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Pre-service Biology Teachers' Mixed Model of Darwinism and Lamarckism

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<ABSTRACT>

This study investigated pre-service teachers' mixed idea on natural selection. Research analysis was carried out on specially designed questionnaires given to thirty-nine university fresh and sophomore pre-service teachers. Ten of these participants were also asked to partake in interviews aimed at collecting supplementary qualitative data. Study findings found that students held mixed evolutionary explanations like "natural selection with use/disuse." Moreover, qualitative data gathered via interviews found students possessed strong Lamarckian views connected to natural selection rather than views connected to scientifically acceptable concepts. In line with the Lamarckian view, students consistently drew upon personal experience regarding individual variation by employing the "effect of use/disuse." The compounding of evolution logic regarding evolution suggested that for study subjects the use and disuse hypothesis appeared to be quite similar to a phenomenological primitive (p-prim). Lastly, this research followed a constructivist teaching strategy to separate students' Lamarckian views from natural selection.

Key words : natural selection, Darwinism, Lamarckism, mixed model, pre-service teacher, biology teacher

Introduction

Evolution theory has influenced not only science but also other disciplines and society. Evolution theory, in particular, natural selection idea, has been understood to be the most important concept in terms of unifying and synthesizing biological concepts (Mayr, 1982). Dobzhansky (1973) addressed the importance of evolution concept in biology through his article 'Nothing in biology makes sense except in light of evolution.' The evolution conception has been adopted not only into biology but also into various disciplines such as economics, ethics, psychology, sociology (Dietz, et al, 1990; Sober, 1993). The importance of evolution concept results in the emphasis of teaching evolution. National Science Education Standards (NSES) emphasize the evolution as a unifying concept in biology (NRC, 1996). National Science Teachers Association (NSTA) has focused on its necessity in the biology curriculum (NSTA, 2003) and National Association Biology Teachers (2008)

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promulgated that teaching evolution should be taught in class in an effective and scientifically honest manner.

In spite of importance of evolution concept in learning, students and even biology teachers lack of the accurate knowledge of evolution. Lawson and Worsnop (1992) examined the high school students' knowledge of evolution. Their result showed that test scores on the knowledge of evolution before and after instruction were respectively 8.19 and 11.78 (out of 20) which were approximately less than 60% of understanding of evolution regardless of instruction. Brumby (1984) examined the understanding of evolution from medical biology students who were elite group and had many instructions on evolution. The research indicated that that even elite medical college students do not have accurate and scientific understanding of evolution but naïve idea such as use and disuse. Rutledge and Warden (2000) investigated the knowledge of evolution theory of high school biology teachers. Their results showed that biology teachers answered correct answer only about 15 items among 21 items. That is, biology teachers have approximate 70 % of understanding evolution theory. Nehm and Schonfeld (2007) conducted the intervention research with pre-service biology teachers. They served the 14 weeks graduate biology course that was part of their biology certification program and assessed their achievement using measures administered both pre and post the course. Their research informed that less than 50% of biology teachers responded scientific concepts such as genetic variation, selective survival, origin of variation, and changes in the population even after 14 evolutionary biology courses.

The one of reasons for difficulty to learn evolution is that evolution theory per se is difficult to understand. The concepts that are required to understand evolution are genetic variance (mutation), the heritability of variation, the differential survival or reproduction, the overproduction of offspring, limited resources, the competition between individuals, and a change of frequency in population (Nehm & Ha, 2012). Moreover, naïve ideas of evolution such as teleology and use and disuse idea are also very stable in mental framework so it can be adopted in evolutionary questions. The fact that even elementary graders have their own explanation of the evolutionary question (Inagaki & Hatano, 2006), shows how strongly the evolutionary naïve ideas are rooted and how long it has been in students' mental framework. Because of two reasons- the understating scientific evolution concept is difficult and naïve ideas can be easily adopted the evolution question-, students' naïve idea of evolution do not easily move to scientific ideas. For instance, if students are given the question why giraffe has long neck, they can easily give the answers that 'the giraffe needs the long neck in order to get the tree leave' or that 'the giraffe has used their short neck frequently so they have long neck.' Such naïve ideas are not scientific but making sense.

Evolutionary misconception or p-prim

The traditional notion of student's conception is tabula rasa view that students do not have any conceptions before students are taught scientific concepts (Smith et al., 1994). This idea was rejected since the many students' misconceptions were identified. No matter whether they learn or not, people have their own ideas about the nature before instruction. Most of those preconceptions are non-scientific or intuitive so it is called as misconception. Misconception has many different names such as preconceptions, alternative conceptions, or naive ideas (Smith et al., 1994). Students formulate such misconceptions from the prior informal learning or their cognitive interaction with the nature. For instance, young students think that the sun moves around the earth because they observe the movement of sun every day. Hammer (1996) summarized several characters of misconceptions. First, misconceptions are strongly held, stable cognitive structures. Most misconceptions can be corrected by the informed instruction but some misconceptions are strongly held in student's conceptual framework. It is hard to remove such misconceptions so it could sometimes be obstacles of the learning. Second character of misconception is that its meaning is different from scientific ideas. Young children or even university students think that plants take the soil and water to grow. The scientific idea on this is that plant synthesizes the glucose from the photosynthesis. Because the photosynthesis process cannot be observed, students cannot formulate such a scientific idea in everyday life.

Capturing students' misconceptions plays important role in instruction. The first phase of the BSCS 5E instructional model is the engagement (Bybee et al., 2006). In this phase, the teacher should assess the learners' misconception. Posner et al. (1982) addressed the four conditions for the conceptual change. The first condition is that students must have dissatisfaction with existing conceptions. The importance of assessing students' misconceptions is based on this dissatisfaction with existing conceptions. If students do not have conflict between their existing conceptions and new scientific concepts, they are more likely to employ their misconception to explain the nature. For the successful learning, teachers should provide the question that cannot be solved by students' misconception.

For the past thirty years, many science educators have found the misconception on evolution (Bardapurkar, 2008; Brumby, 1984; Creedy, 1993; Demastes et al., 1996, 1995; Kampourakis&Zogza, 2008; Lawson & Thompson, 1988; Nehm&Schonfeld, 2008). Four common misconceptions on evolution that have been found in many studies are teleology, intentionality, individual transformation, and use and disuse. First is the teleology or 'need' idea as driving force of evolution. The instance of such a 'need' idea is that giraffe need a long neck in order to get the leave of tall tree when students are given the question why the giraffe has the long neck. Interestingly, Darwin who first established the natural selection theory also had such a need idea (Lennox, 1993). This means that the 'need' idea is fundamental cognitive bias of human. Next is the intentionality or anthropomorphism which is 'want' idea as driving force of evolution process. For example, the answer of the question why giraffe has the long neck may be that the giraffe wanted to have a long neck so they now have it. Such a conception includes the 'want' idea. Early scientist Erasmus Darwin, who C. Darwin's grandfather, had such a 'want' idea. Thirdly, the common misconception of evolution is that individual transformation which is 'adapt' idea. Given the question why giraffe has long neck, the answer that giraffe has been adapted to their environment so it has the long neck includes such an 'adapt' idea. This naïve idea may be from the everyday life experience. For example, once human moves to an alpine region such as Kilimanjaro, the number of red blood cells increases. This phenomenon is the adaptation in individual level. Another example, bacteria have been exposed to antibiotic for a long times, the bacteria may immune to the antibiotic. Last, forth misconception the use and disuse that French scientist Lamarck suggested. The basic idea of this 'use' idea is that if individual frequently use or disuse one organ such as a neck, the organ can be developed or degenerated. This idea makes much sense so even Darwin could not discard such a misconception (Mayr, 1991). For instance, given the question why giraffe has long neck, the answer that giraffe has used its neck continuously so its neck has been longer shows such a use and disuse idea.

Recently, the perspective of misconception has changed into 'knowledge in piece' idea. This idea is from the question about why students make such a naïve idea. diSessa (1993) found that the basis of students' thinking that moving object has a force in it is the misuse of the word 'force.' Indeed, the word 'force' is widely used in everyday life. The 'force' notion that students acquire in their conceptual framework is from their everyday life. We cannot say that the notion of such a force is non-scientific idea because it can be used in everyday life. That is, the criterion to judge the naïve idea is not the naïve idea per se but its context where the naïve idea is. Students should not have adopted such a force notion that they use in everyday life into scientific explanation. diSessa (1988) found such small knowledge pieces that can be employed in everyday life, but that cannot be adopted in scientific explanation. He called such knowledge pieces as phenomenological primitives or shortly p-prims.

One good example of such a p-prim is the misconception of seasonal change. When young students were given the question why it is warmer in the summer than in the winter (Hammer, 1996), many students were more likely to answer that the reason is that earth is closer in the summer than in the winter. This answer is completely non-scientific idea. The reason of seasonal change is the incline of earth rotation axis and differential solar heat per unit area in two seasons. Why do students have such a misconception? This is also because of the lack of knowledge about the structure of Earth and the principle of seasonal change. However, actual basis of such a misconception is that their basic idea 'closer is stronger.' Everybody experience that the closer ones get to the candle, the hotter candles are. Likewise, everybody move their hands to wood fire more closely in order to get more heat in the winter. This is a common experience in everyday life. Thereby students formulate such an intuitive idea in their cognitive structure. The small knowledge is called as p-prim. This p-prim 'closer is stronger.' is very useful idea in everyday life, but it should not be adopted in the question why it is hotter in the summer.

The assertions that p-prim perspective should be adopted in evolutionary naïve ideas have suggested. Southerland et al. (2001) asserted that it is more proper that the 'need' idea is considered as a biological p-prim rather than misconception. They called the 'need' idea as a p-prim of need as a rationale for change. P-prims are the knowledge pieces from learner's superficial interpretations of nature or experiences in their everyday life. For example, one asks the reason of the change of window color of car, he or she can answer that the window color of my car changed because my car needs to block the sunlight. This answer includes the 'need' as the reason of the change. In everyday life, we often have such talking. Need as a rationale of change is not wrong; however it should not be adopted in evolutionary change.

Mixed model in history of science

One explanation for the particular phenomenon is composed of several elements. Scientific natural selection explanation is composed of seven conceptual elements including are genetic variance (mutation), the heritability of variation, the differential survival or reproduction, the overproduction of offspring, limited resources, the competition between individuals, and a change of frequency in population (Nehm& Ha, 2012). Like such a natural selection conception, often, conceptual elements that should not link to each other compose a particular explanation. In addition, such mixed model or conceptual mixing were found in the history of science. The French zoologist, Lamarck also has such a mixed model. Lamarck formulated only two fundamental principles on species' gradual change, which are the 'use and disuse' and 'heredity of acquire character' (Roberts, 2000). However, in 1815, he added'need' idea into his initial idea.

Why did Lamarck add such a 'need' idea into his initial explanation? The possible answer is that he could not explain why the giraffe should frequently use its neck. There must be an ultimate reason for the frequent use of particular organ. He resolved his uncertainty with 'need' idea. Indeed, as Southerland et al. (2001) addressed, need as the ultimate rationale of change makes sense. Darwin's idea is more complex because natural selection was added in his explanatory framework. Interestingly, Darwin did not discard the use and disuse idea and teleological idea (Mayr, 1991; Lennox, 1993).

> The eyes of moles and of some burrowing rodents are rudimentary in size, and in some cases are quite covered up by skin and fur. This state of the eyes is probably due to gradual reduction from disuse, but aided perhaps by natural selection. (Darwin, 1861: p. 154)

> It is now commonly admitted that the more immediate and final cause of the cuckoos instinct is, that she lays her eggs, not daily, but at intervals of two or three days; so that, if she were to make her own nest and sit on her own eggs, those first laid would have to be left for some time unincubated, or there would be eggs and young birds of different ages in the same nest (Darwin, 1861: pp. 216-217).

Darwin mentioned about the 'disuse' as a cause of variance and 'need' as a final cause of evolution. Lennox (1993) addressed the teleological characters of Darwin's work. He said "More importantly than his bare use of the term; however, are his consistent arguments that natural selection acts for the good of each being, and that its products are present for various functions, purposes and ends (1993:411)." Mayr (1991) elucidated the fact that Darwin often used the disuse term to explain the evolution of degeneration. He said that "When he(Darwin) says that the reduced size of the eyes of moles and other burrowing mammals is "probably due to gradual reduction from disuse but aided perhaps by natural selection (Mayr, 1991: p. 109)." Also Darwin thought that environment can directly change the bodies of organisms. Winther (2000) said, "Darwin thought that the environment could produce little change through direct action on the bodies of organisms, but through the use and disuse of organs, the environment could produce a fair amount of change (2000: p. 430)."

The mixed model or conceptual mixing was found in the history of science and very similar with students' alternative idea; therefore we hypothesized that such a conceptual mixing may be found in pre-service biology teachers.

Research Questions

This study investigates whether pre-service teachers possess mixed views on evolution and then discusses the characteristics of discovered mixed views via interviews. Next it purports an innovative alternative for teaching evolution based on findings. Specific research questions for this study are listed below.

1. Do pre-service teachers possess mixed views of evolution?
2. How do pre-service teachers synthesize evolution concepts?
3. What characteristics of the Lamarckian view do pre-service teachers show?
4. What implications do study findings have on the teaching of evolution?

Methodology

Study 1: Quantitative study

Participants

Participants in the study are thirty-nine pre-service teachers: twenty fresh and nineteen sophomores, majoring in biology education in Chungbuk, South Korea who learned about evolution in middle and high school.

Instruments

Two kinds of questionnaires, Questionnaire A and B are used to identify whether pre-service teachers hold mixed views of evolution. Questionnaire B, taken from Ha et al. (2006) investigates students' conceptions of evolution. It is composed of eighteen multiple choice questions, each offering the same five views of evolution as answer choices: creationism (C), teleology (T), internal will (IW), use and disuse (U/D), and natural selection after mutation (NS/M). Questionnaire A resembles Questionnaire B except that every question on Questionnaire A has an additional answer choice, "natural selection after use and disuse (NS/UD)" to investigate the existence of a mixed view toward the evolutionary mechanism. Answer choice NS/UD, describes a species with either a specially developed or undeveloped organ such as the brain, an eye, the neck, and skin color after much use or disuse of the organ. Because of this developed or undeveloped organ, the species is better equipped to survive than other similar species of its kind and, as a result, it is naturally selected.

For researchers to investigate changes in the 702 answers (18 questions each answered by 39 students) among questionnaires, participants are first asked to first complete Questionnaire A. A month later Questionnaire B, which excludes the answer choice, NS/UD, is administered to participants to identify mixed views on Lamarckism and Darwinism. One month after completing Questionnaire B, the same participants are once again requested to complete Questionnaire A. The Cronbach alpha value for the first completion of Questionnaire A is 0.835, 0.923 for Questionnaire B, and for the second completion of Questionnaire A 0.934.

Study 2: Qualitative study

Interview Process

To collect qualitative data, ten pre-service teachers are selected for an interview centered on three cases of trait evolution: the human brain, the sight of a mole, and the body color of a polar bear. Each of these three cases represents a possible evolution trait: development, degeneration, and adaption to the surrounding environment. The interview process is a semi-structured. In accordance with pre-service teachers' questionnaire responses, interviewers construct follow-up questions. Specifically, for students with apparent misunderstandings regarding the evolutionary mechanism, the interviewer points out the misconception and records how interviewees alter their initial responses based on interviewer's comments.

Results

Table 1 shows changes in response choices between the two completions of Questionnaire A and Questionnaire B. 12.5 percent of the total 35.8 percent of NS/UD responses on the first completion of Questionnaire A became response choice U/D on Questionnaire B. Similarly, 18.9 percent of the total 35.8 percent of NS/UD responses shifted to the choice of NS/M. Most subjects who appropriately chose response U/D on Questionnaire B in the absence of choice NS/UD continued to select response choice U/D on the second completion of Questionnaire A.

Figure 1 illustrates shifts in respective responses by showing the number of participant

<Table 1> Cross tabulation of questionnaire responses

Unit: Number of response (%)

*C: Creationism, T: Teleology, IW: Internal will, U/D: Use and disuse, NS/M: Natural selection after mutation, and NS/UD: Natural selection after use and disuse

Questionnaire A \ Questionnaire B		C	T	IW	U/D	NS/M	Sum
First Completion	C	0(0.0)	1(0.1)	0(0.0)	1(0.1)	1(0.1)	3(0.4)
	T	1(0.1)	14(2.0)	1(0.1)	10(1.4)	17(2.4)	43(6.1)
	IW	1(0.1)	0(0.0)	2(0.3)	3(0.4)	2(0.3)	8(1.1)
	U/D	1(0.1)	12(1.7)	0(0.0)	89(12.7)	34(4.8)	136(19.4)
	NS/UD	6(0.9)	22(3.1)	2(0.3)	88(12.5)	133(18.9)	251(35.8)
	NS/M	1(0.1)	14(2.0)	2(0.3)	13(1.9)	231(32.9)	261(37.2)
	Sum	10(1.4)	63(9.0)	7(1.0)	204(29.1)	418(59.5)	702(100.0)
Second Completion	C	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
	T	0(0.0)	9(1.3)	1(0.1)	11(1.6)	3(0.4)	24(3.4)
	IW	1(0.1)	0(0.0)	0(0.0)	6(0.9)	5(0.7)	12(1.7)
	U/D	1(0.1)	5(0.7)	2(0.3)	54(7.7)	50(7.1)	112(16.0)
	NS/UD	8(1.1)	29(4.1)	2(0.3)	90(12.8)	113(16.1)	242(34.5)
	NS/M	0(0.0)	20(2.8)	2(0.3)	43(6.1)	247(35.2)	312(44.4)
	Sum	10(1.4)	63(9.0)	7(1.0)	204(29.1)	418(59.5)	702(100.0)

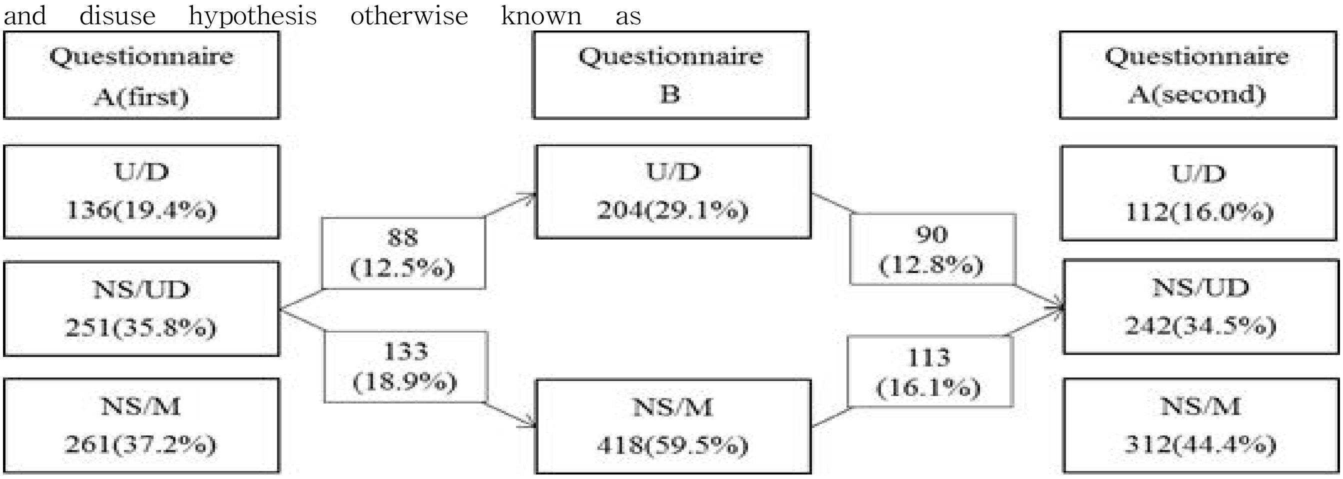
responses on the three questionnaires. On the first Questionnaire A, which included natural selection after use and disuse (NS/UD), 35.8% of all responses were NS/UD. Responses of NS/UD on the first Questionnaire A became use and disuse (U/D) and natural selection after mutation (NS/M) responses on Questionnaire B. However, generally, responses returned to NS/UD on the second administration of Questionnaire A (34.5%).

Table 2 summarizes the data collected during interviews with ten participants. "Before indication" denotes pre-service teachers' immediate responses to being asked to explain the evolutionary mechanism. "After indication" stands for interview participants' responses after the interviewer points out several fallacies in their explanations. The pre-service teachers participating in this study major in biology education, and not only did they learn about evolution during middle and high school, they also took a general introductory biology class at university. Moreover, they all had a deep desire to be biology teachers. Nevertheless, they drew on nonscientific terminology like "need", "goal", and "use and disuse" to explain the evolutionary mechanism. The most common misconception among these is the view associate with the use and disuse hypothesis otherwise known as Lamarckian thought.

Three of the 10 interviewees initially explained evolution via NS/UD, and interestingly, one interviewee related the conception of use and disuse to mutation (UD/M) even before any indication of explanation fallacy by the interviewer. Regardless of the interviewer's convincing justification that the hypothesis of use and disuse was laden with shortcomings, further mixed models were established; models that intermixed with use and disuse. Pre-service teachers did not abandon the use and disuse hypothesis towards evolution despite enlightenment on the erroneousness of the Lamarckian view. Several interviewees even asserted that use and disuse stimulated mutation or that it was necessary to explain evolution using one of the various plausible theories, irrespective of scientific acceptability.

The mixed evolution models of pre-service teachers

Below are several examples, taken from the onset of interviews with participants, which confirm the existence of mixed models among pre-service teachers to explain evolution.



[Figure 1] Pre-service teacher questionnaire response shifts (U/D: Use and disuse, NS/M: Natural selection after mutation, and NS/UD: Natural selection after use and disuse)

<Table 2> Changes to pre-service teachers' views on evolution

*C: Creationism, T: Teleology, IW: Internal will, U/D: Use and disuse, M: Mutation, NS/M: Natural selection after mutation, and NS/UD: Natural selection after use and disuse

Interviewee	Before indication		After indication	
	Concepts	Category	Concepts	Category
A	T	Naïve	UD/M	Mixed
	UD	Naïve		
B	NS	Scientific	NS/UD	Mixed
	UD	Naïve	NS	Scientific
	T	Naïve	M	Scientific
	NSM	Scientific		
C	UD	Naïve	UD/M	Mixed
	T	Naïve	NS/UD	Mixed
	NS/UD	Mixed	NS	Scientific
			NS/M	Scientific
			M	Scientific
D	T	Naïve	NS/M	Scientific
	NS/UD	Mixed		
	UD	Naïve		
E	T	Naïve	UD	Naïve
	UD	Naïve	NS	Scientific
			UD/M	Mixed
F	UD	Naïve	M	Scientific
			UD/M	Mixed
G	UD	Naïve	UD/M	Mixed
			UD/M/NS	Mixed
H	UD	Naïve	UD	Naïve
	NS	Scientific	NS	Scientific
	NS/M	Scientific	M	Scientific
	UD/M	Mixed	UD/M	Mixed
	NS/UD	Mixed		
I	UD	Naïve	UD/M	Mixed
	M	Scientific	T	Naïve
	T	Naïve	NS/M	Scientific
J	UD	Naïve	T	Naïve
	T	Naïve	UD	Naïve
			NS	Scientific
			NS/UD	Mixed
	Frequency	Percent	Frequency	Percent
Naïve	17	65.4	5	17.9
Mixed	4	15.4	11	39.3
Scientific	5	19.2	12	42.9
Total	26	100.0	28	100.0

> “Apes and humans come from a common ancestry, which includes several other species. One of these species might have learned to use tools. This species, then, would have been selected naturally and their brain size developed according to tool usage”(Interviewee C)

> “Monkey groups would have separated instinctively... for instance, one group might continue to live primitively, while the other began to use tools… Facing situations necessitating the use of their brains caused the direction of evolution to differ…” (Interviewee H)

The above two comments by pre-service teachers highlight views on natural selection after use and disuse, the focus of this paper. After conceding that the use and disuse hypothesis was no longer scientifically acceptable in modern biology, pre-service teachers made comments alike those that follow.

> “Though various methods, mutation occurred in their genes. In other words, mutation takes place because they use and reuse a particular organ, bringing about evolution…” (Interviewee A)

> “According to the use and disuse hypothesis, the more a feature is used, the more a gene develops or mutates in one of the parent individuals, which is good for survival in terms of natural selection. The interlinking of three of the factors (use and disuse, mutation, natural selection) causes evolution.” (Interviewee G)

Pre-service teachers viewed the use and disuse hypothesis a logical mixed part of evolution either as a cause or as a facilitator of mutation, and hence, synthesized it with natural selection. In other words, pre-service teachers connected use and disuse with mutation and natural selection as if they were logically related, albeit prior evolution learning that explains why acquired traits are not hereditary.

Discussion

The phenomenon that pre-service teachers at teaching colleges majoring in biology education retain synthesized conceptions on evolution like natural selection after use and disuse authorizes the discussion of several theoretical viewpoints associated with the conceptual change theory. These viewpoints are discussed according to 1) the mixed models of Vosniadou (2007), 2) the p-prim theory of diSessa (1993), and 3) the history of science as maintained in the 1991 book written by Mayr.

First, this study not only found that pre-service teacher mixed views on evolution were quite diversified they also showed dissimilar traits from the mixed model “dual earth” advocated by Vosniadou (2007). That is to say, participating students held a conceptual framework that integrated unscientific and scientific conceptions. The concept of use and disuse expressed by pre-service teachers in this study is synthesized with natural selection and mutation. To be more precise, they appear to be expressing a “blending of conceptions” rather than ‘a total synthesis of conceptions.” Participants cite the effect of use and disuse as causes of various traits or as stimulants for mutations. Hence, it is doubtful whether the conception of use and disuse, a deep-rooted conceptual framework, may be altered and whether it is possible to design an effective teaching strategy that entirely amends misconceptions of evolution because of students strong confidence in the logicality of their ingrained conceptual framework.

Noteworthy is the fact that all participants, currently enrolled in a teaching college and majoring in biology education, learned about evolution at three distinct stages in their formal education: middle and high school and first year at university. Moreover, the Korean education curriculum emphases the Lamarckian view of evolution is no longer accepted by modern genetics, and to ensure students learn this notion student understanding is assessed through formal examinations. Nevertheless, as this study finds, students still possess the Lamarckian viewpoint on evolution and, what is more, even after the fallacies of Lamarckism are pointed out, students do not abandon their Lamarckian view but utilize it to support their thoughts. This phenomenon is meaningful and may be of great importance in the research area of conceptual change.

Having ruled out Vosniadou's "dual model" it seems more reasonable to suspect use and disuse is not an ingrained conception but knowledge that leads to the logical piecing together of explanations. According to diSessa (1993), p-prims are basic reasoning elements people possess based on experience and because "things just happen." Southerland et al. (2001) assert that the teleological explanation of evolution shows a representative aspect similar to a p-prim.

There are several reasons for considering the use and disuse conception a p-prim. First, the use and disuse conception is comparable to the p-prim, "the closer the stronger." (Hammer, 1996) When asked to explain why it is hotter in summer than winter, many students claim it is hotter because Earth is closer to the sun in summer than in winter. Students use the p-prim, "the closer the stronger" to explain this phenomenon because most have experienced candles being hotter and brighter the closer one stands near to them. That is to say, empirical knowledge is used to explain the change of seasons. Pre-service teachers employ the use and disuse hypothesis in much the same manner. The following are two responses given during interviews.

> "I think that the more something is used the more it develops. Look at the human arm. The more one uses it, the more developed its muscles become…" (Interviewee G)

> "Look at the difference between fingers and toes. Fingers are quite maneuverable because we have been using them to pick up things. However, toes were used only for the movement of walking, so toes cannot freely move like fingers. Thus, humans have a different range of movements between fingers and toes…" (Interviewee D)

When asked to comment on their responses, participants explained their rationale using knowledge related to "effect of use and disuse." The effect of use and disuse is easily observed and experienced in everyday life. Therefore, this research suggests that the use and disuse hypothesis is closely related to a p-prim. Secondly, because a p-prim cannot be judged by scientific criterion (Hammer, 1996), it is possible to claim that the use and disuse hypothesis is not an unscientific explanation. There are numerous examples of a human muscle becoming stronger the more the organ is used. Thus, when faced with the question, "Why does a marathoner's heart-lung system excel that of others?" the best explanation is through the use and disuse hypothesis. Whereas misconceptions are unacceptable by present-day scientists, p-prims are knowledge that cannot be scientifically judged. Lamarckism is believed to contain partial characteristics of p-prims.

Misconceptions about evolution such as the use and disuse hypothesis appear when students explain the evolutionary mechanism Removal of the Lamarckian view to explain evolution would resolve misconceptions related to the use and disuse hypothesis. In other words, when teaching modern evolution via natural selection and mutation, educators should link the natural selection theory to the use and disuse hypothesis.

Last, the history of science, especially Darwin and Weismann's early thoughts on evolution, needs to be addressed. As aforementioned in the introduction, Darwin and Weismann held mixed views toward evolution including natural selection after use and disuse. Mayr (1991) stated that Darwin even admitted to employing the use and disuse hypothesis to explain degeneration cases like a mole's eyes. Weismann, who laid the foundation for the modern evolution theory, also followed Lamarckism. However, he endeavored to overcome the use and disuse explanation for evolution by researching genetics. Therefore, educators should reflect on Weismann's endeavor to teach evolution. In addition, it may be that the fundamental reason Darwin pondered the effect of use and disuse was the lack of any scientific explanations for trait variation at that time. In terms of Weisman's early beliefs, an acquired trait can be inherited. It is noted, however, he later established that acquired traits could not be hereditary (Mayr, 1991). With respect to the history of science, pre-service teachers in this study seem to struggle with the same conflict faced by Darwin and Weisman. One possible solution, at the classroom level, is for teachers to draw a connection between evolution and mutation.

Discussion

This study reveals that pre-service teachers hold mixed viewpoints, a mix of Lamarckism and Darwinism, toward the explanation of evolution. This phenomenon has a variety of key implications for the current curriculum regarding evolution. Despite learning about evolution since middle school, university biology education majors are still not consciously aware that the use and disuse hypothesis is laden with several fallacies when used to explain genetics and is currently considered unscientific. Knowing that students have yet to accept these issues related to use and disuse, what aspects of the current curriculum on evolution causes the generation of misconceptions? First of all, the curriculum's sequence of lessons on evolution may be problematic. In the current organization of textbooks on evolution, Lamarck's thought is compared with Darwin's. Although biology teachers try to enforce the notion that the use and disuse hypothesis is unacceptable in modern science because acquired traits are not hereditary, students have yet to internalize this idea. Without ample knowledge about mutation and acquired hereditary characteristics, students are likely to misunderstood Lamarckism to be an accepted scientific explanation for evolution. In addition, there are few conflicts between Lamarckism and Darwinism. According to Mayr (1991)'s book, both Darwin and Weismann made use of the use and disuse hypothesis and natural selection. To facilitate conceptual change following a constructivism teaching strategy must address the conflict between new concepts and misconceptions. The absence of any conflict between Lamarckism and natural selection suggests the current teaching method, which compares Lamarckism and Darwinism, needs revamping.

Secondly, educators need to accentuate how variation first appears. Darwin, Weismann, and many pre-service teachers all incorporate the use and disuse hypothesis as a cause of variation. However, according to modern evolution theory, variation is caused by a change in genes, namely mutation. To ensure correct understanding of the cause of variation, the teaching of evolution should concentrate on the teaching of genetics, especially the notion that new characteristics are caused by mutation.

On the basis of the afore-discussion, this paper suggests a new teaching method. First, the teaching sequence of evolution must be adjusted. It is important that the connection established between the use and disuse hypothesis and natural selection be cut rather than its present conceptual replacement into scientific concepts or its total removal. Everyone must accept the reason the use and disuse hypothesis cannot be regarded a scientific evolutionary explanation is that acquired traits cannot be inherited. Only, once this idea is firmly internalized in students' knowledge, will students stop using it to explain the evolutionary mechanism. To implement this at the classroom level, the teaching of genetics related to evolution such as mutation and genetic drift should be introduced before the actual teaching of evolution. That is to say, the arrangement of curriculum content on evolution should be adjusted to place the teaching of mutation before the teaching of natural selection. Presently, the science curriculum separates the topics of genetics and evolution. However, a unit that harmonizes genetic and evolution would be of enormous benefit in establishing understanding and correct learned knowledge. Although it will not be easy to harmonize genetics and natural selection for inclusion into the formal school biology curriculum, it should be attempted to ensure successful evolution learning at school.

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