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Preservice Elementary Teachers' Beliefs about Nature of Science and Constructivist Teaching in the Content-specific Context

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The purpose of this study was to explore how Korean preservice elementary teachers' beliefs about nature of science (NOS) and their beliefs about constructivist teaching were structured and related and if any relation was prevalent in the content-specific contexts. As the same format, three versions of questionnaires were developed in three different science content topics, using episodes about rival theories in the history of science and students' relevant alternative conceptions. The data analysis suggests that the content context can partially affect teachers' beliefs about NOS and their beliefs about constructivist teaching. Additionally, no significant correlation between beliefs about NOS and constructivist teaching was found.

Keywords: pre-service elementary teacher, teacher beliefs, nature of science, constructivist teaching

INTRODUCTION

Over the past three decades, educational researchers have demonstrated that teachers' beliefs play an important role in their teaching practices in the classroom (Pajares, 1992; Luft, 1999; Mansour, 2009). As an important factor, research studies identified teacher beliefs concerning personal epistemologies (Kang, 2008), epistemological beliefs (Luft & Roehrig, 2007), nature of science (NOS) (Lederman, 2007; Kim & Yoon, 2013), inquiry (Wallace & Kang, 2004), science teaching and learning (Bryan, 2003; Levitt, 2002; Tsai, 2007), learning environment (Haney et al., 2003), and the teacher's and the student's role (Feldman, 2002). Consensus among researchers is that teacher beliefs are a complex system of several dimensions and thus individuals can hold sets of independent, interdependent, or sometimes contradictory beliefs. Rokeach (1986) described the structure of teacher beliefs with

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State of the literature

- Teacher beliefs have an important impact on teachers' teaching practices, but not necessarily consistent with teaching practices.
- The complexity of teacher beliefs is also attributed to the context-dependent nature since teachers' espoused beliefs play differently in context.
- Teachers' sophisticated beliefs about NOS are not necessarily translated into their practices.

Contribution of this paper to the literature

- Preservice teachers can be committed to holding and expressing contradictory beliefs based on how they perceive the context of science content.
- The content context can partially affect teachers' beliefs about NOS and their beliefs about constructivist teaching.
- The current findings support that a teacher belief system is composed of complex sets of more independent beliefs.

central beliefs, which are more important and resistant to change, and are the less important peripheral beliefs. Bryan (2003) used the metaphor of a bird's nest comprised of twigs to articulate the intertwining and interdependent nature of teacher beliefs.

In addition to multiple categories of teacher beliefs, the complexity of the role of teacher beliefs in teaching practices is attributed to the context-dependent nature of teacher beliefs. The interaction between cognitively perceived beliefs and actions is complex when a belief system plays out in context. Teachers negotiate differently in their commitment to their espoused beliefs with their perceived teaching contexts and thus, teachers' beliefs are not necessarily consistent with their practices (Bartos & Lederman, 2014; Bryan, 2003; Kang & Wallace, 2005; Savasci & Berlin, 2012).

As a dimension of a teacher belief system, teachers' beliefs about NOS has gained great attention in science education as a potential factor that affects teachers' practices (Brickhouse, 1989; Luft & Roehrig, 2007). The underpinning assumption is that different beliefs about science may lead to different interpretations of teaching and learning. Even though researchers used slightly different terms such as beliefs about NOS, epistemological beliefs, beliefs about science and beliefs about science, researchers have reported that how preservice and inservice teachers view science affects their decisions on instruction and their teaching practices (Bryan, 2003; Hashweh, 1996; Kang, 2008; Roehrig & Luft, 2004; Tsai, 2007; Yerrick et al., 1997). Yet, research evidence also indicates that sophisticated beliefs about NOS are not necessarily translated into their practices (Bartos & Lederman, 2014; Kang & Wallace, 2005). One of the important factors that affect teachers' beliefs about NOS and their translation into practice is the context of science content. Individuals' particular beliefs about NOS can differ depending on science topics (Abd-El-Khalick, 2001; Brickhouse et al., 2002) and teachers' NOS instruction can be hindered by their subject matter knowledge (Schwartz & Lederman, 2002). The findings from these studies indicate that individuals' beliefs about NOS assessed in the content-general context (e.g., does the scientific theory ever change?) should not be generalized to specific science content contexts (e.g., does the theory of evolution ever change?). In addition, teachers' teaching practices can be implemented in a constructivist teaching mode and also a transmission mode based on given science content contexts. Thus, it is important to assess teachers' beliefs in specific science content rather than in the content-general context in order to explore their beliefs about NOS and their beliefs about teaching.

Preservice teachers enter the education program with well-established beliefs about teaching and learning that are grounded in school science learner experiences (Nespor, 1987; Otero & Nathan, 2008; Pajares, 1992). To understand the complexity of preservice teachers' beliefs and its context-dependent nature, more research is necessary with regards on how different categories of beliefs are related, especially in the content-specific contexts. The purpose of this study was to explore the relationship between preservice teachers' beliefs about NOS and their beliefs about constructivist teaching in the context of different science topics. We sought to explain how preservice teachers' beliefs about NOS and their beliefs about constructivist teaching were structured and related and if any relation was prevalent in the content-specific contexts. Research questions that guided this study were: (1) What were preservice elementary teachers' beliefs about NOS? (2) Were preservice elementary teachers' beliefs about NOS consistent across different science content contexts? (3) What were preservice elementary teachers' beliefs about constructivist teaching? (4) Were preservice elementary teachers' beliefs about constructivist teaching consistent across different science content contexts? (5) What was the relationship between preservice elementary teachers' beliefs about NOS and their beliefs about constructivist teaching?

LITERATURE REVIEW

NOS

NOS typically refers to "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). Among many aspects of NOS, research on teacher beliefs has mainly focused on or identified whether teachers view science as dynamic and subject to revision or as multiple interpretations of reality (Kang, 2008; Kim & Yoon, 2013; Luft & Roehrig, 2007). These tentative and subjective (i.e., theory-laden) aspects of NOS are also key to the epistemological perspective of constructivism that reality exists but cannot be known (Tobin et al., 1994). Scientific knowledge is constructed by humans rather than discovered as a set of truths. From this epistemological perspective, scientific knowledge, especially scientific theories, is perceived as reliable and durable explanations for observable phenomena but is subject to change through new evidence or new theoretical advances (Lederman et al., 2002). In addition, scientific knowledge is partially subjective due to the theory-laden nature of observation (Lederman et al., 2002). Scientists' theoretical commitments, prior knowledge and experiences, and expectations influence their processes of knowledge development. Popper (1992) also asserted that science never starts with neutral observations. Therefore, sophisticated beliefs about the subjective aspect of NOS entail the recognition of multiple interpretations of the same phenomena and the evaluation of different interpretations in relation to contexts due to the theory-laden nature of observation (Hodson, 1996; Perry, 1970). This study focused on these two aspects of NOS: the tentative and subjective aspects of NOS.

Constructivist teaching

Constructivism is a widely accepted theoretical paradigm in science education. But constructivism is both an educational and epistemological theory, not a theory of teaching or curriculum design. So when discussing constructivist teaching, the pedagogical implications of constructivism should be applied. von Glaserfeld (1989) asserted two principles of constructivism:

> (1) Knowledge is not passively received but actively built up by the cognizing subject;
> (2) The function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality. (p. 114)

As these principles are applied to student learning contexts, it is evident that the key implication of constructivism is the role of students' prior knowledge in learning (e.g., Bransford et al., 1999; Otero & Nathan, 2008). So a teacher should accept students' alternative conceptions as the product of reasonable and personal sense-making rather than a barrier of learning that must be removed or replaced (Hamza & Wickman, 2008; Smith et al., 1993). In addition, eliciting students' ideas and providing opportunities for students to evaluate their ideas center on constructivist teaching practices (Baviskar et al., 2009). Otero and Nathan (2008) described how preservice teachers viewed students' prior knowledge of scientific concepts and how the preservice teachers' views influenced their instructional practices. When a preservice teacher perceived students' prior knowledge as resources for learning, they tended to modify their lesson plans to incorporate students' ideas and create learning opportunities for all students. On the other hand, some preservice teachers with responsive views did not revisit their lesson plans and carried on with their lessons without modifications on the basis of assessment data that elicited students' preconceived ideas. Thus, simply eliciting students' alternative conceptions does not suffice. Successful learning occurs when a teacher appreciate students' ideas and actually incorporates such ideas into instructional practices to support their learning (Ruiz-Primo & Furtak, 2007).

In this study, we defined constructivist teaching with two aspects: teachers' justification and pedagogy for alternative conceptions. Sophisticated beliefs about the justification and pedagogy aspects of constructivist teaching are justifying and accepting students' alternative conceptions as reasonable and personal sense-making and helping students to elicit, articulate, and evaluate their own ideas, respectively. It should be noted that these two aspects of constructivist teaching are well aligned with the main interests of previous research on teachers' beliefs about teaching and learning (e.g., Bryan, 2003; Kang, 2008; Luft & Roehrig, 2007; Tsai, 2002). For example, Luft & Roehrig (2007) illustrated sophisticated beliefs about how students learn science best as eliciting, encountering, and constructing their own ideas about phenomena. Yet, the context of this study is unique in that these beliefs about teaching should be expressed with regards to how to deal with students' specific alternative conceptions of particular science topics, rather than how to teach general science topics. In this study, therefore, teachers' beliefs about constructivist teaching refer to how they perceive and instructionally support students' knowledge in the content-specific contexts while NOS is about scientists' knowledge.

The relationship between beliefs about NOS and constructivist teaching

Few can dispute that teachers' beliefs influence their actions. Some research has shown that teachers' epistemological beliefs about science tend to reflect their teaching practices (e.g., Bennett & Park, 2011; Brickhouse, 1989; Tsai, 2007). A teacher who holds naïve beliefs about NOS is more likely to possess epistemologically consistent beliefs about teaching and learning and implement traditional teaching orientations. However, research on the role of teachers' beliefs about science in teaching practices indicated that their relation was not necessarily consistent (e.g., Bryan, 2003; Kang, 2008; Kang & Wallace, 2005). Especially when teachers hold sophisticated beliefs about NOS, their beliefs do not guarantee constructivist teaching in their science instruction.

Without examining teaching actions, some research has been more focused on the relationship among teacher beliefs about science, teaching, and learning (e.g., Hashweh, 1996; Kim & Yoon, 2013; Tsai, 2002). The findings from these studies lead to the inference that teachers' beliefs about NOS and their beliefs about teaching science are more likely to be closely aligned with each other when teachers hold naïve beliefs about both constructs. These research studies provide a better picture of how different categories of teachers' beliefs are related. But their findings are limited to inservice teachers and, in most of the studies, the relationship between beliefs about NOS and teaching was explored in content-general contexts.

From the literature on teacher beliefs, researchers often explore and assess teachers' beliefs about NOS without considering content contexts, which seemingly implies content-independent NOS. But an extensive amount of evidence has been obtained in favor of the content-dependent NOS. Individuals' beliefs about NOS can vary in different content contexts: familiar versus unfamiliar content (Abd-El-Khalick, 2001), the theory of gravity versus the Big Bang Theory (Brickhouse et al., 2002), photosynthesis versus human evolution (Sinatra et al., 2003), psychology versus chemistry (Hofer & Pintrich, 1997), and different fields of science (Ryder et al., 1999). With respect to teaching NOS, teachers' informed beliefs about NOS were not consistently translated into their NOS instruction in the context of teaching particular science content topics (Akerson & Abd-El-Khalick, 2003; Schwartz & Lederman, 2002). These NOS studies suggest that preservice teachers may hold different or contradictory beliefs about NOS in diverse content contexts. In addition, these findings raise a question regarding whether preservice teachers' beliefs about teaching science is content-dependent as well. Akerson and Abd-El-Khalick (2003) reported that one elementary teacher who held informed beliefs about NOS often had difficulty incorporating NOS aspects into particular science content that she viewed as factual knowledge (e.g., the model of the earth). Similarly, science teaching practices can differ in content contexts. For example, Kang (2008) found that some preservice teachers' teaching practices were not in alignment with their beliefs for multiple reasons; one of which was the preservice teacher's content knowledge. When a preservice teacher was not knowledgeable about a targeted content topic, the preservice teacher implemented a traditional pedagogy with one-way communication from teacher to student. Therefore, the relationship between preservice teachers' content-specific beliefs about NOS and constructivist teaching is still worth investigating.

METHODS

Participants

A total of 173 Korean preservice elementary teachers from a university elementary teacher education program participated in this study. The participants were junior undergraduate students (40 male and 133 female students) who enrolled in Science Methods Course II. During the first two years of the elementary education program, the participants took two general science courses (two semester hours for each) and Science Methods Course I, which covered science content in elementary science curricula and the introduction of several instructional strategies. No specific courses about NOS were offered during the first two years of the program. The participants' concentration subjects varied, but about 65 percent of participants' subjects were art, music and physical education. Only 14 percent of participants selected science as a concentration and the other 21 percent from math and practical arts.

Procedure and data collection

This study was conducted as a survey study. Previous case studies relying on interviews and observations were significant to presenting a clear picture of the relationship between beliefs and practice in context (e.g., Wallace & Kang, 2004). Such studies required interpretations to be drawn from teachers' actions because researchers sought to ascertain beliefs implicit in actions. The intention in this study was to explore a large number of participants' espoused beliefs about NOS and teaching, and to test the relation between these two categories of views with inferential statistics. Thus, this study was conducted as survey research involving the data collection through participants' responses to open-ended questions.

We developed a questionnaire for this particular study. We assumed that teachers' beliefs about NOS and their beliefs about constructivist teaching were contextualized. When developing a questionnaire, the first step was to set content contexts. Although there are different kinds of scientific knowledge, the nature and the role of scientific theories has been an integral component of NOS assessments (see Lederman, 1992). Thus, we sought well-known scientific theories that Korean national standards covered in grades K-8 by assuming that topics covered in these grade levels would be familiar and understandable to preservice teachers. We also considered the subject areas such as biology, physics, and chemistry and students' common alternative conceptions which have been well identified from previous studies (Wandersee, 1994). Three topics were selected; evolution (the theory of evolution), force and motion (the principle of inertia), and heat transfer (the theory of heat). The second step was to develop episodes about rival theories in the history of science and in a science class. Research on students' alternative conceptions has reported that there is a parallelism between students' alternative conceptions and the history of scientific ideas (Wandersee, 1985). Three episodes of rival theories in the history of science were developed: Darwin's theory of evolution by natural selection vs. Lamarck's use/disuse theory, the impetus theory vs. the principle of inertia, and a caloric theory vs. a theory of heat. These episodes of rival theories were applied to teaching episodes in which a teacher confronted students' alternative conception. For example, one of teaching episodes was the situation when a student expressed an alternative conception similar to Lamarck's use/disuse against a teacher's explanation about Darwin's natural selection. After providing this episode, preservice teachers were asked about their instructional plan to help such students.

Finally, questionnaire items were developed. For NOS, items from the Beliefs about Nature of Science questionnaires (Lederman et al., 2002) were adopted and revised. Two subjective NOS items (Items 1 & 2) and one tentative NOS item (Item 3) were finally formed. Three items were developed to assess the aspects of beliefs about alternative conceptions: justification of alternative conceptions (Item 4), and pedagogy for alternative conceptions (Items 5 & 6). All items were applied to the three different content contexts as the same format (See Appendix). As a result, three versions of questionnaires were developed: Questionnaire A (evolution), B (force and motion), and C (heat transfer). The face validity of the NOS questionnaire was established by conducting a pilot test with 15 preservice elementary teachers. After two rounds of review processes, all items were finalized. During a science methods class, the three versions of the questionnaire were administered and each participant was randomly selected and asked to fill out one of them. After data collection, 59, 56, and 58 participants completed Questionnaire A, B, and C, respectively.

Data analysis

We jointly developed descriptive codes from the participants' responses to the questionnaire items. Participants' written responses were all word-processed for analysis. After several rounds of data analysis, eight to ten descriptive codes were developed for each aspect of the two constructs (Table 1). We then clustered similar codes and categorized them into four ordinal scales: (a) Informed Views: a response that clearly reflected a more informed view and was well articulated (3 points); (b) Partially Informed or Mixed Views: a response that partially reflected an informed view but was poorly articulated or that mixed an informed and a naïve view (2 points); (c) Naïve Views: a response that fully reflected a more naïve view (1 point); and (d) no response or response without any explanation (0 points). Inevitably, there was a discrepancy between our ratings with some responses that we categorized into either informed or partially informed and into either mixed or naïve. All disagreements were resolved through discussion to determine a final score.

Table 1. Descriptive data codes from the responses to the questionnaire items

NOS	
Subjectivity	Different interpretation of data and difficult to determine which theory was more valid due to: scientists' background knowledge, religious beliefs, social/cultural environment, authorities, scientists' ignorance, no technology, no direct observation, having wrong ideas, having different data, no reasons. Easy to determine which theory was more valid due to proving evidence, technology, and experimentation.
Tentativeness	Subject to change due to: new evidence, new/different interpretations or theories, disproving/abnormal data, the lack of proving evidence, the invisibility, nothing true, pattern of history of science, no reasons. No change due to: its certainty, no reasons.
Constructivist Teaching	
Justification of Alternative Conceptions	Valid based on students' experiences, a possible alternative idea, a wrong idea, a non-scientific idea, the lack of scientific knowledge, observation/experience-based, non-experimental idea
Pedagogy for Alternative Conceptions	Judging a student's alternative conception, helping students express their own ideas, accepting students' ideas, helping students become aware that their ideas are not working, comparing students' ideas with a scientific one, challenging students' ideas, judging a student's ideas, not dealing with students' ideas, providing a clear explanation, explaining why students' ideas are wrong.

Informed beliefs about the subjective NOS are in light of the notion that scientific knowledge is constructed by scientists. The subjective NOS represents the theory-laden nature of observation and the recognition of multiple interpretations of the same phenomena, attributed to scientists' background knowledge and commitments, and social or cultural influences. Unlike the informed views, naïve beliefs about the subjective NOS focus on science as the objective true representation of reality such as seeing is believing (Chalmers, 1999). Based on this naïve notion, old theories are considered invalid and non-scientific, and are often ascribed to scientists' ignorance. Multiple interpretations are viewed as the result of the lack of definite evidence or advanced technology. Informed beliefs about the tentative NOS represent science as evolving and subject to change due to new empirical evidence, an emerging new theory, and advances in technology. In this regard, scientific theories are viewed as the most valid explanations for observable phenomena. Naïve beliefs about the tentative NOS are associated with beliefs in certain and absolute knowledge. These absolutist beliefs about science often bring a misconceived view that scientific theories are neither legitimate scientific products nor proven explanations.

Informed beliefs about constructivist teaching are well aligned with reform-based perspectives and pedagogies. Informed beliefs about the justification aspect focus on the validity of students' ideas which are contextualized in students' experiences or within their conceptual framework. Based on these views, students' alternative conceptions should be accepted and admitted as a reasonable explanation accountable for certain phenomena or empirical experiences. On the other hand, it is regarded as naïve that students' alternative conceptions are faulty ideas since they are incomparable with the scientific ones.

With regards to the pedagogy aspect of constructivist teaching, informed views focus on helping students elicit and evaluate their own ideas through active processing such as engaging in inquiry projects and reflective discussions. The key goal of instruction is to provide opportunities for students to articulate, use, justify, and revise their ideas based on evidence by letting them control their learning rather than imposing a scientific explanation on students through being passive listeners. Naïve beliefs about pedagogy reflect beliefs that students' alternative conceptions will disappear when clear instruction is delivered. This view considers a scientific concept a transmittable entity and is aligned with transmissional teaching modes. Thus, instructional goals aim to logically and clearly explain why students' alternative conceptions are wrong and why a scientific concept is correct. Sometimes those who hold such views believe that science instruction should not deal with students' alternative conceptions.

It should be noted that participants' responses to all NOS items were cross-checked to secure a more valid interpretation of what their responses meant in each NOS item. The same cross-checking process was also applied to the items for beliefs about constructivist teaching. This analysis of responses to NOS and constructivist teaching items does not imply a restrictive one-to-one correspondence between each item and its target aspect of NOS or constructivist teaching.

To test the statistical significance of the difference of participants' beliefs about NOS and their beliefs about constructivist teaching in the three different contexts of science content, a Chi-squire test of independence, a non-parametric statistical hypothesis test, was performed. Kendall's tau rank correlation coefficient was calculated to find the correlation between participants' beliefs about NOS and their beliefs about student alternative conceptions. The level of significance was .05, which is a generally accepted level in educational research.

RESULTS

Beliefs about NOS

Subjective NOS

The analysis of beliefs about NOS indicates that only 21% of participants possessed informed beliefs about the subjective NOS (Table 2). They attributed scientists' different theories to their background knowledge, experiences, and/or theory-laden observations. One participant stated that:

> Even though the same phenomenon is given, scientists who interpret the phenomenon think differently. It is because scientists' own previous experiences are different and their scientific imagination would also be different. (C29-Q1)[1]

With respect to whether scientists could determine which theory was more valid when two rival theories were accountable for certain natural phenomena, this informed group of participants believed that it is not a simple task to evaluate the superiority of two rival theories if they are supported by their own empirical evidence. One sample response reads, "Since each theory had its own evidence to support it, I believe that they (biologists) could not definitely determine which theory was more valid (A56-Q2)."

On the other hand, more than a third of participants (36%) held naïve beliefs about the subjective NOS. They ascribed scientists' subjectivity to the lack of definitive data and advanced scientific knowledge or to the fact that a given theory was not proven.

Table 2. Frequency and percentages of each score for beliefs about NOS

	Subjective NOS		Tentative NOS	
Score	**Frequency**	**%**	**Frequency**	**%**
3	36	21	29	17
2	71	41	104	60
1	62	36	37	21
0	4	2	3	2
Total	173	100	173	100

Note. 3-Informed views, 2-Partially informed or mixed views, 1-Naïve views, 0-No response

[1] Group Letter, Participant # and Question #

> [It is because the theories] were not proven. At the time, people were often superstitious so they might think in such a [non-scientific] way. In addition, since scientific knowledge at the time was not well developed there was the limitation of scientists' explanations. (B17-Q1)

These participants also tended to believe that two rival theories were debated because of a lack of definitive evidence and scientific logic without considering scientists' subjectivity such as theory-laden observations. One sample response reads, "Scientists could not be sure [which theory was superior to the other] because it was impossible to conduct an experiment that could prove something invisible (C20-Q2)."

Forty-one percent of participants were categorized as Score 2, partially informed or mixed views. They often possessed mixed views in which they believed that scientists' different points of views or experiences could bring about different interpretations of the same data set, but also believed that scientists could objectively determine which theory was right with definite data.

Tentative NOS

Table 2 shows that only 17% of participants held informed beliefs about the tentative NOS. They considered not only new discoveries or data in theory change, but also a new theory. In addition, they believed that a current theory is accepted and supported because it has been proven not to be true, but most valid.

> When disconfirming evidence is accumulated for the theory of natural selection and its rival theory obtains more evidence to support, this [natural selection] theory will be destined for demise in the scientific community. (A17-Q3)

On the other hand, 21% of participants possessed naïve views. They explicated that scientific theories were already proven knowledge. One stated, "Inertia is a law that has been proven to be true with many experiments (B7-Q3)." Or, some of them viewed the term theory as unproven knowledge:

> [The theory of evolution by natural selection] is scientific knowledge that will change. It is just a hypothesis. It is not objective knowledge that was scientifically proven…Therefore, this hypothesis can change at any time. (A6-Q3)

More than half of the participants (60%) were categorized as Score 2, partially informed or mixed views. They simply viewed that scientific knowledge could change in the future due to new data and/or the development of new technologies with no more articulation about the process of theory change or the role of a new theory. They also often stated that "there is no perfect knowledge" and "all knowledge is subject to change."

Beliefs about NOS in different content contexts

The participating preservice teachers were divided into three groups: Group A, B, and C based on what questionnaire version they completed. Each group filled out Questionnaire A, B, and C, respectively. The Chi-squire analysis reveals there was no significant difference in participants' beliefs about the subjective NOS between Group A and Group B ($p > .05$). However, it was found that participants' beliefs about the subjective NOS in Group C were significantly different from both Group A and Group B ($X^2 = 13.6$, $p < .05$; $X^2 = 13.2$, $p < .05$, respectively). There were more naïve beliefs about subjective NOS in the context of the theory of heat than evolution and inertia. The frequency of each descriptive code for participants' responses indicates that about 30% of participants in Group C believed that scientists proposed two different theories (i.e., the caloric theory and the kinetic theory) because they could not observe the existence of caloric or heat. As a result, they tended to believe that scientists could not validate or prove any theories, which brought out a continuous debate over these two theories. A sample response to two items is as follows:

> If theories don't have definitive and visible evidence that disproves other rival theories, any theories cannot be determined as valid. (C23-Q2)

Unlike the subjective NOS, no significant difference of participants' beliefs about the tentative NOS was found among the three groups (p>.05).

Beliefs about constructivist teaching

Justification of alternative conceptions

As shown in Table 3, only 15% of participants held informed views for the aspect of justification of alternative conceptions. They valued the student's alternative conception, as described on the questionnaire, because it was deduced from their personal experience. Their point of view suggests that students' ideas can be evaluated based on their evidence or support rather than authority.

> Since [the student] inferred it from his own experience, it is valid as his own way. [It is because his idea] was backed up by something that it made sense to others. (B12-Q4)

As shown in Table 3, 32% of participants possessed partially adequate views. These participants were not explicit about the relationship between the student's idea and his personal experience. But, they conceived the student's idea as making sense enough for his age. One stated, "It makes sense because [he] tried to explain invisible mechanism (C39-Q4)."

Almost half of the participants (49%) endorsed naïve beliefs about justification of alternative conceptions. Twenty-three percent of participants pointed out that a student's alternative conception was not consistent with a scientific theory so it was eventually wrong. They disregarded whether a student had any evidence to support his or her idea.

> The student's conception is wrong. A projectile travels with a parabolic trajectory not because of the force saved inside of the object, but the downward force of gravity. (B26-Q4)

The other 26% of participants claimed that a theory tied to a student's alternative conception was valid because they personally believed the theory was valid.

> [The student's idea] is valid in itself. Personally, I believe that Lamarckism and Darwinism work together. Within the scope of individual organisms, they evolve by adapting to the natural environment [as the process of Lamarckism evolution]. But within the scope of species organisms, those who adapt better to the same environment can survive. So [the student's idea] is valid enough. (A15-Q4)

This response clearly reveals that the respondent did not have an adequate understanding of the relevant theory. She justified the student's idea based on her personal knowledge of the given theory and disregarded how the student supported his idea.

Table 3. Frequency and percentages of each score of beliefs about constructivist teaching

	Justification of Alternative Conceptions		Pedagogy for Alternative Conceptions	
Score	**Frequency**	**%**	**Frequency**	**%**
3	26	15	24	14
2	56	32	53	31
1	85	49	90	52
0	6	3	6	3
Total	173	100	173	100

Note. 3-Informed views, 2-Partially informed or mixed views, 1-Naïve views, 0-No response

Pedagogy for alternative conceptions

When preservice teachers were asked if it is appropriate to point out a student's alternative conception as wrong (Item 5) and how a respondent would enact the rest of the lesson (Item 6), only 14% of participants articulated informed views. They regarded students' alternative conceptions as valid ideas. They placed more emphasis on having students evaluate various ideas, including their own, than on teaching students a correct concept. Here are one participant's responses to Items 5 and 6:

> It is not appropriate [to point out a student's idea is wrong.] The teacher seems to impose the currently accepted theory on students. A teacher should respect students' ideas because people can interpret the same phenomena differently. (A59-Q5)
>
> People can provide different interpretations on the same research results or phenomena….I would have students come up with various solutions, as scientists do, and then ask students what would be the most valid explanation. And I would lead a classroom discussion to draw a reasonable conclusion. (A59-Q6)

Thirty-one percent of participants were categorized as partially informed or mixed views. They also admitted that students' alternative conceptions can be valid ideas, but current theories are more valid and accepted than students' ideas. These participants did not necessarily view students' alternative conceptions as wrong or needing to be fixed.

> I would let students know that current scientists view the kinetic theory as more valid and getting more support [than the caloric theory.] I would provide students with concrete experiments to compare the caloric theory to kinetic theory and help them realize the difference between these two theories. (C48-Q6)

About half of the participants (52%) held naïve beliefs about dealing with alternative conceptions. They did not count students' alternative conceptions as valid, but as wrong. So their teaching activities were more aimed to fix their alternative conceptions.

> I will listen to students' ideas and then explain a scientific concept by providing counterexamples of their misconceptions. (B56-Q6)

Beliefs about constructivist teaching in different content contexts

A Chi-square test was performed to determine if preservice teachers' beliefs about constructivist teaching distributed differently across the three different content contexts. The test failed to indicate a significant difference between Group B and Group C. This means preservice teachers in these two groups held beliefs about constructivist teaching in a similar distribution pattern across different content contexts.

However, this was not the case with Group A. The distribution of beliefs about constructivist teaching in Group A was significantly different from Group C in the justification of alternative conceptions (X^2 = 8.1, $p < .05$). More naïve beliefs about justification of alternative conceptions were identified in Group A than Group C. This indicates that more preservice teachers expressed naïve beliefs about justification of alternative conceptions in the context of the theory of evolution than the theory of heat. No significant difference was found between Group A and Group B.

Interestingly enough, more preservice teachers in Group A held informed beliefs about pedagogy for alternative conceptions and it was significant compared to both Group B and C (X^2 = 21.1, $p < .05$; X^2 = 13.0, $p < .05$, respectively). This result appears to be controversial in that more naïve beliefs about justification of alternative conceptions resulted in more informed beliefs about pedagogy for alternative conceptions for Group A as compared to other groups.

In order to obtain more valid interpretation of these results, we conducted an additional analysis of preservice teachers' responses. We found that their responses to the questionnaire often revealed their conceptions of the three different theories and written responses from some participants did not seem to align with scientific concepts. In the context of evolution, for example, some participants expressed that they believed the theory of use/disuse was true. It was evident that about half of preservice teachers in Group A appeared to possess alternative conceptions in favor of Lamarck's use/disuse theory. This seemed to be a significantly large number, compared to Group B (17 %) and C (15%) in favor of the impetus and caloric theory, respectively. As a result, they were more likely to evaluate the student's alternative conception as valid by describing how and why Lamarck's theory was right, which was evaluated as naïve beliefs. When preservice teachers had similar alternative conceptions, interestingly their instructional plans tended to be more constructivist teaching modes by acknowledging students' ideas.

Relationship between beliefs about NOS and constructivist teaching

The two aspects of NOS and the two aspects of constructivist teaching were cross-checked by performing Kendall's tau test, a nonparametric measure of the correlation (Table 4). This test revealed that there was no significant correlation between any aspects of NOS and aspects of constructivist teaching (p >.05).

It was not evident that participants who held informed or naïve beliefs about NOS also expressed informed or naïve constructivist teaching modes, respectively. For example, one participant who held informed beliefs about the subjective aspect of NOS, stating that "scientists have different thoughts and backgrounds so they can have different views of what they observe and both can make valid interpretations" (B1-Q1). However, she expressed naïve beliefs about teaching, saying that "The teacher should tell the student that his (alternative) conception is incorrect" (B1-Q6).

DISCUSSION

A teacher belief system is described as a complex set of several dimensions of beliefs that can be independent, interdependent, or contradictory (Pajares, 1992). The complexity of teacher beliefs is also attributed to the context-dependent nature since teachers' espoused beliefs play differently in context (Kang, 2008). Among diverse types of context, the current study has shown that the content context can partially affect teachers' beliefs about NOS and their beliefs about constructivist teaching. Additionally, the current findings support that a teacher belief system is composed of complex sets of more independent beliefs.

Beliefs about NOS

Compared to relatively consistent beliefs about the tentative NOS across the three different content contexts, the preservice teachers explicated significantly more naïve beliefs about the subjective NOS in the context of the theory of heat than evolution and inertia. This result appears to contrast the previous finding that

Table 4. Values of Kendall's tau-b between aspects of NOS and constructivist teaching

	Constructivist Teaching	
	Justification	**Pedagogy**
Subjective NOS	.091	.084
Tentative NOS	.131	.075

Note. N = 173. All coefficients are not statistically significant at the p < .05 level.

knowledge in biology is considered more certain, so less subjective, than knowledge in physical science (Brickhouse et al., 2002). It may seem reasonable to interpret the results beyond domains such as biology and physics. The current and previous findings indicate that the aspect of direct observation seems to be associated with more objectivity and less subjectivity. The preservice teachers in this study ascribed scientists' subjectivity to the lack of the visibility of a theoretical entity (i.e., caloric) more than scientists' different theoretical commitments or background. The college students in the study of Brickhouse et al. (2002) perceived evidence in biological science as being tangible and involving observable objects less subjective than ones in astronomy.

In research on domain-specific epistemological beliefs about knowledge, science is described as a well-structured domain or a hard field, compared to other ill-structured domains or soft fields such as history and psychology (see Buehl & Alexandra, 2001). The current findings suggest that individuals' epistemological beliefs about knowledge can vary in accordance with the features of a specific content topic within the same domain. This finding is supportive of the previous findings of research on NOS such as familiar versus unfamiliar content (Abd-El-Khalick, 2001), the theory of gravity versus the Big Bang Theory (Brickhouse et al., 2002), and photosynthesis versus human evolution (Sinatra et al., 2003). However, there were no statistically significant differences of the preservice teachers' beliefs about the tentative NOS across three different theories and of their beliefs about the subjective NOS between the contexts of the evolution and the inertia contents. Thus, these insignificant results indicate that preservice teachers' beliefs about NOS may be composed of both a content-specific and a content-general aspect (Hofer, 2000). As such, preservice teachers may negotiate differently in their commitment to their content-specific and content-general beliefs about NOS in their perceived content contexts.

Beliefs about constructivist teaching

With regard to beliefs about constructivist teaching, the current results partially support the content-dependency of teacher beliefs. The preservice teachers significantly expressed more naïve beliefs about the justification aspect and more informed beliefs about the pedagogy aspect in the context of the evolution content than the contents of heat and inertia. But, there were no statistically significant differences of their beliefs about constructivist teaching between the theory of heat and the principle of inertia. More data analysis indicated that the preservice teachers' beliefs about constructivist teaching appeared to be affected by their understanding of content knowledge. Those who possessed the same alternative conception (i.e., Lamarck's use/disuse theory; Ha and Nehm, 2014) as a student's tended to defend the student' alternative conception rather than seek the reasoning or evidence embedded in the student's claim. But in a positive way, the credibility of the alternative conception was reflected as more constructivist teaching modes of teaching, which focus on eliciting and evaluating different ideas. Though it may seem plausible to attribute the inconsistency of beliefs about constructivist teaching across different content topics to the inadequate understanding of content knowledge, this may be too simple an explanation. A teacher's content knowledge may not be necessarily congruent with the teacher's evaluation of the credibility of the content knowledge (e.g., Sinatra et al., 2003). Regardless of whether a teacher possesses an adequate or inadequate understanding of particular content knowledge, the credibility of the knowledge evaluated by the teacher should be taken into consideration.

Relations between beliefs about NOS and constructivist teaching

Some research on teacher beliefs suggests that different categories of beliefs are intertwined (e.g., Tsai, 2002). The current study sought the relation between beliefs about NOS and constructivist teaching, in particular science content contexts, but no statistically significant results were found. This result reinforces a view of teacher beliefs as a set of more or less independent and separate categories of beliefs (Pajares, 1992), at least when it comes to beliefs about NOS and constructivist teaching. Preservice teachers holding informed beliefs about NOS may possess naïve beliefs about constructivist teaching simultaneously and vice versa, in specific science topics. For example, an adequate view of scientists' multiple interpretations of data is not necessarily reflected in the context of accepting students' alternative conceptions and implementing constructivist teaching approaches. This finding corresponds to some previous research findings with preservice teachers (e.g., Bryan, 2003; Kang, 2008). Kang found that more than half of the preservice teachers holding tentative beliefs about science endorsed the passive role of the science learner, and some of them ignored students' alternative ideas. Bryan (2003) reported a preservice teacher's two contradictory nests of beliefs about teaching and learning science.

But the current finding appears to be in contrast to other research studies (e.g., Kim and Yoon, 2013; Tsai, 2002). More than half of the teachers from Tasi's study and about 40 percent of the teachers from Kim and Yoon's study held closely aligned beliefs about NOS, learning, and teaching science. These contradictory findings seem to be ascribed to the research context of these two studies. The two studies were conducted with inservice teachers who already had teaching experiences and the teachers' beliefs were assessed through interviews in the content-general context. As aforementioned, the preservice teachers in the current study held partially inconsistent beliefs about NOS and constructivist teaching across different science topics, which may negatively affect the correlation between their beliefs about NOS and their beliefs about constructivist teaching.

The current results about beliefs about NOS and constructivist teaching indicated that the majority of preservice teachers held informed beliefs about neither NOS nor constructivist teaching. They explicated either mixed or naïve beliefs about NOS and constructivist teaching. These results are not surprising, considering what science educators have reported in previous research on teachers' beliefs about NOS (Lederman, 2007), preservice teachers' beliefs about students' prior knowledge (Otero & Nathan, 2008), and teachers' beliefs about teaching science (Kim & Yoon, 2013; Tsai, 2002). Preservice teachers already hold well-established knowledge and beliefs about teaching and learning that have been shaped by their participation as students in science classrooms for many years (Pajares, 1992; Richardson, 1996). Thus, the present results are not unexpected since preservice teachers' beliefs about NOS and constructivist teaching may reflect their previous school experiences that may be tied to conventional methods of teaching and learning science.

IMPLICATIONS FOR TEACHER EDUCATION

The current findings about the content-dependency of preservice teachers' views imply that preservice teachers can be committed to holding and expressing contradictory beliefs based on how they perceive the context of science content. Preservice teachers may intuitively judge the certainty of scientific knowledge by considering the visibility of theoretical entity or the credibility of knowledge claims. As such, preservice teachers' beliefs about NOS and their beliefs about constructivist teaching can vary in different forms of scientific knowledge and claims; based on the degree of certainty such as scientific facts, concepts, theories, and laws (Lederman, 2007), based on observation versus unobservable hypothesized causes (Lawson, 2002), or based on the degree of credibility that preservice teachers evaluate (Sinatra et al., 2003). From the perspective of conceptual change (Baviskar et al., 2009), preservice teachers' inconsistent beliefs about NOS and constructivist teaching can be meaningful learning resources in that they can realize their existing views vary in different content topics. In helping preservice teachers improve their beliefs about NOS and constructivist teaching, it seems imperative to explicitly address the aspects of NOS and constructivist teaching approaches in diverse content contexts. For example, it has been well reported that teachers often hold different beliefs about NOS in the context of scientific theories and scientific laws (Lederman, 2007). As such, it would be more effective to explicitly teach sophisticated beliefs about NOS in the context of relatively less certain or debatable scientific claims first and then shift the NOS instruction to the science contents that have a higher level of certainty. Similarly, the constructivist teaching perspectives and approaches may need to be addressed to preservice teachers first in the ill-structured content contexts in which various credible ideas are generated. As shown in the present results, when preservice teachers perceive two rival claims as equally credible, their informed beliefs about constructivist teaching are endorsed. Thus, in the less certain or ill-structured content context, preservice teachers may be able to readily assimilate constructivist teaching modes into their knowledge structures, which can be challenged in later instruction for the more structured content topics.

The present findings about preservice teachers' beliefs about NOS and constructivist teaching are not promising. The preservice teachers do not hold informed views and their beliefs about NOS are not correlated to their beliefs about constructivist teaching. Thus, helping preservice teachers improve their beliefs about NOS does not guarantee the enhancement of their beliefs about constructivist teaching and vice versa. Beliefs about NOS and teaching may not necessarily develop in synchrony. The discrepancy between preservice teachers' beliefs about NOS and their beliefs about constructivist teaching may play a negative role in their learning to teach. From the literature, it is not expected to observe constructivist teaching practices from a teacher who holds absolutist beliefs about NOS. It is more likely that a teacher's naïve beliefs about NOS interfere with the teacher's constructivist teaching (Kang & Wallace, 2005; Tsai, 2007). In addition, a coherent belief system is also found to be crucial to teaching confidence. Waters-Adams (2006) asserted that when elementary teachers hold onto deep and consistent beliefs about how to teach science, NOS, and general pedagogical strategies, they acquire confidence of teaching science. Therefore, the efforts to help preservice teachers change their beliefs toward more sophisticated ones should include instructional plans to address multiple categories of beliefs together, such as NOS and constructivist teaching. Among many pedagogical efforts may be the integration of NOS into the instruction for constructivist teaching perspectives and approaches in science teaching methods courses. Such integrated instruction may include explicit-reflective discussion (e.g., Bartos & Lederman, 2014) and epistemic discourse (e.g., Christodoulou & Osborne, 2014; Duschl, 2003) with regards to constructing, justifying, and evaluating students' own claims as well as scientists'. As the current study has shown, preservice teachers' informed beliefs about multiple interpretations attributed to scientists' background knowledge does not necessarily reflect informed beliefs about justifying students' alternative conceptions as the product of their personal sense-making. Preservice teachers' inconsistent views between NOS and constructivist teaching urges teacher educators to be more explicit about addressing the aspects of NOS and constructivist teaching together if we expect them to hold more consistent beliefs about science and teaching science.

REFERENCES

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science courses: Abandoning scientism, but…*Journal of Science Teacher Education, 12*(3), 215–233. doi: 10.1023/A:1016720417219

Akerson, V. L., & Abd-El-Khalick, F. (2003). Teaching elements of nature of science: A yearlong case study of a fourth-grade teacher. *Journal of Research in Science Teaching, 40*(10), 1025–1049. doi: 10.1002/tea.10119

Bartos, S. A., & Lederman, N. G. (2014). Teachers' knowledge structures for nature of science and scientific inquiry: Conceptions and classroom practice*, Journal of Research in Science Teaching, 51*(9), 1150–1184. doi: 10.1002/tea.21168

Baviskar, S. N., Hartle, R. T., & Whitney, T. (2009). Essential criteria to characterize constructivist teaching: Derived from a review of the literature and applied to five constructivist-teaching method articles. *International Journal of Science Education, 31*(4), 541–550. doi: 10.1080/09500690701731121

Bennett, W. D., & Park, S. (2011). Epistemological syncretism in a biology classroom: A case study. *Journal of Science Education and Technology, 20*(1), 74-86. doi: 10.1007/s10956-010-9235-6

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academies Press.

Brickhouse, N. W. (1989). The teaching of the philosophy of science in secondary classrooms: case studies of teachers' personal theories*. International Journal of Science Education, 11*(4), 437–449. doi: 10.1080/0950069890110408

Brickhouse, N. W., Dagher, Z. R., Shipman, H. L., & Letts, W. J. (2002). Evidence and warrants for belief in a college astronomy course. *Science & Education, 11*(6), 573–588. doi: 10.1023/A:1019693819079

Brickhouse, N.W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53–52. doi: 10.1177/002248719004100307

Bryan, L. A. (2003). Nestedness of beliefs: Examining a prospective elementary teacher's belief system about science teaching and learning. *Journal of Research in Science Teaching, 40*(9), 835–868. doi: 10.1002/tea.10113

Buehl, M. M., & Alexander, P. A. (2001). Beliefs about academic knowledge. *Educational Psychology Review, 13*(4), 385–418. doi: 10.1023/A:1011917914756

Chalmers, A. F. (1999). Science as knowledge. In *What is this thing called science?* Queensland: University of Queensland Press, Ch. 1, pp. 1–18.

Christodoulou, A., & Osborne, J. (2014). The science classroom as a site of epistemic talk: A case study of a teacher's attempts to teach science based on argument. *Journal of Research in Science Teaching, 51*(10), 1275–1300. doi: 10.1002/tea.21166

Duschl, R. A. (2003). Assessment of inquiry. In J.M. Atkin & J.E. Coffey (Eds.), *Everyday assessment in the science classroom* (pp. 41–59). Washington, DC: National Science Teachers Association Press.

Feldman, A. (2002). Multiple perspectives for the study of teaching: Knowledge, understanding and being*. Journal of Research in Science Teaching, 39*(10), 1032–1055. doi: 10.1002/tea.10051

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome and N. G. Lederman (Eds.), *Examining pedagogical content knowledge: the construct and its implications for science education,* (pp. 3–17). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Ha, M., & Nehm, R. H. (2014). Darwin's difficulties and students' struggles with trait loss: Cognitive-historical parallelisms in evolutionary explanation. *Science & Education, 23*(5), 1051–1074. doi: 10.1007/s11191-013-9626-1

Hamza, K. M., & Wickman, P-O. (2008). Describing and analyzing learning in action: An empirical study of the importance of misconceptions in learning science. *Science Education, 92*(1), 141–164. doi: 10.1002/sce.20233

Haney, J. J., Lumpe, A. T., & Czerniak, C. M. (2003). Constructivist beliefs about the science classroom learning environment: Perspectives from teachers, administrators, parents, community members, and students. *School Science and Mathematics, 103*(8), 366–377. doi: 10.1111/j.1949-8594.2003.tb18122.x

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching, 33*(1), 47–63. doi: 10.1002/(SICI)1098-2736(199601)33:1<47::AID-TEA3>3.0.CO;2-P

Hodson, D. (1996). Laboratory work as scientific method: three decades of confusion and distortion. *Journal of Curriculum Studies, 28*(2), 115–135. doi: 10.1080/0022027980280201

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology, 25*(4), 378–405. doi: 10.1006/ceps.1999.1026

Hofer, B. K., & Pintrich, P. P. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*(1), 88–140. doi: 10.3102/00346543067001088

Kang, N-H. (2008). Learning to teach science: Personal epistemologies, teaching goals, and practices of teaching. *Teaching and Teacher Education, 24*(2), 378–405. doi: 10.1016/j.tate.2007.01.002

Kang, N-H., & Wallace, C. S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education, 89*(1), 140–165. doi: 10.1002/sce.20013

Kim, J-I., & Yoon, H.-G. (2013). Elementary school teachers' beliefs about science teaching, science learning and the nature of science. *Journal of Science Education, 37*(2), 389-404.

Lawson, A. E. (2002). Sound and faulty arguments generated by preservice biology teachers when testing hypotheses involving unobservable entities. *Journal of Research in Science Teaching, 39*(3), 237-252. doi: 10.1002/tea.10019

Lederman, N. G. (2007). Nature of science: past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831–880). Mahwah, NJ: Lawrence Erlbaum Associates.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497–521. doi: 10.1002/tea.10034

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331–359. doi: 10.1002/tea.3660290404

Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education, 86*(1), 1–22. doi: 10.1002/sce.1042

Luft, J. A. (1999). Teachers' salient beliefs about a problem-solving demonstration classroom in-service program. *Journal of Research in Science Teaching, 36*(2), 141–158. doi: 10.1002/(SICI)1098-2736(199902)36:2<141::AID-TEA3>3.0.CO;2-P

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2), 38–63.

Mansour, N. (2009). Science teachers' beliefs and practices: Issues, implications and research agenda.*International Journal of Environmental and Science Education, 4*(1), 25–48.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*(4), 317–328. doi:10.1080/0022027870190403

Otero, V. K., & Nathan, M. J. (2008). Preservice teachers' views of their students' prior knowledge. *Journal of Research in Science Teaching, 45*(4), 395–523. doi: 10.1002/tea.20229

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307–322. doi: 10.3102/00346543062003307

Perry,W. G., Jr. (1970*). Forms of intellectual and ethical development in the college years: A scheme*. New York: Holt, Rinehart, & Winston.

Popper, K. R. (1992). *The logic of scientific discovery*. London: Routledge. (Original work published 1934).

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula, T. Buttery, & E. Guyton (Eds.), *Handbook of research on teacher education* (pp. 102 – 119). New York: Macmillan.

Roehrig, G. H., & Luft, J. A. (2004). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *International Journal of Science Education, 26*(1), 3–24. doi: 10.1080/0950069022000070261

Rokeach, M. (1986). *Beliefs, attitudes, and values*. San Francisco: Jossey-Bass.

Ruiz-Primo, M. A., & Furtak, E. M. (2007). Exploring teachers' informal formative assessment practices and students' understanding in the context of scientific inquiry. *Journal of Research in Science Teaching, 44*(1), 57–84. doi: 10.1002/tea.20163

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching, 36*(2), 201–220. doi: 10.1002/(SICI)1098-2736(199902)36:2<201::AID-TEA6>3.0.CO;2-H

Savasci, F., & Berlin, D. F. (2012). Science teacher beliefs and classroom practice related to constructivism in different school settings. *Journal of Science Teacher Education, 23*(1), 65–86. doi: 10.1007/s10972-011-9262-z

Schwartz, R. S., & Lederman, N.G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching, 39*(3), 205–236. doi: 10.1002/tea.10021

Sinatra, G., Southerland, S., McConaughy, F., & Demastes, J. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching, 40*(5), 510–528. doi: 10.1002/tea.10087

Smith, J. P., diSessa, A. A., & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences, 3*(2), 115–163. doi:10.1207/s15327809jls0302_1

Tobin, K., Tippins, D., & Gallard, A. J. (1994). Research on instructional strategies for teaching science. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (44–93). New York: MacMillan.

Tsai, C-C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education, 24*(8), 771–783. doi: 10.1080/09500690110049132

Tsai, C-C. (2007). Teachers' scientific epistemological views: The coherence with instruction and students' views. *Science Education, 91*(2), 222–243. doi: 10.1002/sce.20175

von Glasersfeld, E. (1989). Constructivism in education. In T. Husen & N. Postlewaite (Eds.), *Internationational Encyclopedia of Education* [Suppl.], (pp.162-163). Oxford, England: Pergamon Press.

Wallace, C. S., & Kang, N-H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing beliefs sets. *Journal of Research in Science Teaching, 41*(9), 936-960. doi: 10.1002/tea.20032

Wandersee, J. H. (1986). Can the history of science help science educators anticipate students' misconceptions? *Journal of Research in Science Teaching, 23*(7), 581–597. doi: 10.1002/tea.3660230703

Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 177–210). New York: Simon & Schuster Macmillan.

Waters-Adams, S. (2006). The relationship between understanding of the nature of science and practice: The influence of teachers' beliefs about education, teaching and learning. *International Journal of Science Education, 28*(8), 919–944. doi: 10.1080/09500690500498351

Yerrick, R. K., Parke, H., & Nugent, J. (1997). Struggling to promote deeply rooted change: The ''filtering effect'' of teachers' beliefs on understanding transformational views of teaching science. *Science Education, 81*(2), 137–159. doi: 10.1002/(SICI)1098-237X(199704)81:2<137::AID-SCE2>3.0.CO;2-G

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APPENDIX

Questionnaire A (Due to the page limit, only A version is attached here)

In the early nineteenth century Lamarck proposed a theory of *use/disuse* and in the middle of the nineteenth century Darwin proposed a theory of evolution by *natural selection* to explain the evolution of living organisms. The proponents of a use/disuse theory thought that more frequent and continuous use of an organ by adapting to the environment develops the organ and the acquired change in traits can be passed to its offspring. They also believed that the permanent disuse of any organ weakens it gradually and causes it to disappear.
On the other hand, the proponents of a theory of evolution by natural selection argued that organisms compete with each other to survive in the given environmental context and only the fittest organisms in the environment prevail and evolve. Until the early twentieth century, biologists continued the debate between a use/disuse theory and a theory of evolution by natural selection.

1. How were these different theories possible even though biologists at the time shared a lot of fossil data and embryological and anatomic data with each other?
2. Could biologists in the middle of the nineteenth century determine which theory was more valid when they proposed two different theories with the same data?
3. Modern biologists agree with the theory of evolution by the synthesis of natural selection and mutation, and this theory is taught to students through science textbooks. Do you think this scientific knowledge ever changes?

Teacher Yoon was discussing about a theory of evolution with middle school students. When asked, "Why have giraffes evolved long necks?" most students said that "It is because they kept using their necks to reach fruits and leaves on the higher branches of trees, like humans' muscles develop by continuous exercise."

4. These students' conception is similar to Lamarck's theory of use/disuse. From a teacher's point of view, do you think the students' conception is valid in their own way?

Teacher Yoon started to explain Darwin's theory of evolution. "One hundred years ago, white-bodied moths were dominant and black-bodied moths were hardly seen in the area of Manchester in England. It was because white-bodied moths were camouflaged against white lichens of trees which they rested upon. On the other hand, black-bodied moths were apparently visible on trees and more likely to be eaten by birds. However, after the Industrial Revolution in England, soot from the coal-burning factories polluted the environment. White lichens on trees died and the trees became covered with black soot. As a result, the population of white-bodied moths decreased. Black-bodied moths, on the other hand, were camouflaged very well and flourished."
Teacher Yoon explained that this was the evidence for Darwin's natural selection. And then asked again, "Why did giraffes evolve long necks?" and as a hint, "Think about an environment in which there was not enough food so giraffes had to get food from the higher branches of trees."
Chol-Soo said, "Giraffes that tried to reach food high in trees came to have long necks by the continuous use of their necks and the other giraffes who did not try were extinct." Young-Hee said, "Giraffes who had long necks were better able to survive than those who had short necks."

5. Chol-Soo still possessed a conception of use/disuse. If Teacher Yoon pointed out that Young-Hee was right and Chol-Soo was wrong, do you think Teacher Yoon's way of teaching was appropriate?
6. Explain how you would lead the lesson if you were Teacher Yoon. And explain why you intend to teach in that way.