How to tell a constructivist science teacher: An interview protocol to diagnose a constructivist teacher

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Abstract

As a research paradigm, constructivism offers accounts of the epistemology of science, inspires science education curriculum reform programs, underpins major research programs in science education, and is also the foundation of many science-teacher training programs where constructivist teaching methods are widely advocated. Underlying all versions of constructivism are the philosophical constructs of epistemological commitments and ontological beliefs. Specifically, educational constructivism can be divided into individual, radical, and social constructivism depending on the unique ontological, epistemological, and pedagogical commitments for each version. In this article, we present an interview protocol with which researchers can elicit the philosophical foundations (i.e., ontological beliefs and epistemological commitments) that preservice teachers gave to support of their developing notions of several versions of educational constructivism through in-depth interviews. By providing researchers and educators with our interview protocol and methods, we intend to show one way of revealing an individuals often implicitly held philosophical beliefs and commitments. For each ontological and epistemological beliefs subcategory, a detailed definition along with two to three exemplary quotes taken from the interview transcripts from a previous research is also provided. The development of a system of categories for identifying constructivist ideas (i.e., ontological, epistemological, and pedagogical profiles), and its use in tracing of the development of preservice teachers beliefs changes throughout their university coursework, has the potential to contribute to a better understanding of how preservice teachers learn to teach. Accordingly, this interview protocol will be a valuable theoretical and analytical framework in describing the relationship between a teachers beliefs about nature of knowledge (or reality) and his or her conceptions of science teaching and learning. This understanding can lead to a restructuring of the science teacher education program's methods courses.

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Key words: educational constructivism, epistemology, interview protocol, constructivist profile, teacher education

Ⅰ. Introduction

Constructivism is a major influence in present day science teacher preparation programs (Richardson 1996; Matthews 1994). That is, regardless of the usage or misusage of the term or the version of constructivism (e.g., constructivist theories of learning, constructivist theories of teaching, and constructivist epistemologies), there is little argument that construction of knowledge is the contemporary overarching issue in science learning and science teacher education (Matthews 1994, p. 1). As a research paradigm, constructivism offers accounts of the epistemology of science, inspires science education curriculum reform programs, underpins major research programs in science education, and is also the foundation of many science-teacher training programs where constructivist teaching methods are widely advocated (p. 183). Underlying all versions of constructivism are the philosophical constructs of epistemological commitments and ontological beliefs. Accordingly, any view of constructivism has pedagogical implications that should result from the ontological and epistemological presuppositions associated with that version. Specifically, educational constructivism can bedivided into individual, radical, and social constructivism depending on the unique ontological, epistemological, and pedagogical commitments for each version.

The teaching of constructivism assumes that preservice teachers will, as a part of their preservice preparation, examine their existing ideas, beliefs and prior experiences as they construct new views about teaching and learning. While the ultimate objective for many preservice programs is to have teachers facilitate construction of knowledge by their students through instructional activities, there is little evidence to indicate the degree to which these teachers themselves understand philosophical differences in the versions of constructivism that they are expected to understand. In the larger study, Kwak (2001) sought to understand the philosophical foundations (i.e., ontological beliefs and epistemological commitments) that preservice teachers gave to support of their developing notions of several versions of constructivism. Kwak also sought to understand the implications thattheir philosophical foundations had on these preservice teachers' developing views of teaching. That is, to what degree, if any, is there consistency between a preservice teacher's philosophical views on constructivism and their conceptions of science teaching and learning? In this article, we examined how Kwak (2001) elicited the philosophical foundations (i.e., ontological beliefs and epistemological commitments) that preservice teachers gave to support of their

developing notions of several versions of educational constructivism through in-depth interviews. Through theoretical comparison between various versions of constructivism, Kwak (2001) also showed each version of educational constructivism (i.e., individual, radical, and social) is epistemologically as well as ontologically different from others since the conceptual features change as one moves through the profile of constructivism. For example, individual constructivism is characterized as an ontologically Realist and epistemologically Piagetian position in that individual constructivists should accept the (ontological) reality of an external world (Geelan, 1997). That is, Piaget stated, external reality is playing a role in constraining or shaping the views we construct about it and we only construct those that are in some logical sense isomorphic with nature, not copies of the real world (Phillips, 1997b, p. 184). For Piaget, a person exists as a real biological entity in a real physical world who constructs mental structures (schemas) to deal with that world through internalizing actions on or about the world (Ogborn, 1997). According to this position, public knowledge as well as personal knowledge of science is a carefully checked construction rather than discovery of a "real" world that exists independent of cognizing experience (Driver & Oldham, 1986).

Driven by the epistemological perspective described above, individual constructivists seek harmony between scientific and children's conceptions (Driver, et. al. 1994). An individual constructivist pedagogy emphasizes active engagement of students in their own learning processes and the impacts of prior knowledge or conceptualizations on new learning. Therefore, instructional experiences planned by a teacher may facilitate or obstruct further learning. Moreover, they presume that there is a public, symbolic, created world of science that children have to be introduced to and whose concepts they should internalize. That is, learning science is essentially a process of enculturation into the ideas and models of conventional science (Driver, 1989, p. 103). Therefore, scientific understanding requires initiation into a scientific tradition and this initiation needs to be intentionally provided through a science teachers instruction.

Considering the difficulties in changing the ontological or epistemological beliefs (generally implicit or unconscious), which each version of constructivism is assigned to, this feature has special importance. In the conceptual profile notion Mortimer (1995) contends, the teaching process and its steps depend on the specific epistemological and ontological features of each profile zone of the concept to be taught in that these features could be obstacles to the development of a new zone of the profile (p. 274). That is, the faulty or discrepant ontological or epistemological beliefs not only lead preservice teachers to reject other versions of constructivism but also make it difficult for them even to comprehend other constructivist paradigms (Chinn & Brewer, 1993). Therefore, by identifying, acknowledging, and making explicit each preservice teacher's ontological and epistemological obstacles identified in the previous zones of his or her constructivist profile, we can help preservice teachers overcome the obstacles as well as help them understand each version of constructivism in terms of epistemological and ontological features. As part of the larger study, in this article we discuss how Kwak

(2001) developed and used an interview protocol and methodology whereby we elicited and identified each preservice teacher's unique ontological and epistemological beliefs. By providing researchers and educators with our interview protocol and methods, we intend to show one way of revealing an individuals often implicitly held philosophical beliefs and commitments. For each subcategory, a detailed definition along with two to three exemplary quotes taken from the interview transcripts of Kwak's (2001) research is provided in Appendix B. The definitions of each category are derived from related literatures where theorists articulated their positions, whereas exemplary quotes are taken from the interview transcripts that show ontological position statements made by preservice teachers in their own words.

Ⅱ. Collection of interview data using the protocol

This interview protocols were designed to enable interviewees to consider each component of the conceptual ecology (e.g., epistemological, ontological, and pedagogical beliefs (CSTL) that are consistent with constructivist views of teaching and learning), while providing alternative options. In addition, considering the characteristics of a conceptual ecology which is often held unconsciously by a cognizing subject, the use of quantitative methods to identify some components of the conceptual ecology may be counterproductive in that they may not capture some of its relevant qualities. According to Kagan (1990), any short-answer test of teacher belief, such as an instrument consisting of prefabricated statements, has certain inherent limitation in that standardized statements may mask or misrepresent a particular teacher's highly personalized perceptions and definitions (p. 426). Moreover, each individuals conceptual ecology is idiosyncratic in that the personal context--cognitive as well as social--in which one resides is never the same as that of anyone else. Thus, we needed in-depth interview methods whereby each preservice teacher could reveal and confront his or her own conceptual ecology, and furthermore one could experience constructive or reconstructive change in ones cognition (refer to Lathers catalytic validity). On the one hand, interview itself could provide preservice teachers with an opportunity to begin thinking about their implicit beliefs and to think reflectively about their own views of teaching and learning, or during the interview process they could come up with and elaborate pedagogical language with which they could describe their pedagogical perspectives. On the other hand, considering various components of conceptual ecology and the inherent complex, multifaceted aspects of teaching and learning, which are the main concerns of constructivism, the use of multiple approaches seems to be superior, to provide triangulation (Kagan, 1990).

The overview of our analytical framework is summarized in Table 1. After an interview, each cell of the table could have sample statements as well as the frequency of

statements identified by each category.

Table 1. Analytical framework: Factors that influence how preservice teachers respond to constructivist epistemology (CE) versus possible responses

	Does the preservice teacher offer an explanation for his/her position in terms of conceptual ecology, which foster or hamper his/her perception change?					
Conceptual Ecology / Response	Constructivism			Explainers		
	Ontological beliefs	Epistemological beliefs	Characteristics of theory: Conceptions of Science Teaching & Learning (CSTL)	Conflict or Anomaly	Past Experience (Personal History)	Other knowledge (background knowledge)
Outright rejection						
Capture of CE						
Exchange for CE						

By providing preservice teachers with alternative options, they will be able to express a variety of views by assimilating a specific option ones own or modifying pre-given statements to better describe ones unique position. Based on several times of longitudinal interview data, the analysis entails identifying each component of preservice teachers' conceptual ecology; categorizing them into three subsuming categoriesontological, epistemological, and pedagogical beliefs on constructivism; and tracing any perspective change by identifying each teacher's constructivist profile (refer to Kwak (2001) for specific examples of a constructivist profile). Data from interviews will be used to construct a constructivist profile for each preservice teacher's views of learning (i.e., a profile containing ontological beliefs, epistemological commitments, and pedagogical beliefs). The interview protocol consists of four main categories: questions related to ontological beliefs, epistemological beliefs, conceptions of science teaching and learning (CSTL), and explainers.

A. Personal Background Characteristics

In spite of the same pedagogical interventions, some preservice teachers may be more open-minded toward constructivist epistemology than others. Information about each preservice teacher's personal backgrounds—each candidate's biography, in a sense, including his or her prior experiences in classrooms as students, which is to determine what could be learned from course work—can help the researcher to understand, in part, a preservice teachers peculiar responses to new constructivist epistemology. The background information included his or her subject area to teach, personal schooling history along with science courses previously taken (science content background), what

kind of educational pipeline they went through, etc (refer to Appendix A for specific questions asked during the interview).

B. General Open-Ended Questions on Constructivist Epistemology

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 ontological, epistemological and pedagogical beliefs with their own language. For example, to elicit each preservice teacher's conceptions of science teaching and learning, general open-ended questions about pedagogical beliefs were used 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.

C. Forced-Choice Questions on Constructivist Epistemology

Ascertaining a preservice teacher's perspective on various types of constructivism, we asked the teachers to respond to specific quotations that exemplify different ontological standpoints, such as Realist, Radical, and Idealist, without identifying its author or origin. Through probing each teacher's judgment about the validity of such a statement, eliciting verbal explanations to give a descriptive assessment of constructivist epistemology, and asking its degree of compatibility to his or her own current beliefs, we hoped to develop insight into each preservice teacher's specific position along the spectrum of constructivism, as well as his or her metaphysical assumptions (Posner et al., 1982) about the role of reality and the nature of scientific knowledge.

These exemplary position-statements were taken from various theorists published articles and books that showed and categorized positions taken by different versions of educational constructivismindividual, radical and social constructivismand various philosophical positions (e.g., realist, idealist, etc.) on ontological and epistemological issues. Sample constructivist papers used in developing the interview protocol include: Phillips (1997a, 1997b), Matthews (1992, 1994), Ernest (1995, 1998), Prawat (1996, 1997), Geelan (1997), Wheatley (1991), Gergen (1995, 1997), Hardy & Taylor (1997), Driver (1989), von Glasersfeld (1995a, 1995b), etc.Foracompletedescription of each ontological preference, refer to the interview protocol in Appendix A.

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.

In addition, it is important at this point to reemphasize that there are epistemological and ontological differences between different versions of educational constructivism (i.e., individual, radical, and social constructivism). These different ontological and epistemological positions that emerged from the synthesis and conceptual analysis of different versions of educational constructivism were used as forced-choice items in the interviews, and formed coding categories in assigning segments of the interview transcripts related to each interviewees ontological and epistemological beliefs. The three main categories are described below.

D. Ontological Beliefs

Ontological beliefs include any statements related to the status of the mode of existence of types of entities in the world. This category included any statements in which preservice teachers were commenting on the status of reality or the existence of scientific objectsany comments concerning the issue of the relation between our ideas and the nature behind them (Phillips, 1997b, p. 176) and any philosophical claims about reality.

These statements were divided into three subcategories in light of different ontological commitments: Realist, Radical, and Idealist. These three analysis categories were also presented to the subjects as forced-choice items throughout the interviews. Of the given statements, each interviewee was allowed to choose one ontological position that would most align with the way he or she thought about reality or status of outside world. If a chosen view did not fully describe their position, interviewees were encouraged to further describe their position by combining the given options, making any necessary modifications, or creating their own version. For each subcategory, a detailed definition for each category is provided in Appendix B.

E. Epistemological Beliefs

This category includes any statements related to epistemological issues such as what counts as knowledge, how this is produced and warranted or justified (Phillips, 1997b, p. 162), and the role of reality in knowledge construction, as well as any statement revealing what each interviewees view of the relationship of ones own epistemological commitments to each version of constructivism. This category is further divided into the four subcategories: [Progressive] Absolutist, Piagetian, Fallibilist, and Relativist. These four epistemology preferences were also used as forced-choice items throughout the interviews. For each epistemology subcategory, a detailed definition is provided in Appendix B.

F. Conceptions of Science Teaching and Learning (CSTL)

This category includes any statements in which preservice teachers were commenting on inferred practical pedagogical outcomes and principles based on their differing ontological and epistemological standpoints, as well as the means to facilitate learning according to an epistemology. The purpose of this category is to examine implications of the differing ontological and epistemological understanding of knowledge taken by different versions of constructivism in terms of pedagogical activity. Each teacher's conceptions of science teaching and learning were elicited through (1) open-ended questions about pedagogical beliefs, (2) an interview-about-instances task, and (3) forced-choice questions on pedagogical preferences. Each preservice teacher's CSTL

could include statements ofideals which include behaviors, values, dispositions, the role of herself as a teacher, the expected role of students in her science class, how to teach, how she thinks students learn, rationales of her way of teaching, as well as rationales of expected learning outcomes.

The forced-choice items about 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, Piagets individual constructivists views, von Glasersfelds radical constructivists views of science teaching and learning, and Social Constructivists views of science teaching and learning. The summaries and position-statements used in the interview protocol 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 in terms of their views of science teaching and learningviews that guide their instruction. Each set of ideals include statements related to how they think people learn, what is involved in learning and teaching science, what the central focus of planning instruction is, what an individual (radical or social) constructivist teacher would be like, and, sometimes, what instructional approaches they adopt, which has to do with their view of how people, specifically students, learn. A detailed definition of each subcategory is provided in Appendix B.

The ultimate task of this investigation could be regarded as identifying and tracing the development of each preservice teacher's belief changes towards constructivist epistemology using the constructivist profile notion. The identification of the existence of constructivist profiles in their belief changes and the description of components of profiles drawn from the data sources will provide valuable research tools in answering further questions of further research in teachers' belief changes.

G. Interview about Instances on Science Teaching and Learning

This technique, developed by Osborne & Gilbert (1980), is used to explore a preservice teacher's understanding of a particular concept in terms of differentiating instances from non-instances of the label corresponding to the concept under consideration. Provided with a series of instances, the respondent is asked to categorize each instance in his or her view and then asked to provide the supportive reasoning on which the categorization has been based.

It was noted earlier that the focus of the research is on probing preservice teachers' pedagogical perspectives on science teaching and learning in which theirontological and epistemological commitments and other conceptual ecology components are situated. Therefore, in the first interview, without confronting the technical language of constructivism or philosophical terminology, a researcher could elicit preservice teachers' general conceptions of science teaching and learning using an interview-about-instances task similar to the one developed by Hewson & Hewson (1989). The original interview consists of 10 descriptions of activities or tasks intended to represent both instances and non-instances of science teaching and learning inside and outside of the classroom contexts, whereby respondents are to consider the components of an appropriate conception of teaching science as they respond to particular events. The 10 events are to provide teachers with an environment in which a variety of views could be expressed by encouraging them to link the events to larger conceptual issues (Hewson & Kerby, 1993, p. 7). Except minute modification of science content of two or three interview events, we used the original format and protocol intact. Each preservice teacher was shown in sequence a written description of each event and asked, whether, in his or her view, there was any science teaching happening there, and invited to give reasons for his or her answer (p. 7). The interview transcripts were examined with a view to identifying examples of conceptual ecology components, which were embedded in their conceptions of science teaching and learning.

Ⅲ. Discussion

We intended to provide researchers with an interview protocol whereby they can investigate (preservice) science teachers' ontological and epistemological understanding of constructivist notions of science teaching and learning. A main purpose of this interview protocol is to describe the status of preservice teachers' pedagogical perspectives in terms of versions of the constructivist paradigm. The basic analytical framework of this study, as shown in the previous sections, is to use categories derived from the conceptual ecology components to interpret preservice teachers' pedagogical perspectives on constructivism. The significance of this interview protocol is that it

attempted to explore different ontological and epistemological assumptions of preservice teachers' notions of constructivism and the implications of these constructs on their developing views about science teaching and learning. Using this interview protocol, Kwaks (2001) study demonstrated the feasibility of analyzing development of and change in preservice teachers' constructivist ideas throughout a constructivist-oriented preservice teacher education program.

Before a preservice teacher can adopt and ultimately apply constructivism to students learning, which we argue is inseparable from their views of teaching and learning, we wanted to know the extent to which these teachers internalize the ontological and epistemological characteristics oftheir 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. Along this line, the development of a deeper understanding of changes in preservice teachers' developing views on constructivism will be instrumental in providing a framework for considering both the learning processes involved in changing [preservice teacher's] conceptions, as well as providing a framework for designing instruction that [might] facilitate those changes (Hewson & Kerby, 1993, p. 5). 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 (p. 6). The findings of this investigation have considerable potential to make contributions to both instruction of teacher education programs and research.

The development of a system of categories for identifying constructivist ideas (i.e., ontological, epistemological, and pedagogical profiles), and its use in tracing of the development of preservice teachers' beliefs changes throughout their university coursework, has the potential to contribute to a better understanding of how preservice teachers learn to teach. Accordingly, this interview protocol will b e a valuable theoretical and analytical framework in describing the relationship between a teacher's beliefs about nature of knowledge (or reality) and his or her conceptions of science teaching and learning. This understanding can lead to a restructuring of science teacher education methods courses.

APPENDIX A

Interview Protocol on Constructivist Perspectives

Part 1: Interview-about-instances of constructivism as a theory of knowing and learning

Protocol: (O: Open-ended questions, P: Probing questions)

O: In your view, is there science teaching happening here (how would you interpret what happened in each situation)?

P1: If you answered yes or no, what tells you that this is the case? Please give reasons for your answer.

P2: What do you think the students learn in each situation?
P3: How is she learning it?
P4: Could this kind of learning happen in a classroom?
P5: How do you judge if students have learned?
P6: Can and should everybody learn the same things in school?
P7: If you had to help students learn science, what approaches (strategies) would be most helpful?

Items:

1. [Handing out crystals] Teacher in a middle school at the start of a topic on crystals, asking the class, "What can you tell me about the crystals I've passed around the class?"
2. [Student watching TV] A student at home watching a TV program on chemical plants which produce new plastics from coal. (Or, watching the Discovery channel which shows El Nino and related global weather anomaly).
3. [Students in library doing problems]Two10thgradestudents in a libraryworking on a set of vapor pressure problems from the chemistry textbook given for homework.
4. [College professor and first graders] College professor lecturing on molecular orbital theory to a small group of first graders. Or, College professor lecturing on integral calculus to find the areas of regions bounded by curves for which no standard area formulas are known to a small group of the gifted (ages 5 to 6).
5. [Teacher describes algorithm] Teacher in front of 10th grade chemistry class, describing the steps used in balancing oxidation-reduction equations by the method of half-reactions.
6. [Teacher questioning student statement] Teacher reads a 10th grade chemistry student's statement that "Ideal gases have no volume" and asks, "Were you referring to the gas particles or the gas as a whole?"
7. [Teacher asks students to label diagram] Teacher at end of a demonstration of the electrolysis of water distributes a drawing and asks students to label the apparatus used in the experiment from memory.
8. [Student asks question] Junior high school student in class, watching an experiment on the electrolysis of water which has been going for some time asks the teacher, "Do you think you've got all the oxygen out of there yet?"
9. [Student making muffins] A student at home following a recipe for blueberry muffins.
10. [Teacher locating error sources for the following days experiment] A teacher, conducting an experiment by himself to locate possible error sources after school.
11. [Teacher searching for weather map data] A teacher, searching Internet Web site at home to locate local weather map raw data that is to be analyzed meteorology class.

Part 2: Ontological Beliefs

[Open-ended questions]

O: What is scientific knowledge?

P1: How is scientific knowledge arrived at?

P2: What the nature plays in giving shape to the knowledge that is constructed?

P3: Is there an external world (a real nature) that influences or stimulates each individual cognizing agent, and helps to shape in some way thatknowledge that is constructed?

--- And if there is, how does it exert its influence?

P4: Does the natural world in some way constrain what we can believe about it?

P5: In your view, what is the difference between the real objects of science (the world such as falling apples, planets, or a rusting iron bar) and the theoretical objects of science (the material and events as described by the theory such as a point mass, gravity, mutation, inertia, or photosynthesis)?

[2a: Forced-choice questions: Provide the preservice teachers with alternatives]

Protocol:

In your view, how does the knower come to know about the world considering the status of the world of nature external to the knower?

Would you be able to choose one argument over the other as your own opinion?

Discuss or comment on these options one by one and then finally choose one as your own position?

A: Science is a study of objectively existing physical entities. The statements of science are true or false depending on the properties of those entities (i.e., the extent to which structures in the head correspond to real objects present in the world), independent of our ability, or lack of ability to determine which is true. Theories refer to real features of the world and science has discovered a world independent of humans.

B: There is a reality but there is no way to directly access that reality. The best we can say about our attempts to get in touch with reality is that our theories, so far, have avoided points of friction with the environment. That is, concepts which cohere (resonate) with what one already knows are judged truthful or valid provided that they also avoided constraints or obstacles present in the real world.

C: Individuals, in their role as co-participants in socially shared activities, develop certain common perspectives with regard to objects and events in the world. Groups of individuals carve the world up through a process of social interaction and social negotiation. They see meaning as a product that arises in the process of the interactions between people who are engaged in a shared activity. Scientific society creates the world that the mind must respond to.

D: The world, like a literary text, is open to multiple interpretations. The language

members of particular discourse communities agree on what is considered reality. The objects of science are taken to exist only within these systems of thought and culture. It is meaningless to speak about the absolute reality of scientific objects. A reality existing outside of language may exist but there is no way to get at it other than through a communitys way of talking about it.

Part 3. [Epistemology: How do preservice teachers view scientific knowledge]

[Open-ended questions]

O: Are science principles in textbooks always true?

P1: When learning new ideas, which is better: memorizing facts or trying to understand complicated materials?

P2: In your view, how do you learn best? When and where?

P3: How do you know thats the better way to know, or better way of understanding the world?

P4: How do you know when you have learned? How do you know when you know something?

P5: Is science too complicated and difficult for ordinary students to understand well?

P6: Do you believe that the science you learn in school has little or nothing in common with your life outside of school?

P7: Learning science for you is more like·. Following a recipe/ a mixture of memorizing words and facts/ understanding things that didnt make sense before/ etc.

P8: How do scientists convince other scientists that the other scientists results are wrong?

[Forced-choice question]

Discuss or comment on these options one by one and then finally choose one as your own position?

A:Allscience theories are fallible and liable to refutation, but over the course of history, scientific theories approach truth more closely. That is, the replacement of older scientific theories by newer ones is a progressive step toward ultimate scientific truth.

B: Scientific truth is fallible and controvertible (tentative), and can never be regarded as beyond revision. Our knowledge is always provisional, in that it is always open to confirmation, elaboration, revision or change.

C: Nature serves as an instructor, or as a sort of template which the knowers merely copy (or absorb) in a relatively passive fashion. Therefore, the aim of science is the understanding or explanation of our world. Statements of science are true or false depending on the extent towhich structures in the head correspond to those present in the world.

D: External nature plays a decisive role in shaping what we know about it, that nature somehow leaks in and acts as a constraint in our knowledge-constructing

activities. As a result of interacting with the real world, we only construct those ideas that are in some logical sense isomorphic with nature.

E: Knowledge is a social construct (a property of organized collectives). Scientific theories not only result from the interaction of individual with phenomena but they also pass through a complex validation process by the scientific community. The community decides the acceptance of every knowledge claim based on these agreed-upon rules and conventions. Scientific knowledge is invented in order to make sense of observations.

Part 4: The role of teacher

[4a: Open-ended questions]

O: In your view, whats the ideal role of the teacher?

P1: How would you describe yourself as a classroom teacher?

P2: What role model do you have for yourself as a classroom teacher?

P3: What do you consider to be the founding principles of teaching?

[4b: Forced-choice questions: Provide the preservice teachers with alternatives]

Protocol:

In your view, whats the ideal role of teacher?

Would you be able to choose one argument over the other as your own opinion?

Discuss or comment on these options one by one and then finally choose one as your own position?

A: The teacher, representing society (cultural representative), has an obligation to educate students and to assist them in learning what is currently represented as scientific knowledge that they do not seem to have, because the teacher thinks it would be good and useful for them to have it. **[Teacher's role]** The teacher, in this view, not only displays the materials to be learned, but has the important function of ensuring the students attention and of preventing distractions. Because time and circumstance do not allow sufficient knowledge to be acquired through direct experience of the world, the student is expected to expand his/her understanding through the expert accounts provided by the disciplines—biology, chemistry, history, etc.

B: At issue is the question of how members of the classroom community can reach consensus about the nature of subject matter objects and events. The teacher should act with the intentions of encouraging the students to explain and, when necessary, justify their interpretations. Teaching becomes a matter of creating situations in which students actively participate in scientific activities that enable them to make their own individual constructions rather than practiced routines or standard interpretations. **[Teacher's role]** Teachers facilitate and support students as they construct ideas by themselves (students are viewed as being scaffolded or

apprenticed as they gain understanding of scientific ideas).

C: Learning represents a process of self-organization, and knowing is a subjective sense-making activity located in learners minds. It follows an unvarying sequence, ending in the construction of a scheme. Schemes, constructed in the head, mediate between the mind and world, subject and object. **[Teacher's role]** The teacher must be concerned with what goes on in the students head in an attempt to change the students conceptual structures. The teacher, representing society, must structure and facilitate learning environments with a range of experiences so that students can learn what the current society regards as having greatest viability at that particular time.

D: The teacher, as a more knowledgeable other, structures the learning experience in a way that allow students to overcome whatever limitations might impede their attainment of a desired learning goal. The teachers, as cultural representatives, present ideal forms for the child to emulate. **[Teacher's role]** Teachers, as experts, model scientific methods for students, highlighting the verbal and physical moves that constitute mastery of the process. Teachers mediatebetween students and the public standard. Scientific understanding and modes of thought require initiation into a scientific tradition, an initiation provided by school science teachers.

E: To steer or funnel the students towards the accepted scientific interpretation or solution by deciding what is sense and what is nonsense. In doing so, the teacher evaluates the students' ideas (solutions) with respect to a standard interpretation that the teacher has in mind. Or, the teacher is obligated to acculturate her students to the scientific ways of knowing of the wider community. **[Teacher's role]** If the teaching is to lead pupils towards conventional science ideas, then the teachers intervention, both through providing appropriate experiential evidence and making the theoretical ideas and conventions of the science community available to pupils, is essential.

[4c: **Past experience of teacher's role**: Provide the preservice teachers with alternatives]

P1: **Do any of these describe your previous teachers?**

Can you tell me about that?

Part 5: Personal History

O: Could you tell me briefly your personal history, such as why you want to be a secondary school teacher, and what have you done before you enter this M.Ed. program in terms of schooling a career experience?

APPENDIX B

Structure of Analysis Scheme: Definitions of Coding Categories

Coding/Analysis Category	Definition/Exemplary Quotes
Ontological Beliefs	Ontological beliefs include any statements related to the status of the mode of existence of types of entities in the world. This category included any statements in which preservice teachers are commenting on the status of reality or the existence of scientific objects. That is, any comments concerning the issue of the relation between our ideas and the nature behind them (Phillips, 1997b, p. 176) and any philosophical claims about reality.
Realist: an ontological position advocated by Piaget	[Definition] According to the realist, the material world (objects of knowledge) as a real structure exists independently of human experiences and knowledge. Realists maintain that science has discovered a human-independent world, including the world of unobservable entities such as electrons, viruses, and tectonic plates (Matthews, 1994; Nola, 1997). Realism consequently presupposes a representational correspondence between mental representations and whatever they represent in the world (Bickhard, 1997).

	[Exemplary Quotes] I think that theres some sort of material universe and that human perception might change that reality, but theres still an independent reality that still exists : So I mean I think if humans weren't here, the universe would still exist with everything in it. I only believe that the world will go along without us and these natural processes are real and they are happening whether we think about them or not. (Young 1) There are existing physical entities and those entities are independent of humans : and we may not be able to know that objective reality completely, but that doesn't mean that there is not an objective reality out there. (Young 3)
Radical: An ontological position advocated by von Glasersfelds radical constructivism	[Definition] This ontological preference is newly developed in this research to depict von Glasersfelds radical constructivists ontological position according to which there is a reality but there is no way to directly access that reality (no extraexperiential reality). In a sense, what radical constructivism denies is the possibility of any certain knowledge as a representation of the world, not the existence of the physical world; therefore, radical constructivism could be assigned an ontologically neutral position (Ernest, 1993).

	[Exemplary Quotes] I most liked the reasoning and argument with von Glasersfeld's constructivism [where] he talked about people's knowledge of reality and everybody constructs their individual reality based on acceptance of their social community, also an influence of social community. I thought that again von Glasersfeld explained it well that it probably, there is a reality that exists independently, but there's no unmediated access to the world : The reality that everyone is seeing is based on their experiences, their conceptions, and their interpretations. (Ellen 2) I would say, you have your world of images and you never really have access to the reality · everything is a construct, everything is, whatever interpretation we give it, we do agree on things, but we all have different filters, and that's going to affect the way that we assimilate information. (Rob 3)
Idealist: an ontological position advocated by Social constructivist	**[Definition]** Idealists maintain that either there is no world outside of human experience, or that such a world, including human experience, is all ideational and is constructed or constituted by our discourse and theorizing.

	[Exemplary Quotes] Basically I feel that we're exposed to stimuli or phenomena, about which their existence we really dont know, all we have is our stimuli, and throughout thought processes if you reflect on it, and you give meaning to those phenomena to the sense, and outside of that meaning that we can think of nothing. (Ben 1) I also think that we are determined more or less by our social interactions, by environments that we grow up in, the negotiation, and all of this forms our world; our language sculptures our world; our relatives, our family, friends and all those things have an influence on who we are and how we come to see the world. (Rob 4)
Epistemological Beliefs	This category includes any statements related to epistemological issues such as what counts as knowledge, how this is produced and warranted or justified (Phillips, 1997b, p. 162), and the role of reality in knowledge construction, as well as any statement revealing what each interviewees view of the relationship of her own epistemological commitments to each version of constructivism.

[Progressive] Absolutist (also known as Objectivism; Foundational-ism	[Definition] (Progressive) Absolutists hold that over the course of history, science approaches the truth (Truth) more closely. That is, the replacement of old scientific theories by new ones is a progressive step toward the ultimate truth about the world and how it works (Ernest, 1998). Moreover, scientists could work in science because they have faith in progressive absolutism, and tend to believe that increasingly accurate approximations can be made to account for the world and how it works (AAAS, 1989, p. 26; Harding & Hare, 2000). [Exemplary Quotes] I think there is an objective reality but we are still far from understanding it completely : we can come up with ideas that are more and more consistent · more often correct or predictive : every scientific study gives us another piece of the puzzle. And we can probably go on for millions of millions of years, but I think that with each successive piece we come close to the true picture of reality. (Young 2) Theories tend to evolve all the time : Theories change because we are constantly finding new information. The more knowledge we have, the more knowledge we realize : as we know more we come close to the scientific truth and we replace old theories with new ones. (Lynda 3)

Piagetian: an epistemological position advocated by Piagets individual constructivism	[Definition] According to Piaget, as a result of interacting with real structures in the real world, the inquiring child will come to construct his or her internal cognitive structures that, while not copies of those in the world, will be logically isomorphic with them (Phillips, 1997b, p. 183). Piaget is admitting that external reality is playing a role in constraining and shaping the views we construct about it (p. 184), but nature does not uniquely and unequivocally determine our interpretations or construction of the world (p. 170). This epistemological commitment emphasizes that science is a creative human endeavor which is historically and culturally conditioned, and that its knowledge claims are not absolute (Matthews, 1994, p. 139).

	[Exemplary Quotes] We judge whether a theory is valid or invalid based on how well it supports the evidence of what we know of the world : human beings are creating scientific theories to explain what's in nature · and I think you have to come to terms with nature and nature is probably our defining criteria. (Ginny 4) I don't think there is ultimate scientific truth. I think there is a point where you integrate more and more things and you expand your base of knowledge but I don't know that there is an ultimate scientific truth. I do think that the nature does play a role and shaping what we know about it because we base ourselves on phenomena that we observe to create laws and explanations. We are trying to come up with, say, a dictionary of explanations for things and we have to change things in that dictionary. So it's kind of like a book that we are constantly editing. We are changing things in the book all the time based on things that are happening. Some things have made more constant over longer period of time. Other things are more susceptible to change. There is no absolute, ultimate scientific truth. There is no final answer. (Rob 4)

Fallibilist	[Definition] Fallibilism is an epistemological position that is opposed, on the one hand, to [the epistemological position of] relativism and, on the other hand, to absolutism (Matthews, 1994, p. 37). Fallibilists maintain that scientific knowledge is fallible and controvertible (tentative), and can never by regarded as beyond revision. Our knowledge is always provisional in that it is always open to confirmation, elaboration, revision or change. [Exemplary Quotes] I believe that everyone filters that reality through their senses in different ways, depending on what they know, what they don't know, their current emotion state, and some other factors like that. (Young 2) We should not stick to something and say this is never going to change : so you want to always leave them with an open mind to accept that there is nothing that is absolute or set in stone. Things should be subject to further questioning and possible modification. (Rob 4)
Relativist: An epistemol -ogical position advocated by social constructi onism	[Definition] Relativists hold that knowledge is constructed within a particular community. Following from Kuhns picture of science, relativists maintain that no reliable comparison can be made between competing views since different paradigms construct different natural universes and there is no one way that the world is. At an extreme end of this position, some strong social constructivists contend, the natural world has a small or non-existent role in the construction of scientific knowledge (Phillips, 1997b, p. 190).

	[Exemplary Quotes] We give meaning to phenomena, the outside world.... everybody tends to try to define their own, define their own world and science becomes part of that. (Ben 1) What you consider to be rational or logical depends on the culture and society : for example, the witch doctor in the Amazon or medicine man in the Amazon, would you call it subjective scientific knowledge? It's not accepted in the sense that nobody has done studies to see, you know certain drugs have, but, I would call that accepted within his community. If you have a witch doc, a medicine man, who cures people because he knows a lot about interactions of plants and stuff. It is accepted within his community even though it might not be accepted within the larger scientific community. (Rob 3)
C S T L/ Optio ns	Driven by their ontological and epistemological perspective, individual, radical, or social constructivists have different sets of ideals in terms of their views of science teaching and learning, views that guide their instruction. Each set of ideals include statements related to how they think people learn, what is involved in learning and teaching science, what the central focus of planning instruction is, what an individual (radical or social) constructivist teacher would be like, and, sometimes, what instructional approaches they adopt, which has to do with their view of how people, specifically students, learn.

Traditional	[Definition] Inferred pedagogical implications adopted by the authoritarian, teacher-centered, transmission model of science instruction, so called banking model of education (Matthews, 1994, p. 138). [Exemplary Quotes] If they're paying attention, they will learn it · teaching is transferring knowledge or skills or concepts from one person to another · learning is receiving the same things, information, and concepts. (Ellen 1) The founding principle of teaching is passing on knowledge [because] the students need the knowledge to live their everyday world. (Ginny 1) I think the teacher should let the students know what the teacher expect them to know and I think because of time constraints the teacher needs to use expert accounts provided by other disciplines : the role of the teacher can be a mentor, I feel often times, the role model of students, for the students to look up to, and a source of information. (Young 3)

Piagets Individual	[Definition] In this view, the teacher is obligated to acculturate her students to the scientific ways of knowing of the wider community. In other words, the teacher is necessarily an authority in that she has to guide the institutionalization of scientific activities in the classroom. This is because many, if not most, things in science are beyond the experience of students and the capabilities of school laboratories to demonstrate (e.g., the cellular, molecular, atomic, and most of the astronomical realm). Students cannot generate these ideas for themselves. If the teaching is to lead students towards conventional science ideas, then the teachers intervention, both through providing appropriate experiential evidence and making the theoretical ideas and conventions of the scientific community available to students, is essential (Driver, 1989, p. 92). Many of the constructivist teaching programs, such as Drivers work at Leeds, and much of the conceptual change literature fall within this category (Geelan, 1997, p. 21). [Exemplary Quotes] Learning is a process, which goes through some sort of conceptual change, and that misconceptions need to be restructured in order to for children to really understand what's going on. (Ellen 2) I guess my focus of my science class would be on the conceptual change aspect · if any meaningful learning is to take place, I need to know what the student knows already and then work from there in order to modify what they know : by the time they leave your classroom that you would want them closer to the accepted norm of what the scientific community says. (Young 4)

von Glasers-feld's Radical	[Definition]. From a radical constructivists view, the cognizing subject generates cognitive schemes to guide actions and represent its experiences. In his suggestions for the practice of teaching, von Glasersfeld contends, the teacher must be concerned with what goes on in the students head : try to build up a model of the students conceptual structures to modify the students conceptual structures (1995a, p. 15). Pedagogies based on this perspective identify knowledge as a subjective sense-making activity located in learners minds and focus on developing the experiential fitness of learners concepts for making sense of their intersubjective experiences (Taylor, 1993, p. 283). From this view, the teacher, representing society, must structure and facilitate learning environments with a greater range of experiences so that students could learn what current society regards as having greatest viability at that particular time (Taylor, 1993; Tobin & Tippins, 1993; Wheatley, 1991, 1993).
	[Exemplary Quotes] The role of the teacher is to help, bring along the thought progress of the students. (Ginny 3) I think for the most part at least in the Western world, we do build plans in our head and then we try to relate things in our head to the outside world based on those plans that we make. So therefore the teacher should definitely know what is going on in the student's head and try to understand what the student understands. (Rob 4) Learning processes or information is just mediated and organized in such a way that fits into the context that the person learns and therefore becomes part of their own, become extends of their context. It's a constant process, extending your context or your world. Its almost like existential, kind of giving meaning to your world. (Ben 4)

Vygots-kys Social	[Definition] The pedagogy of this position could hinge on the notion of apprenticeship, or legitimate peripheral participation. This involves admitting novices into social practices at the periphery, and then letting them take up full player roles as they develop mastery (Ernest, 1995, p. 471). Because of the historically constituted nature of the objects of science as the discourses in which they persist, scientists join and learn to participate in a preexisting and already populated realm of discourse (Ernest, 1998, p. 193). From this view, the teacher, as a more knowledgeable other, structures the learning experiences in ways that allow the students to overcome whatever limitations in skill might impede his or her attainment of a desired goal by modeling tool use for novice, highlighting the verbal and physical moves that constitute mastery of the process (Prawat, 1996, p. 222). In this view, at issue is the question of how members of the classroom community can reach consensus about objects and events in the world. The role of the teacher is to help students construct ideas by themselves and students are viewed as being scaffolded or apprenticed as they gain understanding of scientific ideas.
	[Exemplary Quotes] The teacher never really shows what the standard is so the students then have to really think about what it is that they're doing, and make decisions about what's right or wrong on their own rather than being told what that right or wrong thing is. (Ginny 2) I am kind of there to link students and the scientific community, between students and the public standard. In a way you would help them interpret things from a scientific community back and forth until they have enough of conceptual framework to do their own interpretations and go off on their own. (Rob 4) Learning is acculturation, I mean, any individual went into a society, to a culture, maybe learning to give meaning to phenomena of the world outside of themselves where there is a shared meaning. Learning is mediated by others in a culture otherwise we will be solipsistic. (Ben 4)

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