this study. The instructional strategy was designed to first stir cognitive conflict in order to exclude Lamarckism, a well-known pervasive idea held by learners. The 5Es learning cycle model based on constructivist learning was outlined to design the lessons. Evidence of human evolution dealing with the human brain (Mekel-Bobrov *et al*., 2005) and human jaw (Steadman *et al*., 2004) published in recent science journals were introduced along with the other teaching subjects to create positive student beliefs in evolution.

The new strategy suggested in this study is recommended for trial by science teachers who are concerned with constructivist teaching. The study strategy follows the same idea of constructivist teaching. The lessons are efficient and exclude Lamarckism, the typical cause of students' misunderstanding of evolution. Teleology, another learner alternative idea of evolution can also change into the scientific conception of natural selection after mutation. Moreover, once the correct scientific conception is acquired it lasts for sixty days and possibly longer. Evidence of human evolution published in recent science journals is suitable for improving students' concerns about and opinions of evolution. Moreover, students' beliefs in evolution become more positive after instruction.

Table 9

Changing belief levels about evolution evidences contacted ordinarily (p=0.168)

Follow-up / pre	SD	D	N	A	SA	Total
Strongly disagree	0 (0.0)	0 (0.0)	2 (4.3)	1 (2.2)	3 (6.5)	6 (13.0)
Disagree	0 (0.0)	0 (0.0)	4 (8.7)	1 (2.2)	1 (2.2)	6 (13.0)
Neutral	0 (0.0)	2 (4.3)	9 (19.6)	10 (21.7)	1 (2.2)	22 (47.8)
Agree	0 (0.0)	0 (0.0)	4 (8.7)	4 (8.7)	1 (2.2)	9 (19.6)
Strongly agree	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.2)	2 (4.3)	3 (6.5)
Total	0 (0.0)	2 (4.3)	19 (41.3)	17 (37.0)	8 (17.4)	46 (100.0)

This study shows that this new approach using recent evidence of human evolution helps students to learn evolution as a scientific explanation. Therefore, it is essential that future science textbooks be constructed following new methodologies based on constructivist perspectives as proposed in this study.

This study was not conducted by the pretest-posttest control group design; thereby it is the limitation of this study that we cannot generalize the effect of present teaching modules. Compared to other studies, however, we can estimate the effects. Nehm& Schonfeld (2007) also conducted one group pre-posttest study with inservice biology teacher. They found that even after 14-week evolution program, only 50% of participants could explain the mechanism of evolution with scientific viewpoints. The results of Jensen & Finley's study (1995) also showed that one third of the worst responses before the evolution program became best responses and two third of functional misconceptions were removed. Despite different methodologies used in the studies mentioned, it is convinced that the results of present study are relatively effective for teaching evolution.

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