Jour. Korean Earth Science Society, v. 23, no. 2, p. 119–131, January 2002

Pre-service Teachers' Internalized Meanings of Educational Constructivism

Youngsun Kwak

Department of Earth Science Education, Seoul National University, Seoul 151-748, Korea

Abstract: Constructivism is defined in a variety of ways (e.g., constructivist research paradigm, sociological constructivism, and philosophical constructivism) and applied in vastly different contexts. Among the various usages and interpretations of constructivism, one is educational constructivism that embodies an epistemological view of knowledge and learning that is an alternative to naive empiricism or classical behaviorism. To represent the full range of stances taken by educational constructivists, three versions of educational constructivism were considered in this study: individual constructivism originating in the work of Piaget, the radical version of constructivism associated with von Glasersfeld, and the social constructivism of Vygotsky. I investigated preservice teachers' meaning construction about constructivist epistemology as they went through their preservice teacher education program using in-depth interviews. This preservice teacher education program employs constructivist aspects of teacher education and generates applications of constructivism to the practice of teaching. Features of preservice teachers' internalized meanings of educational constructivism include: (1) traditional pedagogy as the default, (2) Literal interpretation of constructivism, (3) Individual constructivism as conceptual change learning, (4) Radical constructivism as a strong individualistic philosophy, (5) Social constructivism as being too ideal to be practical. A compilation of the teachers' own statements about how to implement conceptual change learning and their projected role as constructivist teacher is also provided.

Key words: educational constructivism, individual constructivism, radical constructivism, social constructivism, conceptual change learning, internalized meaning of constructivism

INTRODUCTION

Considering that teachers can not be expected to learn effective science pedagogy on their own, teacher educators are mainly responsible for preparing them to meet this challenge and teacher education programs should address the issue of preservice teachers' pedagogical knowledge (Shulman, 1986). Along this line, the development of a solid base of knowledge about preservice teachers pedagogical perspective changes will be instrumental in providing a framework for considering both the learning processes involved in changing their conceptions, as well as providing a framework for designing instruction that facilitates those changes (Hewson and Kerby, 1993). That is, such knowledge is fundamental to efforts to design preservice models that will be successful in helping individuals acquire more appropriate conceptions of science teaching. A purpose of this study was to describe the nature of preservice teachers' pedagogical perspective changes upon meeting constructivist epistemology which is anomalous to their prior traditional pedagogical beliefs. I investigated preservice teachers' meaning construction about constructivist epistemology as they went through their preservice teacher education program. This preservice teacher education program employs constructivist aspects of teacher education and generates applications of constructivism to the practice of teaching.

A larger study associated with the results reported here investigated change in sixteen preservice teachers' understanding about constructivism and the reasons for changes in their understanding (Kwak, 2001). Constructivism was a major theme in the instruction these students received as will be demonstrated later. The larger study also documented that each preservice teacher's self-reported understanding of educational constructivism could be analyzed in terms of the ontology, epistemology and conceptions of teaching science supporting a particular view of constructivism.

*E-mail: ykwak@hanmir.com

It is important at this point to reemphasize that there are significant epistemological and ontological differences between different versions of educational constructivism (e.g., individual, radical, and social constructivism) and that these differences imply different pedagogical practices.

In this article the main tenets of each version of educational constructivism (Phillips, 1997a; Matthews, 1994, 1998; Ernest, 1995) were briefly examined with regard to pedagogical practices. That is, each version of educational constructivism should result in different teaching practices depending on the philosophical position taken towards ontological and epistemological issues (Kwak and Beeth, 2001; Kwak, 2001).

THEORETICAL OVERVIEW

Among various versions of constructivism psychological constructivism can be divided into individual (e.g., Piaget and radical) constructivists and social (e.g., Vygotsky) constructivists. That is, within educational (or psychological) constructivism, two major trends can be identified: one emphasizing the individual as actively constructing schemes and meaning through accommodation in the Piagetian sense, and the other emphasizing social or guided constructions within the zone of proximal development in the Vygotskian sense (Cobb, 1996). To represent the full range of stances taken by educational constructivists, three versions of educational constructivism were considered in this study: individual (or trivial) constructivism originating in the work of Piaget, the radical version of constructivism associated with von Glasersfeld, and the social constructivism of Vygotsky. The sections that follow focus on the implications each form of educational constructivism has for understanding instructional practice and student learning.

Pedagogical Implications: Conceptions of Science Teaching and Learning (CSTL)

A constructivist's pedagogy acknowledges learners as actively building knowledge individually and collectively. Each version of educational constructivism has implications for a teacher's ideal view of teaching and student learning. Internalizing the ontological beliefs and epistemological commitments that underlie any view of educational constructivism, preservice teachers should act in accord with the pedagogical implications that result from these beliefs.

For example, driven by the individual epistemological version of educational constructivism described above, a teacher who viewed him/herself as an individual constructivist would seek harmony between canonical science and students' conceptions. This view of science and science teaching is recognized by Driver, *et. al.* (1994) and consistent with much of the pedagogy used in conceptual change teaching. Along this line, Driver and Oldham (1986) suggest that students' be enculturated with scientists' ways of interpreting the world. Pedagogies consistent with individual constructivism emphasize active engagement of students in their own learning processes, taking into account the impacts of prior knowledge or conceptualizations on new learning. Therefore, instruction planned by a teacher who espouses individual constructivism should help students reconcile the differences between their ways of thinking and those used in the scientific community. Moreover, an individual constructivist would presume that children have to be introduced to the public, symbolic, and created world of science and that they should internalize knowledge produced by this community. That is, learning science is essentially a process of enculturation into the ideas and models of conventional science (Driver 1989). Therefore, learning science involves initiation into scientific traditions and this initiation needs to be intentionally provided through a teacher's instruction.

Pedagogies based on a radical constructivist version of educational constructivism focus on developing the experiential fitness of learners' concepts for making sense of their inter-subjective experiences

(Taylor 1993). This version identifies knowledge as a subjective, internally located, meaning construction that is constrained by experience (Taylor 1993). Emphasizing the adaptive function of cognition in relation to the experiential world, learning can be interpreted as a process of restructuring (reorganizing) existing knowledge structures in order to neutralize cognitive perturbations or problematic experiences and determining the viability of the new knowledge structures (Taylor, 1993). Accordingly, the teacher should be concerned with what goes on in the student's head so that they can understand and respond to the student's conceptual structure. Even though the teacher may introduce conflicts, they are unlikely to lead to a change in a student's thinking if the conflict situation is taken from areas that lie outside the student's field of experience. Moreover, what really matters is to teach students to see why a particular conception or theory is considered viable by the scientific community rather than present it as truth (von Glasersfeld, 1995).

At the other extreme of this continuum, the social constructivist version of educational constructivism emphasizes the essential and constitutive nature of language and social interactions in science learning. Much of the instruction and learning that takes place in a social context results from socially negotiated understandings, what Phillips (1997b) calls public bodies of knowledge. Social constructivists stress the importance of the group not just as knowledge producing but as validating that knowledge as well (Ernest 1995; Matthews 1998). Contrasted with psychological (or individualistic) perspective focused on an autonomous learner, two contrasting positions for social constructivism can be identified (Cobb and Bauersfeld 1995). First, the Vygotskian tradition in which learning is viewed as co-participation in culturally organized practices whereby scientific meanings are negotiated and institutionalized by members of communities rather than individual mechanisms. Theorists who work in this tradition emphasize social interaction in the activities of the expert, in which language as a culturally developed sign system mediates cultural processes and cognitive processes. The second is the sociolinguistic tradition whereby learning science is viewed as an initiation into the culture of doing science characterized by social and discursive practices. In this acculturation process, students learn to act in accord with the normative rules of the group (Solomon 1989).

Within this theoretical background, the teacher's role is to act as a guide in the building of personalized schema. The teacher is viewed as a valuable resource, not as an authority but as a person who facilitates learning. In the ideal social constructivists' learning environment, the teacher must stimulate learning by providing problematic situations--being problematical for students--in which learners can delve into learning as a meaning-making process rather than trying to infer what the teacher wants or to wait for the teacher to show the official answer. The teacher, as a facilitator, should be cautious not to be judgmental and evaluative as an authority for sanctioning. The crucial role of the teacher in promoting the co-construction of knowledge in classrooms, where the children were validators of one another's ideas, is to focus student attention and facilitate negotiation in the interest of consensus building, called discussion orchestration (Palincsar, 1998). In sum, the teachers' essential role is to determine students' zone of proximal development in that they make judgements about the appropriateness of a learning context in which students are encouraged to restructure their thinking and elaborate on what they already know (Wheatley, 1991).

METHODS

Profiles documenting the ontological beliefs, epistemological commitments, and conceptions of science teaching and learning (pedagogical beliefs) for students in this study were documented in Kwak (2001) and Kwak and Beeth (2001). In this study, I focused on students' pedagogical profiles to investigate how the preservice teachers internalized different versions of educational constructivism into their

conceptions of science teaching and learning.

Subjects

I conducted four in-depth semi-structured interviews with sixteen--nine female teachers and seven male--preservice science teachers through the theoretical coursework in their M.Ed. program. Data were collected periodically over the three-quarters and included four in-depth interviews (e.g., interview about instances, general open-ended questions, and forced-choice questions).

Throughout these interviews, I investigated how each preservice teacher internalized the forms of constructivism taught to them by their education faculty. Although the effects of a teacher education program appear to be erased by classroom practice (Kagan, 1990), it is important to investigate preservice teachers' developing notions of constructivism to know if they are internalizing different forms of constructivism in light of conceptions of science teaching and learning. Obviously, teacher education programs must first make students aware of the various forms of constructivism before these notions of learning can be applied in a classroom. That is, to realize constructivist pedagogies in the classroom, preservice teachers should know what constructivist views they hold, and how each is different before they try to apply that understanding during instruction. This study investigated preservice teachers' internalized meanings of educational constructivism that were presented through the university coursework in their teacher education program.

General open-ended questions on pedagogical beliefs

For each interview, to avoid imposing the technical language of constructivism or philosophical terminology without understanding, general open-ended questions were asked so that preservice teachers could describe their pedagogical beliefs with their own language. The first interview results became the basis for preparing the subsequent interview questions.

For example, to elicit each preservice teacher's conceptions of science teaching and learning, general open-ended questions about pedagogical beliefs were used throughout the four times of interviews in an attempt to reveal how each preservice teacher defines science teaching or learning, what she considers to be the founding principles of teaching as well as the learning outcomes of science teaching, how she describes the processes by which a learner learns, how she could judge when students have learned something, what teaching strategies she is going to implement, what she considers to be the ideal role of the teacher or the expected role of the students in her future classroom, and what role she sees herself playing as the teacher in her classroom. These open-ended questions were followed by probing questions along with forced-choice questions.

Forced-choice questions on constructivist pedagogical preferences

Forced-choice questions containing a priori statements linked to various pedagogical preferences were used throughout the interviews. Each preservice teacher's set of ideals about science teaching and learning in his or her ideal classroom are further categorized into four subcategories of a conceptions of science teaching and learning (CSTL) profile: Traditional, Piaget's Individual Constructivist's views, von Glasersfeld's Radical Constructivist's views of science teaching and learning, and Social Constructivist's such as interactionalist and socioculturalist views of science teaching and learning.

Ascertaining a preservice teacher's perspective on various types of constructivism, I asked each student to respond to specific quotations that exemplify different pedagogical standpoints without identifying its author or origin. Provided with forced-choice items, each interviewee was asked for a clarification of the meaning of each item in the context of the discourse, and modification or combination of given statements to better describe their own positions. The interview protocols were designed to allow each interviewee to better describe or find appropriate words and expressions for her own unique position

by assimilating one of the given items as her own or modifying pre-given exemplary statements to better fit her beliefs. Through probing each preservice teacher's judgment about the validity of such a statement, eliciting verbal explanations to give a descriptive assessment of constructivist pedagogies, and asking its degree of compatibility to his or her own current beliefs, I hoped to develop insight into each preservice teacher's specific position along the spectrum of constructivism.

These preferences or position-statements were taken from relevant literatures written by well-known theorists such as Piaget, von Glasersfeld, Cobb, Bausersfeld, Vygotsky, Driver, Solomon, Gergen, etc. Driven by their ontological and epistemological perspective, individual, radical, or social constructivists have different sets of ideals (or pedagogical implications) in terms of their views of science teaching and learning--views that guide their instruction (see Kwak and Beeth (2001) for the questions asked during the interviews).

Before providing details about the group of science preservice teachers who enrolled in the MSAT preservice teacher education courses in 1999-2000, I will describe details of the context in which these preservice teachers worked in their preservice program. This context is necessary for an understanding of each case and for making interpretations.

Contexts of the Study: the MSAT M.Ed. Program

Program faculty interview results showed that the majority of the MSAT M.Ed. preservice teacher educators explicitly stated in their syllabi that one of the goals and objectives of their methods courses was to promote constructivism as a way of understanding how students learn concepts and as a teaching strategy for improving and stimulating students conceptual changes (a methods course syllabus, July, 1999). Courses were considered to present constructivist philosophies as one of the major principles guiding the program. Sample course texts included Brooks and Brooks (1993), Ernest (1995), and Tobin (1993). In addition, by allowing the preservice teachers to participate in activities that are blatantly constructivist in nature as learners of science content, the methods instructors wanted these preservice teachers not only to gradually move away from viewing teaching from a students viewpoint to viewing teaching from a teacher's perspective (Vellom, personal communication, 2000; Hawkey, 1996), but also to implement constructivist-based approaches in their classroom practices. Against this background, the features of the participants' internalized meanings for constructivism are investigated.

RESULTS

With the influence of constructivist epistemology, these preservice teachers' conceptions of science teaching and learning evolved and were refined over time as they incorporated various constructivist ideas. The following is a discussion of main features of these preservice teachers' pedagogical beliefs changes.

Traditional pedagogy as the default

In the first interview, all 16 participants revealed a traditional view of teaching and learning (i.e., a transmission model of science instruction) to a certain extent, which was constructed based on their prior experiences as students in classrooms (Kagan, 1992; Richardson, 1996). In the second interview, 14 out of 16 participating preservice teachers completely replaced their traditional views with constructivist notions of science teaching and learning in light of the role of the teacher, how to teach, and how to learn. Accordingly, it was rare to find any text unit coded within the traditional pedagogy category for these 14 teachers' CSTL profiles during the second interview. In addition, it is interesting to note that all the participants, after examining their profiles presented during the member check, expressed their satisfaction with their individual changes that they had gotten away from the traditional conceptions of science teaching

and learning over time. One preservice teacher's comment epitomizes participants' common responses: "complete moving away from traditional, which is an accurate reflection of my beliefs" (Young 4).

On the other hand, one participating teacher stated, "as I look back, whenever I was frustrated, that [traditional pedagogy] was my default, giving out students the information through lecture. I think that's how I have been taught and I am obviously comfortable with that. I still have that latent traditional concept of teaching" (Lynda 4). Furthermore, she acknowledged, "if I get uncomfortable with trying other nontraditional ways of teaching, I will probably revert back to what I was taught, or what's worked in the past" (Lynda 4).

Literal interpretation of constructivism

All the participants endorsed a literal interpretation of constructivism as: knowledge is actively constructed, not passively received by students. Therefore, the teachers contended, "care should be taken in diagnosing students prior conceptions that they come in with so that the right idea would then build upon what they do know" (Lynda 3). If they have a concept that will be considered a misconception, they contended, the only way students are going to learn the right way would be to change the misconception (Young 1, 2 and 3, Ellen 2, Ginny 3 and 4, Len 4, Lynda 2 and 4, Rob 2). This directly leads to the next assertion.

Individual constructivism as conceptual change learning

With the influence of the teacher education program, where most of the faculty taught methods courses using approaches informed by constructivism as noted earlier in this article, all 16 participants aligned their CSTL with those recommended by individual constructivism that were represented to them as conceptual change learning.

From the second interview on, most of the teachers maintained and endorsed Piagetian individual constructivist CSTL as the largest component in their profiles--55% of the total text units coded within this category in the first interview, 56% in the second, 51% in the third, and 56% in the fourth interview on average across all 16 teachers[1]. Accordingly, they wanted to deal with students alternative conceptions using conceptual change teaching strategies. In addition, most of the participants continued to insist, "based on the little teaching that I have done, I would say that conceptual change models of learning are definitely how I teach" (Young 4). Refer to Appendix A for a compilation of statements about how to implement conceptual change learning and their projected role as teacher in participants' own words.

Radical constructivism as a strong individualistic philosophy

As a minor component of their CSTL profile, 13 teachers had von Glasersfeld's radical constructivist conceptions of science teaching and learning during the second interview (12 teachers in the third interview, and 11 teachers in the fourth interview) as they endorsed von Glasersfeld's pragmatist (or instrumentalist) views of knowledge as well as a rather strong individualistic philosophy (of learning). As Ben stated, knowledge for its own sake is like "knowledge in vacuum and it should be used in processes such as critical thinking and problem solving" (Ben 2). This position well corroborates an instrumentalist's view of knowledge that maintains our ideas are instruments whose purpose is to lead us fruitfully among our experiences and to resolve problems and blockages of action that confront us (Phillips, 1997b).

These teachers' high emphasis on individualism in knowledge construction as well as science learning led them to acknowledge "the value of each

[1]The average total text unit for each interviewee was 575 text units for the first interview, 343 for the second interview, 509 for the third interview, and 443 for the fourth interview. For each interview, 6.0% (for the first interview), 13% (second interview), 9.5% (third interview), and 9.0% (fourth interview) of the total text units were coded for the pedagogical preference category.

individual's processing information differently than the majority of society and being able to have scientific theories of his or her own that are not yet accepted by a scientific community" (Ben 3, Ellen 2, and Len 1). The participating teachers who valued individualism in knowledge--as well as reality--construction in turn acknowledged that "although a teacher would tell students what the society [whatever society you are in] thinks is the best explanation, it is ultimately each individual student who decides whether or not it is the best explanation for them based on everybody's own experiences that create that person" (Rob 4). Refer to Appendix A for major points of the participants' CSTL informed by von Glasersfeld's Radical constructivism.

Social constructivism as being too ideal to be practical

The social category in these teachers' CSTL profiles, informed by Vygotsky's social constructivism, emerged from the second interview during which 13 participating teachers out of 16 held the social component in their CSTL profiles to differing degrees. It is important to note that for 12 teachers out of these 13, the percentage of the total text units coded under the social category gradually decreased from the third interview as they went through the autumn and the winter quarter field experiences. During the field experiences, these student teachers were frustrated by the constraints of real classroom settings.

Regarding pedagogical implications of social constructivism, although many of the participants were fascinated by the way of teaching embodied in social constructivism where students develop certain common perspectives with regard to objects and events in the world through communicating with each other (Prawat, 1996). The preservice teachers argued that the teacher's being in a small role as in the social constructivism is too ideal to be practical in the schools considering time constraints, the amount of content required to be covered, and what they are supposed to be doing as teachers in classrooms. They also expressed their frustration with students resistance to new ways of learning that were aligned with what social constructivists supported, such as students autonomy in knowledge building processes through communication with each other. Ginny and Young explained their frustration in the following excerpts:

> I kind of said that some of this is very much theory and sometimes it's hard to put that theory into practice. Sometimes the kids don't cooperate with what you want to teach. They don't want to think. They just want you to tell them the answer [laughter]. The kids so much want to be spoon-fed. It's so odd. They want you to tell them what's right and what's wrong and it's almost like you have this conflict. You don't want to tell them, but they are so insistent about it. Sometimes you just give in. I tried to make myself a small role, I tried to give them good directions and then let them go in the activity, but it doesn't always work that way. So I don't know how social [constructivist teacher] I really am in the classroom. I am trying to be... but I think it's hard when you actually practicing to be fit into one of these. It's also important to find an appropriate school district that supports my ideas and what I want to do. (Ginny 4)

> Whenever I was trying to implement this kind of teaching style this quarter it was really difficult and it just a lot of times seemed easier just to try lecture... and it's just really frustrating because the students weren't really used to that kind of thing. I don't think they gained much in the lecture mode, but I don't think they gain much in that area [social constructivists' ways of teaching] either because they didn't know what to do. Students want to hear, they want to know what you want them to know. They don't want to, have to think about things. (Young 4)

It was interesting to note that prior to the field experience, most teachers identified themselves as

social constructivists or endorsed a social constructivist's ideas in that:

(1) "Vygotsky's perspective acknowledged, you can't separate your environment from your learning experience and your learning is determined by the social context which you are developing in" (Rob 2),

(2) "My position is probably more of social because it is probably more close to the idealist ontological beliefs" (Ben 2) and

(3) "My adopted version of constructivism fell close to the social end because it does take peer interactions and teacher-students interactions to construct their knowledge" (Ginny 2).

In addition, it is important to note that all of the teachers talked about their perceived constraints on implementing their beliefs about science teaching and learning acquired in the methods courses. Some selected constraints include standardized tests, the amount of lecturing and content to cover, time constraints, student resistance to new ways of learning, and the society to which the teachers belong. Accordingly, they mentioned that they would wait until they have full control over their own classrooms. Several teachers also indicated that implementing what they learned in the methods courses would be extremely hard in the beginning of their career, not to mention in the field experiences and in others' classrooms.

CONCLUSIONS

The MSAT M.Ed. program provided a personal experience with constructivist views of learning and teaching. The participants who evidenced significant changes in their views of teaching and learning attributed their perspective changes to those who "taught the MSAT preservice program by putting some of [their] theories and ideas into practice and by incorporating those ideas into the M.Ed. methods classes" (Lynda 4).

Data indicated the possibility that a constructivist-oriented preservice teacher education program can influence students' conceptions of science teaching and learning by explicitly introducing constructivism as an epistemology--or a specific theory of learning with profound philosophical assumptions that are different from traditional behaviorism framework--rather than as a specific method of instruction. Before a preservice teacher can adopt and ultimately apply constructivism to students learning, which I argue is inseparable from their views of teaching and learning, I wanted to know the extent to which these teachers internalize or differentiate characteristics of their views of constructivism. For example, pedagogical implications such as sensitivity to a learner's previous constructions, attention to metacognition, and so on should follow from particular views of constructivism.

Continued examination of changes in preservice teachers' beliefs towards constructivist ideas (epistemology) will provide important implications for understanding the extent to which future teachers can internalize contemporary contructivist epistemology, which in turn lead them to at least try to implement constructivist theories of learning and teaching in their science classrooms. The findings of this investigation have considerable potential to make contributions to both instruction of teacher education programs and research. To provide a rich context of the preservice teachers' internalized meanings of educational constructivism, I compiled and presented direct quotes from the interviews where the preservice teachers discussed how to be an individual (or radical or social) constructivist teacher in their future classroom.

APPENDIX A

Preservice Teachers' Projections of How to be Individual, Radical, or Social Constructivist Teachers

Examples of teachers' CSTL quotes regarding how to implement conceptual change learning and how to be an Individual constructivist teacher by:

- Helping students construct their ideas of science as long as the students are on track with what is accepted in conventional science, where teachers can speed up the process by setting up appropriate

learning activities and experiences (Young 2, Ben 1, Ellen 1, Ginny 1, Lynda 2 and 4, Len 3, Rob 4).

- Revealing the students previous experience their conceptions that they walk into the classroom with, and then challenging their misconceptions by presenting something that would contradict the students' theory and showing how the scientific principle can explain while theirs does not fit (Young 1, 2 and 3, Ellen 2, Ginny 3 and 4, Len 4, Lynda 2 and 4, Rob 2).
- Assisting students in making links between things that students have experienced everyday and the scientifically acceptable viewpoints and helping them moving onto a more conventional understanding so that they will be able to interact with the natural science community and be able to talk the scientific language (Ginny 3, Lynda 3, Young 2, Len 4, Rob 1).
- Giving students a range of experiences that point them in the right direction, and the teacher has to engage students in metacognitive discussion so that students can adjust the status (i.e., plausibility and intelligibility) of their conceptions (Young 2, Lynda 4, Ginny 4).
- Teachers are able to introduce the interpretation of the scientific community without necessarily imposing that perspective on her students as an authority as in Sister Gertrude Hennessey's science classroom (Ellen 2).
- Evaluating and checking students' answer in terms of whether that is a reasonable or a viable answer and then providing a regular feedback because students' own ideas constructed for themselves may not be consistent with what the teacher meant or intended for them to learn. (Ellen 4, Len 2, Young 4, Lynda 4)

Major points of preservice teachers' CSTL informed by von Glasersfeld's Radical constructivism: Participants CSTL quotes regarding how to be a Radical constructivist teacher:

- Learning, as a primarily an individual process, is a constant process of extending one's context or giving meaning to one's own world, in a sense of self-organization (Ben 4, Ginny 3, Rob 3).
- Learning is almost like existential where students with their own unique set of experiences and prior knowledge do learn about these things through constructing schemes or plans in their head and then they try to relate things in their head to the outside world based on those plans that they make, still constructing [for] themselves (Ben 4, Young 4, Rob 4).
- The ultimate goal of [science] learning on an individual level is to extend your context, to give meaning to your world through organizing and fitting in new experiences with one's prior knowledge and experience, to get to the solution to their problem in an efficient manner, and to construct viable knowledge structures that are compatible with her experiences (Ben 4, Len 4, Lynda 4, Young 1).
- In the process of an individual student's constructive activity, a social community as well as our prior understanding of the way beings work acts as constraints by determining the best fit or the greatest viability (Ellen 4, Len 2, Young 2, Young 3).

Accordingly, a Radical constructivist teacher should:

- Assess the context of the students and then he kind of can organize, transform the content knowledge into various forms that the learner can take it into himself to construct his own knowledge (Ben 4, Rob 3, Rob 4).
- Have an adequate model of the thought process of the students and how they make sense of things in their heads (Ginny 3, Young 2, Rob 4).
- Deliberately encourage students to learn the scientifically acceptable viewpoint because it is students' benefit and helpful in empowering underprivileged students to know what is accepted by a scientific community, which could change in the future (Ellen 4, Young 2, Rob 4).
- Need to be careful of the limitations they put on

student's in their active searching for knowledge so that they do not restrict a student's creativity in problem solving situations, even though it may not align with what is accepted by the majority of society (Len 4).

Major themes of preservice teachers' CSTL informed by Vygotsky's social constructivism: Participants CSTL quotes regarding how to be a Social constructivist teacher:

- Since we are living in a culture and in a society, a certain amount of learning processes are mediated by others, such as parents and teachers in a culture where the social interaction and the social plane become a mediator of our phenomena or knowledge; otherwise, we will be solipsistic (Ben 2 and 4, Young 4, Rob 4).
- In light of rationales of science teaching and learning, the participating teachers wanted their students to leave their science classes with knowing the criteria of how to judge validity of information, how to do scientific inquiry or investigation, how to give meaning to phenomena of the world outside of themselves where there is a shared meaning, and how to participate in and dialogue in science rather than with a specific science content. Even when they emphasized introducing students to the scientific information that has come before them for the last centuries, that is because, they thought, this scientific information and content is a prerequisite to communicate and participate in science (Ben 4, Len 3, Lynda 2, Young 4, Rob 4).
- Regarding the role of the teacher, the teacher facilitates and mediates the learning of scientific concepts in such a way that students do not have to spend the same amount of time to learn those as the people originally constructed those concepts and do not have to reinvent the wheel (Ben 4, Ginny4, Len 3 and 4, Rob 2).
- Regarding the role of the teacher, the teacher has to guide institutionalization of scientific activities in the classroom and to teach students what science is, by modeling routines or the accepted model for how to do things according to the rules of canonical science (Ellen 3, Ginny 3, Young 4, Rob 3, Rob 4).
- Some of the teachers believed that most students learn best through apprenticeship as they learn best from the apprenticeship in their field experiences where their mentor teachers model the necessary procedures as they engage in a shared teaching activity (Len 3, Ben 3).
- In terms of a way of teaching, the teachers wanted to use a class discussion and students-mentoring where students get an idea of what everybody else is thinking by talking to each other and a student can say in a way that the teacher cannot communicate an idea so that another student gets (Young 4, Rob 4).
- Regarding the role of the students, the students have to come to some kind of agreement on what they think is the most consistent view or explanation, and make decisions about what is right or wrong on their own rather than being told what is right or wrong thing is, and validate their co-constructed meanings in the process of interaction between themselves (Ginny 2, Lynda 2, Young 3, Young 4, Rob 3).
- Rob summed up these teachers' perceived role informed by social constructivism: 'I am kind of there to link students and the scientific community. In a way the teacher would help students interpret things from a scientific community through scaffolding or apprenticeship processes until they have enough of conceptual framework to do their own interpretations and go off on their own' (Rob 4).

REFERENCES

Bey, T.M., 1992, Mentoring in teacher education: Diversifying support for teachers. In Bey, T. and Holmes, C.T. (Eds.), Mentoring: Contemporary principles and issues. Reston, VA: Association for Teacher Educators, 122 p.

Borko, H., and Mayfield, V., 1995, The roles of the cooperating teacher and university supervisor in learning to

teach. Teaching & Teaching Education, 11(5), 501–518.

Boudourides, M.A., 1998, Constructivism and education: A shoppers guide [On-line]. Available: http://www.duth.gr/~mboudour/mab/constr.html

Brooks, J.G., and Brooks, M., 1993, In search of understanding: The case for constructivist classrooms. Alexandria, VA: ASCD, 136p.

Brown, J.S., Collins, A., and Duguid, P., 1989, Situated cognition and the culture of learning. Educational Researcher, 18(1), 32–42.

Cobb, P., 1996, Where is the mind? A coordination of sociocultural and cognitive constructivist perspectives. In Fosnot, C.T. (Ed.), Constructivism: Theory, perspectives, and practice. New York, NY: Teacher College Press, 228 p.

Cobb, P., and Bauersfeld, H., 1995, Introduction: The coordination of psychological and sociological perspectives in mathematics education. In Cobb, P. and Bauersfeld, H. (Eds.), The emergence of mathematical meaning: Interaction in classroom cultures. Hillsdale, NJ: Lawrence Erlbaum Associates, 306 p.

Cobb, P., Wood, T., and Yackel, E., 1991, Analogies from the philosophy and sociology of science for understanding classroom life. Science Education, 75(1), 23–44.

Cobern, W.W., 1993, Contextual constructivism: The impact of culture on the learning and teaching of science, In Tobin, K. (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science Press, 344 p.

Collins, A., Brown, J.S., and Newman, S.E., 1989, Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics. In Resnick, L.B. (Ed.), Knowing, learning, and instruction: Essays in honor of Robert Glaser. Hillsdale, NJ: Erlbaum, 512 p.

Confrey, J., 1995, How compatible are radical constructivism, social-cultural approaches and social constructivism?, In Steffe, L. and Gale, J. (Eds.), Constructivism in education. Hillsdale, NJ: Lawrence Erlbaum Associates, 575 p.

Driver, R., 1989, The construction of scientific knowledge in school classrooms. In Miller, R. (Ed.), Doing science: Images of science in science education. Philadelphia, PA: The Falmer Press, 216 p.

Driver, R., and Oldham, V., 1986, A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105–122.

Driver, R., Asoko, H., Leach, J., Mortimer, E., and Scott, P., 1994, Constructing scientific knowledge in the classroom. Educational Researcher, 23(7), 5–12.

Duit, R., 1995, The constructivist view: A fashionable and fruitful paradigm for science education research and practice, In Steffe, L. and Gale, J. (Eds.), Constructivism in education. Hillsdale, NJ: Lawrence Erlbaum Associates, 575 p.

Duit, R., and Treagust, D.F., 1998, Learning in Science - From behaviorism towards social constructivism and beyond, In Fraser, B.J. and Tobin, K.G. (Eds.), International handbook of science education. Great Britain: Kluwer Academic Publishers, 1271 p.

Ernest, P., 1995, The one and the many, In Steffe, L. and Gale, J. (Eds.), Constructivism in education. Hillsdale, NJ: Lawrence Erlbaum Associates, 575 p.

Fosnot, C.T., 1993, Science education revisited: A defense of Piagetian constructivism. Journal of Research in Science Teaching, 30(9), 1189–1201.

Fosnot, C.T., 1996, Constructivism: A psychological theory of learning. In Fosnot, C.T. (Ed.), Constructivism: Theory, perspectives, and practice. New York, NY: Teacher College Press, 228 p.

Geelan, D.R., 1997, Epistemological anarchy and the many forms of constructivism. Science & Education, 6(1-2), 15-28.

Gunstone, R.F., Slattery, M., Baird, J.R., and Northfield, J.R., 1993, A case study of development in preservice science teachers. Science Education, 77(1), 47–73.

Guyton, E., 1989, Guidelines for developing educational programs for cooperating teachers. Action in Teacher Education, 11(3), 54–57.

Hawkey, K., 1996, Image and the pressure to conform in learning to teach. Teaching & Teacher Education, 12(1), 99–108.

Hennessy, S., 1993, Situated cognition and cognitive apprenticeship: Implications for classroom learning. Studies in Science Education, 22, 1–41.

Hewson, P.W., 1981, A conceptual change approach to learning science. European Journal of Science Education, 3(4), 383-396.

Hewson, P.W., and Hewson, M.G., 1989, Analysis and use of a task for identifying conceptions of teaching science. Journal of Education for Teaching, 15(3), 191–209.

Hewson, P.W., and Kerby, H.W., 1993, Conceptions of teaching science held by experienced high school science teachers. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. Atlanta, GA. (ERIC Document Reproduction Service No. ED 364 426).

Hollingsworth, S., 1988, Making field-based programs work: A three-level approach to reading education. Journal of Teacher Education, 39 (4), 28–36.

Hollingsworth, S., 1989, Prior beliefs and cognitive change in learning to teach. American Educational Research Journal, 26(2), 160–189.

Kagan, D.M., 1990, Ways of evaluating teacher cognition: Inferences concerning the Goldilocks Principle. Review of Educational Research, 60(3), 419–469.

Kagan, D.M., 1992, Professional growth among preservice and beginning teachers. Review of Educational Research, 62(2), 129-169.

Kuhn, T.S., 1970, The structure of scientific revolutions. Chicago: University of Chicago Press, 210 p.

Kwak, Y., 1999, MSAT M.Ed. preservice teachers' perceptions of pedagogical constructivism. Paper presented at the third annual spring conference of the mathematics, science, and technology educators & researchers of the Ohio State University. Columbus, OH. (ERIC Document Reproduction Service No. ED 438 166).

Kwak, Y., 2001. Profile change in preservice science teachers' epistemological and ontological beliefs about constructivist learning: Implications for science teaching and learning. Unpublished doctoral thesis, The Ohio State University, 342 p.

Kwak, Y., and Beeth, M.E., 2001, Profile changes for two students in a (mathematics, science & technology education) preservice teacher education program with constructivist views of teaching and learning. Paper presented at the Annual Meeting of the Association for the Education of Teachers in Science, Costa Mesa, CA.

Matthews, M.R., 1994, Science teaching: The role of history and philosophy of science, New York, NY: Routledge, 287 p.

Matthews, M.R., 1998, Introductory comments on philosophy and constructivism in science education. In Matthews, M.R. (Ed.), Constructivism in science education: a philosophical examination. The Netherlands: Kluwer Academic Publishers. 227p.

Mortimer, E.F., 1995, Conceptual change or conceptual profile change? Science & Education, 4, 267–285.

Newman, D., Griffin, P., and Cole, M., 1989, The construction zone: Working for cognitive change in school, Cambridge, MA: Cambridge University Press, 169 p.

Osborne, R.J., and Gilbert, J.K., 1980, A method for investigating concept understanding in science. European Journal of Science Education, 2(3), 311–321.

Palincsar, A.S., 1998, Social constructivist perspectives on teaching and learning. Annual Rev. Psychol. 49, 345–375.

Phillips, D.C., 1997a, Coming to terms with radical social constructivisms. Science & Education, 6(1-2), 85–104.

Phillips, D.C., 1997b, How, why, what, when, and where: Perspectives on constructivism in psychology and education. Issues in Education: Contributions from educational psychology, 3(2), 151–194.

Phillips, D.C., and Soltis, J.F., 1998, Perspectives on learning. New York, NY: Teacher College Press, 116 p.

Piaget, J., 1970, Genetic epistemology. New York, NY: Columbia University Press, 84 p.

Pines, A.L., and West, L.H.T., 1986, Conceptual understanding and science learning: An interpretation of research within a source-of-knowing framework, Science Education, 70(5), 583–604.

Posner, G.J., Strike, K.A., Hewson, P.W., and Gertzog, W.A., 1982, Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66(2), 211–227.

Prawat, R.S., 1996, Constructivism, modern and postmodern, Educational Psychologist, 31(3/4), 215–225.

Richardson, V., 1996, The role of attitude and beliefs in learning to teach. In Sikula, J. Buttery, T., and Guyton, E. (Eds.), Handbook of research on teacher education(2nd ed.). New York: Macmillan, 1190 p.

Rogoff, B., 1990, Apprenticeship in thinking: Cognitive development in social context. New York, NY: Oxford University Press, 242 p.

Roth, W.M., 1993, Construction sites: Science labs and classroom, In Tobin, K. (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science Press, 344 p.

Shulman, L.S., 1986, Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14.

Solomon, J., 1983, Learning about energy: how pupils think in two domains, European Journal of Science Education, 5(1), 49–59.

Solomon, J., 1987, Social influences on the construction of pupils understanding of science, Studies of Science Education, 14, 63–82.

Solomon, J., 1989. The social construction of school science. In Miller, R. (Ed.), Doing science: Images of science in science education. Philadelphia, PA: The Falmer Press, 216 p.

Stofflett, R.T., 1991, Conceptual change in elementary teacher candidates content and pedagogical knowledge of science. Unpublished doctoral dissertation, University of Utah, Salt Lake City, UT.

Strike, K.A., and Posner, G.J., 1985, A conceptual change view of learning and understanding. In West, L.H.T., and Pines, A.L. (Eds.), Cognitive structure and conceptual change. Orlando, FL: Academic Press, 274 p.

Strike, K.A., and Posner, G.J., 1992, A revisionist theory of conceptual change. In Duschl, R.A., and Hamiliton, R.J. (Eds.), Philosophy of science, cognitive psychology, and educational theory and practice. Albany, NY: State University of New York Press, 287 p.

Sudzina, M., Giebelhaus, C., and Coolican, M., 1997, Mentor or Tormentor: The role of the cooperating teacher in student teacher success of failure. Action in Teacher Education, 18(4), 23–35.

Taylor, P.C., 1993, Collaborating to reconstruct teaching: The influence of researcher beliefs, In Tobin, K. (Ed.), The practice of constructivism in science education.

Washington, DC: American Association for the Advancement of Science Press, 344 p.

Tobin, K., and Tippins, D., 1993, Constructivism as a referent for teaching and learning, In Tobin K. (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science Press, 344 p.

von Glasersfled, E., 1989a, Cognition, construction of knowledge and teaching, Syntheses, 80(1), 121–140.

von Glasersfeld, E., 1989b, Abstraction, re-presentation, and reflection, an interpretation of experience and Piagets approach (Report No. SRRI-209) National Science Foundation, Washington D.C. (ERIC Document Reproduction Service No. ED 306 120).

von Glasersfeld, E., 1993, Questions and answers about radical constructivism, In Tobin, K. (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science Press, 344 p.

von Glasersfeld, E., 1995a, A constructivist approach to teaching, In Steffe, L. and Gale, J. (Eds.), Constructivism in education. Hillsdale, NJ: Lawrence Erlbaum Associates, 575 p.

von Glasersfeld, E., 1995b, Radical constructivism: a way of knowing and learning. London, UK: Falmer Press, 213 p.

Wheatley, G.H., 1991, Constructivist perspective on science and mathematics learning. Science Education, 75(1), 9–22.

Wheatley, G.H., 1993, The role of negotiation in mathematics learning, In Tobin, K. (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science Press, 344 p.

Manuscript received September 8, 2001
Revised manuscript received October 22, 2001
Manuscript accepted December 7, 2001