Korean University Students' Philosophical Stances of Understanding Atomic Structure in terms of the Lakatosian View

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Abstract: The main objective of this study was to investigate Korean university students' understanding of the structure of the atom based on a Lakatosian view. In this study, we examined twenty-three Korean university students' understandings of atomic structure using an open-ended questionnaire. The participants were all junior students majoring in chemistry education in Korea. The characteristics of students' understanding were categorized into three philosophical stances based on the classification criteria. Assertions were constructed concerning students' written descriptions of the development of scientific knowledge with respect to atomic structure: (a) characteristics of positivist response; (b) characteristics of transitional response; (c) characteristics of Lakatosian response; and (d) tendencies in students' responses.

Key words: Lakatosian view, Atomic structure

I. Introduction

There is a growing consensus that scientific literacy is a central goal of science education, and understanding the nature of science is a requisite for scientific literacy (Lederman, 1992; National Research Council, 1996, 2000). Based on this consensus, many studies have suggested the importance of history, philosophy of science, and epistemological issues to science education

(Burbules & Linn, 1991; Blanco & Niaz, 1998; Hodson, 1993). One area of research is the assessment of student conceptions of the nature of science. Research in this area is grounded in the assumption that students' conceptions of the nature of science influence their understanding of science (Blanco & Niaz, 1998; McComas, Clough & Almazroa, 1998). Although the importance of the nature of science is accepted in the science education community, many studies that assessed students' conceptions of the nature of science have indicated that students have not acquired adequate understandings of the nature of science (Abd-El-Khalick & Lederman, 2000; Kang, Scharmann, & Noh, 2004; Lederman, 1992; Lederman & O'Malley, 1990). One limitation of some of these studies is due to the problem of the questionnaire method (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The traditional way of ascertaining students' views about science has been through questionnaires and survey instruments using multiple-choice items or Likert scales. However, students do not always perceive and interpret test statements in the way that test designers intend (Hodson, 1993). Language in the questionnaires and survey instruments is often interpreted differently by students and researchers (Lederman & O'Malley, 1990).

To avoid the problem of the traditional questionnaire method, research on students' conceptions has moved from primarily quantitative to more qualitative assessment approaches (Blanco & Niaz, 1998). However, the qualitative approach is also subject to criticism in that the questions are very general and do not pertain to a domain-specific context. Given the importance of pedagogical content knowledge (Shulman, 1986) and its close relationship to students' understanding of science, the research on students' conceptions of the nature of science should be conducted on a domain specific topic (Blanco & Niaz, 1998). This view is parallel to the view that the most important knowledge

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structures influencing students' learning in science relate to domain-specific conceptual knowledge rather than more global logico-mathematical reasoning skill (Driver & Easley, 1978). Therefore, this study was based on a domain specific topic of atomic structure using an open-ended questionnaire.

Besides the effort to reveal students' general conceptions about science, some studies have been conducted to investigate students' conceptions within a particular philosophical stance. For example, using Popperian methodology, Coxhead and Whitfield (1975) classified students' responses as three alternative views: verificationist, inductivist, and hypothetico-deductivist. Based on the work of Popper and Kuhn, Rowell and Cawthron (1982) investigated the extent to which Kuhnian views had penetrated science education. A major premise of these studies is that there are commonalities between the process of theory development by scientists and the individual's acquisition of knowledge (Duschl & Gitomer, 1991). Moreover, the question of how conceptual changes actually take place in individual students is an unresolved problem that is now receiving attention. The conceptual change model proposed by Posner, Strike, Hewson, and Gertzog (1982) was based on Kuhn's (1970) and Lakatos's (1970) theories about the growth of scientific knowledge (Duschl & Gitomer, 1991). Unlike Kuhn's incommensurability, which does not permit rational debate among different paradigms, Lakatos (1970) conceptualized scientific progress through progressive "problemshifts," that is transitions which increase the heuristic power of the research program. Thus, in many previous studies, Lakatos's methodology of competing research programs was suggested as a useful framework for the reconstruction of students' understanding of scientific content (Gilbert & Swift, 1985; Niaz, 1993).

In high school and general college chemistry, it has been suggested that atomic structure is a suitable topic as a historical model to include the history and philosophy of science in the science curriculum (Justi & Gilbert, 2000). Also, the topic of atomic structure is appropriate to explain the Lakatosian view. For example, Rutherford's alpha-particle scattering experiments provided evidence against a competing framework, viz. J.J. Thomson's model of the atom (Blanco & Niaz, 1998). Atomic structure is appropriate not only to analyze the students' philosophical stance but also to encourage students to have the Lakatosian view. Thus, the main objective of this study is to investigate students' understanding of the structure of the atom based on a Lakatosian view.

II. Theoretical Background

The theoretical framework for this study draws from three bodies of literature: (a) history and philosophy of science (HPS) and science education; (b) atomic structure from a Lakatosian perspective; and (c) Lakatos's methodology and science education.

History and philosophy of science (HPS) and science education.

One of the aspects on which science education should focus is learning about the processes of science. The use of the history of science is suggested to achieve this aspect. In the last 20 years, many educators recommended the study of the history of science in science teaching (Duschl, 1985; Solomon, 1981). The result of these studies presented the benefits of learning about the history of science are: (a) a better learning of the concepts of science, (b) increased interest and motivation, (c) an introduction to the philosophy of science, (d) a better attitude of the public towards science, and (e) an understanding of the social relevance of science (Solomon, Duveen, & Scott, 1992). The insistence on including HPS in science teaching is connected to the recognition of the relationship between the process of theory development in the history of science and students' acquisition of knowledge. Philosophers of science have long recognized the relationship between the process of theory development by scientists and an individual's acquisition of knowledge (Kitchener, 1987; von Glasersfeld, 1989).

Atomic structure from a Lakatosian framework

The topic of atomic structure is an appropriate example for explaining the Lakatosian view. A finite number of models of the atom exist, and the explanation of the model can include what the hard core of the model is, how positive heuristics modified the protective belt, and how one model replaced another model. Thomson's experiments were conducted to test rival hypotheses. Thomson pointed out that his experiments were conducted to clarify the controversy with regard to the nature of the cathode rays, viz., charged particles or waves in the ether. Thomson decided to measure the charge to mass ratio in order to identify cathode rays as ions (if the ratio was not constant) or as a universal charged particle (constant ratio for all gases) (Achinstein, 1991). Rutherford's experiments with alpha particles provided evidence against a competing framework, viz., Thomson's model of the atom (Niaz, 1994). Bohr's main objective was to explain the paradoxical stability of the Rutherford model of the atom, which constituted a competing framework for his own model (Niaz, 1994).

Even though the importance of historical models to science teaching has gained increased attention, they have not been dealt with appropriately in school curricula and textbooks (Justi & Gilbert, 2000). Thus, further research is required: how scientific models, including atomic structure, are presented in science curricula and whether the models include the historical and philosophical perspectives.

Lakatos's methodology and science education

Lakatos (1970) conceptualized scientific progress through progressive "problemshifts," that is transitions which increase the heuristic (explanatory) power of the research programs. Lakatos saw the history of science as the history of competing research programs. For Lakatos, research programs are competing for theoretical extension and better elaboration. This competing process allows research programs to change or progress constantly.

Lakatos's methodology was originally based on progress in physics and mathematics. However, it has been useful for interpreting research in psychology and education as well (Bianco & Niaz, 1998). In many previous studies, Lakatos' methodology of competing research programs has been suggested as a useful framework for the reconstruction of students' understanding of scientific content (Gilbert & Swift, 1985; Niaz, 1993). For science educators, it is a major concern that the Lakatosian framework considers competing research programs as essential for progress and at the same time commensurable. Niaz (1998) considered students' beliefs and scientific theories as competing research programs. Based on this view, Niaz (1998) proposed a Lakatosian conceptual change teaching strategy while insisting that a Kuhnian conceptual change teaching strategy would perhaps consider students' beliefs as more rigid and not open to competition, and hence less conducive to change. A Lakatosian conceptual change teaching strategy looks for "auxiliary hypotheses" that students use to protect core beliefs after identification of the hard and the soft core of students' beliefs, and subsequently to construct alternative explanations that contradict their original beliefs.

Niaz (1995) also analyzed the strategies students use to solve chemistry problems, and showed the progressive transitions that are found in students' problem solving processes are similar to what the history of science refers to as progressive "problemshifts" that increase heuristic power.

Purpose

Twenty-three Korean university students' understanding of atomic structure was investigated using the Blanco and Niaz (1998) questionnaire. The characteristics of students' understanding were categorized into three philosophical stances based on the classification criteria by Blanco and Niaz (1998), and analyzed based on the following research questions:

(1) What are the characteristics of each student's philosophical stance toward the development of scientific knowledge with respect to atomic structure?
(2) What tendencies do students have in their understanding of atomic structure?
(3) Are students' philosophical views consistent according to the context of the problem?

III. Methodology

Participants

The twenty-three participants were juniors in the department of chemistry education in Korea. During the spring semester in 2004, the students took one science education methods course in which they learned about the philosophy of science for 5 hours. The questionnaire was administered approximately three weeks after the students had finished the philosophy of science classes. The students were asked to respond to an 11-item questionnaire and were encouraged to explain their responses in writing. Five of the items dealt with Thomson's experiments, four with Rutherford's experiments and two with Bohr's experiments.

The students learned about atomic structure in high school and in their first year at the university. Hence, it was assumed that the students had sufficient content knowledge about the atomic structure because (a) their science content background was chemistry, and (b) they had taken more than 40 credits of chemistry courses at the time of data collection. Based on this assumption, the Korean students' responses were compared with those of Blanco and Niaz (1998).

The Questionnaire

The questionnaire used for this study was taken from Blano and Niaz, 1998. The questionnaire consisted of three parts, each addressing a different atomic model. Below is a description of each part with its corresponding questionnaire items.

Part A. Thomson: A brief description of Thomson's experiments was presented in order to facilitate students' recall. The five questions listed below followed the description of Thomson's experiment:

Item 1) In your opinion what was most important in Thomson's experiments?

Item 2) Why did Thomson determine the charge to mass (e/m) relation?

Item 3) How do you interpret the finding that on using different gases in the cathode-ray tube, the relation (e/m) remained constant?

Item 4) How would you have interpreted, if on using different gases in the cathode-ray tube, the relation (e/m) would have resulted different?

Item 5) Based on his experiment Thomson proposed a model of atom as a uniform sphere of positive electricity with the electrons embedded in this sphere, much as raisins in a pudding. The following questions were asked: Would you agree that this model represents the information that Thomson had at that time?

Part B. Rutherford: A brief description of Rutherford's experiments was presented. The four questions listed below followed the description of Rutherford's experiment:

Item 6) In your opinion, what was most important in Rutherford's experiments?

Item 7) How would you interpret the finding that most of the alpha-particles passed undeflected through the thin metal foil?

Item 8) How would you have interpreted, if most of the alpha-particles would have deflected through large angles?

Item 9) If Rutherford's experiments changed Thomson's model of the atom entirely, in your opinion did Thomson make mistakes while doing his experiments?

Part C: A brief description of how Rutherford's model of the atom violates one of the classical principles of physics was presented. If the electrons were stationary, there was nothing to keep them from being drawn into the nucleus; and if they were in circular motion, the well-known laws of electrodynamics predicted that the atom should radiate light until al electronic motion ceased. Bohr attempted to resolve this apparent paradox by analyzing atomic structure in terms of the quantum theory. Bohr's postulates, as found in most textbooks were presented followed by the two questions below:

Item 10) In your opinion, what was most important in Bohr's experiments.

Item 11) If Bohr's experiments changed Rutherford's model of the atom, in your opinion did Rutherford make mistakes while doing his experiments?

The instructor of the science methods course administered the questionnaire. Students were given enough time to complete the questionnaire in class. They were not allowed to consult resources, nor each other.

Criteria for Classification of Students' Responses

In their analysis of Venezuelan university students' understanding of atomic structures, Blanco and Niaz (1998) characterized their responses into three categories: positivist, transitional, and Lakatosian. The same characterization categories were used in this analysis of Korean university students' questionnaire responses. The first author categorized students' responses and the second and third author reviewed them. The results were discussed until consensus was reached. A description for each category is described below:

Positivist: Responses included in this category emphasized experimental observation, demonstration and description of an absolute reality that has little to do with the hypotheses and theoretical framework of the scientist.

Transitional: These responses indicated a partial understanding with respect to the existence of alternative/competing models for explaining the experimental observations and that no knowledge is ever absolutely established.

Lakatosian: These responses indicated that scientific progress is subsumed by a process involving conflicting frameworks, based on processes that require the elaboration of rival hypotheses and their evaluation in the light of new evidence.

IV. Results and Discussion

We present the results of this study in two sections. First, we provided a quantitative view of students' responses in Table 1, along with a discussion of the general trends in Korean students' responses versus responses from students participating in the Blanco and Niaz study (1998). Second, we presented a qualitative assessment of Korean students' written responses to the questionnaire, followed by a discussion of the general trends in these responses.

Table 1 compares the responses of Korean students and the responses given by Blanco and Niaz (1998) on all items. The numbers in the table represent percentages. It should be noted that the comparison is limited, as the number of student participants in each study is very different (Korean students: N=23, Blanco & Niaz: N=171). Nonetheless, interesting trends exist and implications can be drawn.

Item 1 of the questionnaire is a general question (What was most important in Thomson's experiments?). From Item 1 to Item 5, questions became more specific and complex. From Item 1 to 4, positivist responses from Korean students

Table 1

Comparison of responses of Korean students and responses given by Blanco & Niaz (1998)

	Positiv		Ttransit		Lakatos		Ambig		No Resp	
Item	B&N	Kor	B&N	Kor	B&N	Kor	B&N	Kor	B&N	Kor
1	91	96	5	4	1		2		1	
2	62	78	8		2		7	17	20	4
3	46	43	6	4	9	13	15	13	24	26
4	42	26	9	39	3		6	13	40	22
5	23	30	1	22	1	4	11	35	27	9
6	78	78	7	13			3	9	12	
7	37	61	9	17	18		14	22	22	
8	27	30	3	43		13	45	13	25	
9	36	43	26	22	2	9	8	13	27	13
10	51	78	8	4	4	9	17	9	21	
11	27	61	30	9	5	4	7	9	30	17

Positiv: Positivist responses, Transit: Transitional responses, Lakatos: Lakatosian responses
Ambig: Ambiguous responses, No Resp: Did not respond, B & N: Blanco & Niaz (1998), Kor: Korean students

decreased and Transitional/Lakatosian responses from Korean students increased. Since Lakatosian responses were very few, the percentage of Transitional/Lakatosian responses (that sum up two responses) seems meaningful. This pattern was also shown in the study of Blanco and Niaz (1998). In their data analysis, Blanco and Niaz (1998) mentioned that positivist responses decreased from Item 1 to 4, transition responses increased from Item 1 to 4, Lakatosian responses increased from Item 1 to 3. They interpreted theses results as a testing effect. That is, students could get more conceptual understanding through the process of testing. They also insisted that the interaction with the sequence of items used in the questionnaire helped students to improve their understanding of atomic structure in terms of Lakatosian view (Niaz, Aguilera, Maza, & Liendo, 2002). In the responses of Blanco and Niaz (1998), as the questions became more specific, ambiguous responses increased from Item 1 to 3 and those who did not respond increased form Item 1 to 4. They interpreted that this trend as indicating the complexity of the issues. However, the responses of the Korean students did not show such a trend.

Item 6 again started with a general question (What was most important in Rutherford's experiments?), followed by more specific items. In the same manner, Table 1 shows that the positivist responses from Korean students decreased from Item 6 to Item 8, and transitional/Lakatosian responses increased from Item 6 to 8 for Korean students. However, there was no clear trend in transitional/Lakatosian responses for Blanco and Niaz (1998).

In Items 5 and 9 require students to evaluate the role of atomic model or scientists. For these two items, Korean students' positive responses increased, and transitional/Lakatosian responses decreased compared to Items 4 and 8 respectively.

In conclusion, students in both groups showed more positivist responses in general questions (Item 1, 6, 10). As the question became specific, transitional/Lakatosian responses increased. In particular, for items that provided conflicting evidence and asked students to formulate an alternative model (Item 4, 8), Korean students gave more transitional/Lakatosian responses compared to the students of Blanco and Niaz (1998).

Characteristics of Each Philosophical Stance

Positivist Responses

Most students' responses were included in this category. The responses of this category usually emphasized the discovery of facts. In this category, science is considered as a set of facts. For the questions that asked what is most important in each scientists' experiments (Items 1, 6, 10), students only mentioned hard facts and generalizations, such as the discovery of electrons, that the atom was for the most part empty space, etc. Even if students were given experimental findings, and asked to interpret them (Item 3, 4, 8), they only emphasized the experimental facts and concrete details instead of providing their own interpretation. This emphasis implies that students of this category focused only on empirically verifiable facts. This view is resonant with "the popular fiction" about science that the primary goal of science is the accumulation of facts (Casti, 1989). Following are examples of students' positivist responses. All examples are presented with item numbers and student numbers.

[The most important thing is] the discovery of electrons (Item 1, S2)

Because the charge to mass (e/m) relation is constant (Item 3, S6)

Alpha particle collides with the nucleus (Item 8, S12)

Students considered scientific models as absolute reality, and they did not try to make alternative models. When students were given conflicting evidence and asked to formulate alternative models (Items 4, 8), they did not suggest alternative models. While they assumed the scientific model were an absolute truth, they tried to change the characteristics of each component within the model. Sometimes, even though they seemed to have hypotheses, they did not formulate an alternative model explicitly.

More advanced quantitative experiments are needed to reveal the influence of the gas (Item 4, S1)

I assume that a repulsive force of an alpha particle would be much greater, which impede penetration of the atom (Item 8, S10)

Students emphasized the importance of experiments and that an atomic structure can be determined by accumulated evidence through experiments. They did not agree that the previous models represent the information at that time (Item 5) because there was insufficient empirical evidence and less developed techniques. The students in this category did not recognize that a scientist's inference plays an important role in construction of a scientific model. Furthermore, they devalued the scientists' inferences compared to observational evidence.

I don't agree that Thomson's model represents the information of that time. There is no experimental evidence to support the model of raisins in a pudding. It is simple inference (Item 5, S4).

I don't agree. The results of Thomson's experiment are not enough to reveal the placement of electrons (Item 5, S14).

For the question that requires considering the relationship between two models, students did not consider that scientific models play a role as competing research programs. Instead, the students referred to a lack of accuracy of previous models. They thought that the scientists who developed previous models made mistakes (Item 9, 11). In the few cases in which students did not think that scientists made mistakes, they did not have any view that aligned with the idea that science can develop gradually through elaboration of a research program and compete with other research programs:

Yes, Because Thomson's experiment could not reveal the existence and distribution of positive charges (Item 9, S6).

Yes, Rutherford suggested that the electrons circled around the nucleus. But he didn't realize that when electrons move in a circle, they lost energy (Item 11, S7).

Transitional response

Transitional responses go beyond the positivist view in that students consider the new model (Blanco & Niaz, 1998). In other words, students think that scientific models are constructions of the scientist and not an absolute reality. For the questions (Items 1, 6, 10) that asked what is most important in each scientist's experiments, students mentioned the establishing of a new model of the atom. In addition, when they were asked to interpret the given experimental findings (Item 3, 7, 8), they related the experimental finding to a model of an atom:

[Rutherford] suggested an atomic model that includes the nucleus and the electrons surrounding it in the big space (Item 6, S11).

Bohr suggested a new model that considers an electron in terms of quantum theory (Item 10, S11).

Students also recognized the tentativeness of a scientific model, and they attempted to suggest unsophisticated alternative models. When students were given conflicting evidence, and asked to formulate alternative models (Items 4, 8), they showed a partial understanding of the need for alternative models.

It is interpreted that the different gases used would have different types of electrons with different mass and charges (Item 4, S2).

The atoms of the gold foil might not have any empty space (Item 8, S3).

Even though they recognize the tentativeness of scientific models, they cannot consider the previous model and the new model as competing research programs in the Lakatosian view. However, unlike the positivist responses, the students of this category agreed that the previous models represent the information at that time (Item 5). They said that the previous model played an important role at that time. They thought that the previous model was valuable compared to the advancement of science at that time.

An atomic model has been developed and modified. I think, at that time, Thomson's experiment was innovative. It was a big discovery, he developed the existence of electrons (Item 5, S21).

At that time, Thomson established the theory, and

Thomson's theory was very reasonable (Item 5, S22).

Lakatosian Responses

Students who presented Lakatosian responses did not consider the scientific model as an absolute reality, and they were willing to give up the model learned in textbooks when they were given conflicting evidence (Item 4, 8). They tried to clearly propose an alternative model:

The nucleus was about as big as the atom itself. The atom itself consists of a big particle charged positively (Item 8, S9).

The responses in this category went beyond emphasizing the hard facts of positivist responses and presenting unsophisticated models of transitional responses. Students were able to postulate the competing framework. They understood the relationship between two models as competing research programs in the Lakatosian view. They tried to explain the development of a scientific model with respect to rival research programs:

By discovering electrons, Thomson suggested the model of raisins in a pudding to represent the neutral atom based on the previous spherical atomic model (Item 5, S17).

Bohr's model supplemented a previous model by resolving the problems of previous models. Thus, Bohr suggested a more advanced atomic model (Item 10, S2).

When students explained the relationship between a previous model and a new model, they did not think that the experiments of the previous model contained mistakes (Item 9, 11). They say that a new model can be improved based on the previous research findings. In addition, they go beyond a Popperian falsification, and consider a new model with respect to heuristic power. For example, these students show the Lakatosian view that Rutherford's experiments give additional powerful explanation, i.e. greater heuristic power, beyond just refuting Thomson's theory.

I don't think Thomson made mistakes. Rutherford added the fact that the nucleus exists in the center of an atom into the theory of Thomson that electrons exist in the atom (Item 9).

I don't think Thomson made mistakes even though Thomson's model might be modified or converted totally by Rutherford. Thomson's model itself was a more advanced one compared to previous models (Item 9, S9).

Tendencies Found in Students' Responses

Overall, most Korean students were not likely to recognize the tentativeness of science. Most resisted the idea of a changing model even when they were asked to construct an alternative model. They considered the scientific model as an absolute reality. The lack of understanding in regards to the tentativeness of science is consistent with most previous studies that investigated students' understandings about the nature of science (Lederman & O'Malley, 1990; Liu & Lederman, 2003; Matkins, Bell, Irving, & McNall, 2002). This lack of understanding implies that the tentativeness of science should be directly dealt with in the nature of science instruction.

When Korean students compared two models, they considered that a previous mode was fallible and was replaced by a new model. To some extent, this tendency is close to a Popperian view. Even when students admitted the role of the previous model, they thought that the previous model was replaced by Popperian falsification. Students did not consider a new model as a competing research program. This finding implies that if we want to encourage students to have an understanding about science, we need to intentionally emphasize the Lakatosian view in the nature of science.

In addition, the students' responses were not consistent. The philosophical stance found in one item was not necessarily reflected in other items. The students' responses seemed to depend on the type and context of the question. Without considering ambiguous and no response, only two students consistently showed the positivist view in all items. Twenty-one students showed inconsistent responses: fourteen students showed positivist and transitional responses; two students showed the positivist and the Lakatosian view, and two students showed the three stances together.

V. Conclusions and Educational Implications

Most Korean students' responses in this study were categorized as positivist, some were transitional, and very few exhibited a Lakatosian view. One of the important reasons why most students presented positivist responses is related to the description in chemistry textbooks (Niaz et al., 2002). Most general chemistry textbooks in university and high school chemistry textbooks emphasize hard facts and experimental details. Even though atomic models are introduced in chronological order, the content does not include a Lakatosian perspective that is found in the actual development of atomic structure theory. In other words, the descriptions in chemistry textbooks lack historical and philosophical perspectives. Thus, students do not have a conceptual understanding about what the scientists were trying to do, and they likely simply tried to memorize the experimental details.

Niaz and colleagues (2002) reported that the percentage of Lakatosian responses increased when students were provided with various alternative responses including Lakatosian and transitional responses, and were asked to select their preference. This result could be possible because students had an opportunity to reflect on transitional/Lakatosian view. This research results also implies that if the content of textbooks provides a philosophical perspective on science in a well-organized way, then students' understanding about the nature of science can be improved. More concrete research is needed to analyze the content of textbooks related to historical contexts including atomic structure. Furthermore, the most effective way to present the history of science in textbooks should be investigated.

The responses of Korean students do not show a substantial difference from the responses of Blanco and Niaz (1998) in that most responses were categorized as positivist responses. It was assumed that Korean students had sufficient content knowledge of atomic structure. In addition, they had an opportunity to learn Lakatos's theory. The fact that did not show any difference implies that, even though the students have some instructional exposure to Lakatos's theory, they did not apply their knowledge about the philosophy of science into a concrete scientific context. This result suggests that the introduction of the nature of science into science education should be related to a specific scientific content.

The result that the students did not apply their knowledge about Lakatos's theory seems to be related to the way in which the theory was taught. The students learned Lakatos's methodology through lecture. Thus, students may not have been able to internalize the theory, and could not apply it to other contexts. Niaz and colleagues (2002) investigated the effect of the classroom discussion based on arguments that were designed to facilitate students' understandings of atomic structure. In the class discussion, they used items and alternative responses that were provided by the students in Blanco and Niaz (1998). During the study, the transitional/ Lakatosian responses, which were provided to students as alternative responses, helped students to better understand the atomic structure experiments. This result implies that students' philosophical stances are changeable, and that we can improve students' understanding of atomic structure in terms of Lakatosian view. At this stage, more concrete research is required to establish effective teaching strategies to improve students' understanding of scientific progress and practice.

The results of this study showed that a short period of teaching could not change students' conceptions about the nature of science. Most science teacher education programs in Korea do not have explicit courses to teach history and philosophy of science. Usually, during science method courses, the content related to nature of science is introduced for a short period. However, students' conceptions about nature of science are not easily changed (Lederman, 1992). Thus, teacher education programs need to develop the explicit courses to teach the nature of science. Through such courses, history and philosophy of science can be taught for extended period, which may lead to a substantial change in students' conceptions.

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