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Case Study: A Preservice Teacher's Belief Changes Represented as Constructivist Profile

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ABSTRACT

This qualitative study investigated a preservice teacher's developing views of learning with the influence of constructivist epistemology taught in the Math, Science, and Technology Education (MSAT) Master of Education (M. Ed.) preservice teacher education program. The MSAT teacher education program employs constructivist aspects of teacher education and generates applications of constructivism to the practice of teaching, as revealed by faculty interview data. It is important at this point to emphasize that there are significant epistemological and ontological differences between different versions of educational constructivism (i.e., individual, radical, and social constructivism) and that these differences imply different pedagogical practices. For the 16 preservice teachers included in a larger study, the epistemological and ontological characteristics for each teacher's developing views of learning were identified through four in-depth interviews. Data from interviews were 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). Of the sixteen participants in the larger study, five significantly changed ontological and epistemological beliefs and eleven did not. Profile changes for the five who did change also resulted in changes in their conceptions of science teaching and learning (CSTL). In this article, one of the five teachers case was presented with rich quotes. This case study documents how a preservice teacher transferred his ontological and epistemological beliefs to his pedagogical beliefs and maintained the consistency between his philosophical beliefs and CSTL. It also demonstrated implications that changes in components for an educational constructivist profile have for a preservice teacher's view of himself as teacher. Data indicated the possibility that a constructivist-oriented preservice teacher education program can influence students' conceptions of science teaching and learning

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by explicitly introducing constructivism as an epistemology rather than as a specific method of instruction. Implications for both instructional practices of teacher education programmes and research are discussed.

Key words: educational constructivism, epistemology, teacher education, constructivist profile change, pedagogical beliefs

I. Introduction

The term constructivism is used broadly throughout education. Constructivism has been used in reference to a research paradigm, a sociological position on learning, a philosophical position on knowledge, and in describing pedagogical approaches to teaching. Among the various kinds of constructivism, one is educational constructivism (Phillips, 1997). Educational (or psychological) constructivism differs from other forms in that it focuses on the ways in which human beings individually or collectively justify their understanding of material objects and mental representations of the world (both social and psychological worlds). Of special interest to educational constructivism are the ontological and epistemological characteristics upon which knowledge is founded. In this research, I documented changes in these characteristics as a preservice teacher completed the university-based coursework leading to teacher certification in science. I was also interested in the implications that changes in ontological beliefs and epistemological commitments had on the preservice teacher's conceptions of himself as teacher and his conceptions of students as learners.

This research focuses mainly on educational constructivism which I subdivide into the categories of individual, radical, and social, depending on the unique ontological, epistemological, and pedagogical commitments of each (see Appendix A for a comparison of versions of educational constructivism, and Kwak, 2001). In spite of all the varieties of educational constructivism, there is little argument that it is an overarching paradigm in contemporary science education or one of the major influences in present day science teacher preparation (Matthews, 1994). While it is common in our experience to hear teacher educators mention different forms of constructivism during their instruction, there is little evidence to support the claim that preservice teachers understand different versions of constructivism beyond using it as jargon. There is also little evidence to support the assumption that a particular version of constructivism should have implications for a preservice teacher's ideal view of teaching and student learning. This is to say that there needs to be evidence to indicate if preservice teachers themselves believe they would be able to teach in ways that are consistent with different versions of constructivism. In a larger study I investigated changes in preservice teachers' profiles of educational

constructivism as they participated in a science teacher education program, and the implications of those beliefs the preservice teachers expected to have on their teaching.

II. Theoretical Overview

Before investigating the implications of any version of educational constructivism on student learning, which I believe are inseparable from teaching, I needed to understand the extent to which teachers can internalize ontological beliefs and epistemological commitments with respect to educational constructivism. And, if they could internalize these characteristics, how did they change during the university-based portion of their teacher education program? For me, a preservice teacher's views of teaching and learning should be founded on these two characteristics. In the section that follows I describe continua for ontological beliefs and epistemological commitments that I will use throughout the remained of this article.

1. Ontological beliefs

Addressing changes in scientific knowledge, philosophers of science strive to explain the objects of human thought, namely, the material existence of the world and objects in it (ontology). Ontological beliefs can be placed along a continuum from realism to idealism. At one extreme on this continuum, realism asserts that there is an existing material world apart from, and independent of, human experiences and human mental activity. Statements consistent with realism maintain that science can discover a human-independent world, including the world of unobservable entities such as electrons, viruses, and tectonic plates (Matthews, 1994; Nola, 1998). Realism presupposes a correspondence between mental representations and the objects they represent in the world (Bickhard, 1997). Ontological positions labeled as realism are consistent with views of learning such as Piaget's individual constructivism and Vygotsky's social constructivism (Phillips, 1997; Ernest, 1995; Geelan, 1997; Gergen, 1997).

The realist stands in opposition to idealism, a position advocated by Gergen's Social constructionism and other radical social positions on constructivism influenced by sociologists of science. Idealists maintain that either there is no world outside of human experience and that the world, including human experience, is constituted only by the human actions of discourse or theorizing about the world. Along this line, in some forms of idealism, scientific knowledge is justified through social interactions, depending on consensus or dissensus within a community of individuals but not against actual observations or reality. According to idealism, our representations, regardless of their individual or social

origins, are all we really have (Matthews, 1994; Nola, 1998; Bickhard, 1997). Furthermore, idealism leads to a relativist epistemological position in that there are no rational criteria whereby some ideas can be judged correct and others incorrect. There is no mechanism for choosing between competing theories or views (Matthews, 1994; Bickhard, 1997).

A third ontological position between the realist and idealist positions is the radical ontological position advocated by von Glasersfeld (1995). This position is neutral with respect to the role of reality (Ernest, 1995). von Glasersfeld contends that while there is realty, there is no way to directly access that reality. That is, there is no extraexperiential reality against which constructions of knowledge could be evaluated (Matthews, 1994). Radical constructivism denies the possibility of any certain knowledge as a representation of the world, not the existence of a physical world.

2. Epistemological beliefs

Epistemology is a theory of the nature, genesis, and warranting of subjective [or shared human] knowledge, as well as a theory of "truth." It is essentially about how the epistemic agent - the knower - knows about the world (Ernest, 1995). It is obvious that thinking and learning are influenced by an individual's beliefs about the nature of knowledge and learning (i.e., a personal epistemology). The continuum for epistemological commitments I use to describe educational constructivism includes social constructionism's Relativism, Radical constructivism's Fallibilism, and Individual constructivism's Piagetian. A forth epistemological position taken by traditional pedagogical practices is represented as Absolutism.

At one end of this continuum, Fallibilists maintain that scientific knowledge is tentative and controvertible, and can never be regarded as beyond revision. Our knowledge is always provisional in that it is always open to change through processes of confirmation, elaboration or revision. Fallibilism is "an epistemological position that is opposed, on the one hand, to relativism and, on the other hand, to absolutism" (Matthews, 1994). Relativists hold that knowledge is constructed and justified within a particular community. Following from Kuhn's notion of science, relativists maintain that no reliable comparisons can be made between competing views since different paradigms construct different natural universes. At one extreme end of this position, some social constructivists would contend, "the natural world has a small or non-existent role in the construction of scientific knowledge" (Phillips, 1997).

In contrast to Fallibilism, Absolutism (also known as Objectivism or Foundationalism) holds that our current theories are absolute and unimprovable. [Progressive] Absolutists hold that over the course of history, science approaches truth (e.g., Truth) more closely. That is, the replacement of old scientific theories by new ones is a progressive step toward ultimate

truth about the world and how it works (Ernest, 1995). Moreover, scientists produce knowledge 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; Harding & Hare, 2000).

On the other hand, an epistemological preference closer to the middle of the continuum, what I call Piagetian, emerged from the interview data I analyzed. Piaget admitted that "an external reality is playing a role in constraining and shaping the views we construct about it" (Phillips, 1997), but nature does not "uniquely and unequivocally determine our interpretations or constructions of the world". 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). This perspective on knowledge incorporates participants' statements related to epistemological issues in a larger study. This Piagetian epistemology preference is well aligned with the position advocated by Piaget's individual constructivism. Exemplary quotes supporting each ontological and epistemological category can be found in Appendix B. These quotes were taken from interview transcripts with the participants of the larger study.

3. Conceptions of Science Teaching and Learning (CSTL)

Internalizing the ontological beliefs and epistemological commitments that underlie any view of educational constructivism, preservice teachers would be in a position to act in accord with the pedagogical implications that result from changes in these beliefs. These actions might take forms such as sensitivity to a learner's previous knowledge, diagnostic teaching, attention to metacognition, and so on. I argue that exposing preservice teachers to issues of learning that does not adequately address the ontology and epistemology of constructivism would provide them with a set of terms but would not challenge previously held views of pedagogy. Therefore, science teacher educators would benefit from knowing if there was change in a preservice teacher's understanding of constructivist ontology and epistemology, change that should result in dissatisfaction with their views of instructional methods that have "usually been composed primarily of exposure to traditional science instruction" (Stofflett, 1991). Along this line, developing a base of knowledge about change in preservice teachers' pedagogical perspectives would 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 facilitate those changes" [in their instruction] (Hewson & Kerby, 1993). That is, such knowledge would provide fundamental insights for designing preservice models that could help preservice teachers acquire more appropriate conceptions of science teaching. Overall this study sought to answer the following questions:

What profile of constructivist beliefs - in terms of ontological beliefs, epistemological commitments and pedagogy (e.g., CSTL) - can be constructed for a preservice teacher during the period of this study? That is, do the ontological beliefs and epistemological commitments of a preservice teacher change as a result of coursework in his teacher education program and, if so, how?

A larger study associated with the results reported here investigated change in sixteen preservice teachers' knowledge about constructivism and the reasons for any change (Kwak, 2001). Constructivism was a major theme in the preservice instruction these students received as will be demonstrated later. In the larger study, each preservice teacher self-reported understanding of educational constructivism was analyzed in terms the ontology, epistemology and conceptions of teaching science supporting a particular view of constructivism. It is important at this point to reemphasize that there are epistemological and ontological differences between different versions of educational constructivism-individual, radical, and social constructivism. As an analytical framework, the main tenets of each version of educational constructivism (Phillips, 1997; Matthews, 1994) were examined with regard to the philosophical notions of ontological beliefs and epistemological commitments. This, in turn, leads to different pedagogical perspectives (Phillips, 1997; Ernest, 1995) depending on which version of constructivism is under consideration. That is, each version of educational constructivism should result in different teaching practices depending on the philosophical positions taken towards ontological and epistemological issues (see Appendix B).

For example, one version of educational constructivism is individual constructivism. This version is characterized as ontologically realist and epistemologically Piagetian position. An individual constructivist should accept the (ontological) reality of an external world (Geelan, 1997). The epistemological commitments for this version of constructivism emphasize that "we only construct those that are in some logical sense isomorphic with nature, not copies of the real world" (Phillips, 1997). For Piaget, a person exists as a real biological entity in a real physical world who constructs mental structures (i.e., 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).

Furthermore, although knowledge is constructed based on experience, these human constructions do not approximate an inherent order in nature. "Many of the constructivist teaching programs, such as Drivers at Leeds University and much of the conceptual change pedagogy, fall within the individual-objectivist" range (Geelan, 1997). Based on the premise that existing ideas are critical to future learning, students' intuitive ideas in science are

known to vary from the ways of seeing adopted and found useful by the scientific community (Duit, 1993). Along this line, Driver and Oldham's (1986) pedagogy suggests that students be enculturated with scientists ways of interpreting the world.

Driven by the epistemological perspective described above, an individual constructivist seeks harmony between scientific and students' conceptions (Driver, et. al. 1994). Individual constructivist pedagogy emphasizes active engagement of students in their own learning processes taking into account the impacts of prior knowledge or conceptualizations on new learning. Therefore, instructional experiences planned by a teacher should help students reconcile any differences between their ways of thinking and those of the scientific community. Moreover, an individual constructivist presumes that children have to be introduced to the public, symbolic, and created world of science and that they should internalize these concepts. That is, "learning science is essentially a process of enculturation into the ideas and models of conventional science" (Driver, 1989). Therefore, scientific understanding requires initiation into scientific traditions and this initiation needs to be intentionally provided through a science teacher's instruction.

A second version of educational constructivism is radical constructivism. Ontological beliefs associated with radical constructivism are a radical position on ontology - there is a reality but there is no way to directly access that reality - "no extra-experiential reality" (Matthews, 1994). In other words, what radical constructivism denies is the possibility of a representation of the world that is certain beyond the individual. Therefore, radical constructivism can be assigned an ontologically neutral position with respect to the external world (Ernest, 1995). A radical constructivist is also characterized by a Fallibilist epistemology - the philosophical view that scientific knowledge is tentative and can never be regarded as beyond revision. Radical constructivists take an instrumentalist approach to scientific knowledge. Sharing roots with skepticism, this view of knowledge maintains a 'functional fit' with the prediction of a subjective experiential reality. That is, knowledge is checked by the extent to which constructions fit with our experience in a coherent and consistent way rather than by a match with an external reality (see Kwak, 2001 for a complete discussion about different ontological, epistemological commitments and pedagogical beliefs advocated by three different versions of educational constructivism).

Ⅲ. Methods

To document preservice teachers' understandings of educational constructivism I used the notion of a profile containing ontological beliefs, epistemological commitments, conceptions of science teaching and learning (pedagogical beliefs), and explainers of change (or lack of change). Borrowing from Mortimer's (1995) notion of a profile change for individual science concepts, I view each preservice teacher as having a constructivist profile - a profile

composed of his or her views on the nature of reality, reason for justifying knowledge, and conceptions of science teaching and learning. Changes in one or more of the components in this profile for the preservice teacher in this study were traced over time. The process of change in the profile is not viewed as the exchange of one belief for another but rather as a shift in components of the overall profile. In other words, even though preservice teachers are able to talk about different versions of constructivism, they could remain attached to their prior views of teaching and learning for a variety of reasons, such as emotional attachment or the low status of an alternative. When change does occur for a preservice teacher, that process will more likely be consistent with the notion of conceptual capture proposed by Hewson (1981). In this article I will demonstrate the feasibility of analyzing changes in constructivist profiles for a preservice teacher and the implications these changes have on his views of teaching and learning.

Constructivist profiles for a student enrolled in the science teacher preparation program are described below. In particular, I sought to identify changes in the ontological and/or epistemological characteristics for the preservice teacher as he completed the university-based coursework for his preservice teacher education program. I also sought to identify the implications of changes in these characteristics on his developing views of teaching and learning. Data were collected over the first three terms (each term lasting 10 weeks) of coursework through four in-depth interviews. The interviews were generally open-ended but included interview about instances on science teaching and learning, and forced-choice questions containing a priori statements linked to various ontological and epistemological ideas[1].

Before presenting my analysis of these data I begin by discussing the intent of the science teacher education program as communicated by faculty teaching in the program. I then illustrate how data collected from the preservice teachers were used to produce constructivist profiles for the preservice teacher presented here. Next, I discuss change in these profiles for the preservice teacher. I conclude by discussing the implications that findings from this study have for teacher education programs that teach constructivism as a significant theme.

1. Description of the science teacher education program

The science teacher preparation program I studied resulted in a Master's of Education degree after five terms of full-time study. The study was conducted from initial enrollment in the program, when students were first introduced to the term constructivism, through the

1) Refer to Kwak (2001) or Kwak & Choe (2001) for a full version of the interview protocol describing detailed interview questions and procedures used in this study, as well as rich direct quotes showing preservice teachers' ontological and epistemological beliefs in their own words.

in the program, when students were first introduced to the term constructivism, through the end of their university-based coursework, just prior to their internship with a practicing high school teacher. Based on statements in the course syllabi and responses to an email interview by faculty teaching in this program, this preservice science teacher education program advocated constructivist perspectives on learning. That is, the majority of faculty in the program stated goals or objectives of their course that were similar to the following: "to promote constructivism as a way of understanding how students learn concepts and as a teaching strategy for stimulating students' conceptual changes" (course syllabus, July, 1999). Syllabi contained required textbooks written by Brooks & Brooks (1993), Ernest (1995), and Tobin (1993), all of which address constructivism at a philosophical level. In addition, instructors for these courses indicated that they modeled what they believed to be constructivism, interpreting constructivism here as the teacher's perspective on how people learn. Providing students with the opportunity to participate in activities that were constructivist in nature, the faculty expected these preservice teachers "to gradually change their views of teaching from that of a student's point of view to viewing teaching from a teacher's perspective" (Vellom, personal communication, 2000). They also wanted their students to plan and implement constructivist-based approaches in the field component of their preservice program.

I concluded this study prior to the student teaching internship, when the influences on my subjects shifted from those planned by the university faculty to those that arise as a result of working with mentor teachers in their school settings. Before examining changes resulting during the theory into practice stage of a preservice teacher's development (e.g., changes due to internship with a practicing science teacher), it is desirable to investigate 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. 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 ontologically and epistemologically before they try to apply that understanding during instruction. This study investigated a preservice teacher's projected pedagogies. Following him into his student teaching and subsequent induction year (s) was not part of this study, although I recognize the importance of doing so in the future.

2. Subjects

In all, thirty-four students were accepted into this science teacher certification program

eight females and seven males - were interviewed four times each for the larger study. Of the sixteen participants in the larger study, five significantly changed ontological and epistemological beliefs and eleven did not. Profile changes for the five who did change also result in changes in their conceptions of science teaching and learning (CSTL). Because of space constraints, in this article I present profiles for one preservice teacher - Rob. Rob's case was chosen because he was aware that his ontological and epistemological positions should be consistent with his pedagogy. In one sense, Rob's case represents the most desirable change in a profile in that it is consistent with the goals of faculty in this teacher education program. This is why he was selected for presentation here - it represents 'best case' scenario. However, he is not a representative of the entire group since only five out of sixteen preservice teachers in the larger study showed any change in their profiles.

3. Data analysis

The four main components of a preservice teacher's conceptual ecology (e.g., ontological beliefs, epistemological commitments, CSTL, and explainers) were derived from four coded interview transcripts. I coded statements from each transcript in terms of four categories (i.e., ontological beliefs, epistemological commitments, pedagogical beliefs, and explainers) using the text unit function in NUD*IST[2]. If a text unit applied to more than one category, it was placed in both. Each preservice teacher's constructivist profile was generated using the coding table function in NUD*IST that presents the number of text units coded at any set of sibling nodes. Each preservice teacher's overall profile consisted of three sub-profiles: an ontological belief profile, an epistemological belief profile, and CSTL profile based on the proportion of text units in that category.

The proportion of text units in each category was then calculated as a percentage of all text units for an interview. Each sub-profile was further divided into categories such as realist, radical, and idealist for the ontology sub-profile. The height of each segment in the ontological profile indicated the percentage of text units for each component. Finally, the change in the number of text units coded for each preservice teacher's sub-profiles over time was recognized as changes in the heights of segments within that profile. Lastly, statements coded as explainers were examined for all transcripts. Explainers included statements in which preservice teachers commented on why change did or did not occur. Emergent categories for these statements included each teacher's past experience (e.g., their memory of previous exemplary teachers, schooling experiences, image of self as learner,

2) NUD*IST stands for Non-numerical Unstructured Data Indexing Searching and Theorizing.. NUD*IST is a computer package designed to aid users in handling non-numerical and unstructured data in qualitative analysis, by supporting processes of coding data in an index system, searching text or searching patterns of coding and theorizing about the data.

Emergent categories for these statements included each teacher's past experience (e.g., their memory of previous exemplary teachers, schooling experiences, image of self as learner, academic history, and life path), the M. Ed. program (e.g., what was learned from coursework of their preservice program, field experiences, observations of other teachers such as the program faculty and their mentor teachers, and discourses with their peers), other background knowledge or statements of dissatisfaction (e.g., complaints about previous schooling experiences). My analysis was verified through member checks with each participant after an interview. The final analysis included presenting each participant with my analysis of changes in his or her profiles throughout all interviews.

Ⅳ. Findings: Rob's Case

This case study begins with a brief sketch of Rob's past experiences and a brief account of his personal history prior to entering the teacher education program. Subsequent sections elaborate on Rob's ontological belief profile, epistemological belief profile, and CSTL profile. In general, the characteristics represented by each sub-component in a profile are illustrated with appropriate examples from interview transcripts. In the final section, I discuss the subject's explanations (i.e., explainers) for change in his profiles.

1. Past experiences

Rob is a Mexican American male in his middle thirties. He enrolled in the preservice teacher education program with the intent to be certified as a high school biology teacher. His previous career experiences included working as a Spanish/English interpreter at children's hospital, as a regional Field Recruiter for a state Department of Migrant Education, and as a part-time biology instructor for undergraduate college students. In his application to the program he wrote about the need for teachers to provide "clear understanding and communication of information to students." He also wrote that "students' resilience and enthusiasm, as well as their level of understanding are characteristics which can be found in most younger people if one is willing to take the time" to look. When applying to the program he indicated his desire to share his "enthusiasm for the natural world with seventh through twelfth grade students" - a fascination he had always had with the biological sciences. He also stated that he felt he could "offer a unique opportunity to engage the interest of students of all ages. He wanted to be a teacher who would "spark students' interest, through the use of everyday examples and applications which might seem to have greater bearing and relevance on their lives" (Rob, personal communication, June 1999).

Analysis of Rob's ontological profile following the first interview showed his preference for the realist ontological position. That is, for text units coded under the ontological belief category, all (100%) were identified as belonging to the subcategory for realist ontology (see Fig. 1). Asked to align his ontological beliefs with one of the forced-choice items during the first interview, Rob selected the a priori realist preference and stated that "[nature] does exist independently, regardless of whether we do appreciate it or not. Those concepts are there for the grasping" (Rob, interviews 1 & 2). According to Rob, "there is a real world of material and other objects which exists apart from our theorizing about it." Rob's realist ontological beliefs were grounded in his science background. That is, the relationship of theoretical objects to reality was, for Rob, determined through his experiences with learning scientific knowledge. In his experience, when he understood a science concept, it had concrete existence for him. If a concept was unintelligible, "it was made up to explain why this is happening." In Rob's case, the plausibility of a theoretical element determines its physical reality. In a sense, Rob believes that for a conception to be true, it needs to be consistent with his worldview.

Preference for a realist ontological position was maintained in Rob's second interview (65% of all text units). However, Rob now offered some statements coded in the idealist ontological belief category during his second interview. Following this interview, Rob's profile included statements categorized into multiple ontological subcategories (i.e., realist, radical, and idealist).

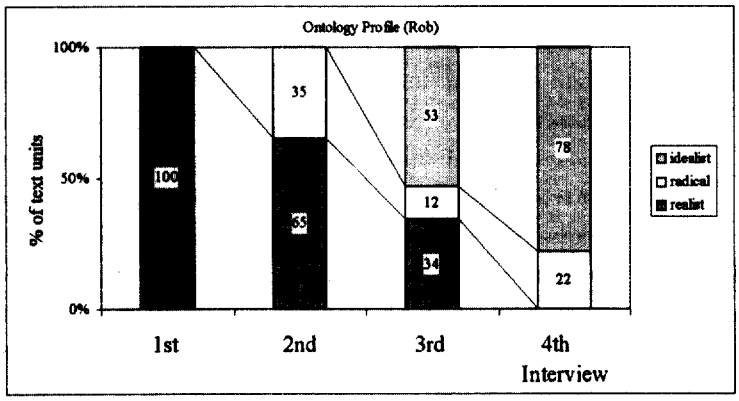

Fig. 1. Rob's ontological belief profile

In the third interview, Rob offered statements of apparently contradictory ontological beliefs (i.e., realist and idealist) as follows: 34% realist, 12% radical, and 53% idealist. Regardless of the incompatibility of his statements, Rob's comments were distributed across all positions (e.g., realist, radical, and idealist). In the second interview, Rob's profile showed radical ontological beliefs as he acknowledged that our perceptions and our

all positions (e.g., realist, radical, and idealist). In the second interview, Rob's profile showed radical ontological beliefs as he acknowledged that our perceptions and our experiences constitute reality. When responding to the forced-choice questions in the third interview Rob offered multiple interpretations regarding the nature of the external world. For example, when responding to a question about his perceptions of the natural world independent of his understanding (i.e., a realist portion for ontological beliefs), his statements were consistent with von Glasersfeld's ontological assumption to the following degree: 35% of text units in the second interview, 12% in the third, and 22% in the fourth interview. Typical statements placed in this radical category for Rob included: "[since] we all have different filters, thats going to affect the way that we assimilate information. You have your world of images and you never really have access to reality· Everything is a construct" (Rob, interview 3). According to Rob, "each individual constructs his or her own subjective reality by interpreting and perceiving our daily laws and everything in different ways" (Rob, interview 3). While Rob's statements indicated that "there is a reality that includes physical objects such as stars, the sun and the moon", he also contended, "there is no way to directly access reality because of each individual's different internal filters." This position is consistent with a radical ontological position.

Rob's ontological belief profile following the fourth interview was 22% radical and 78% idealist. As he read through the exemplary realist option presented during this interview, he questioned, "how do we know that there is a reality?" He further questioned the existence of a known reality stating: "reality is a subjective thing. My reality is different from your reality. I don't think there is one objective realty." Statements like this were placed in the idealist category for Rob. Other examples included: "the language, cultural beliefs, and social group that you grew up in and developed in are going to affect how one perceives the world" (Rob, interview 3). Rob's shift to an idealist position was further elaborated in the fourth interview as he articulated the roles that "cultural differences" and "our social interactions, and environments that we grow up in" determine "how we come to see the world" (Rob, interview 4).

Although it is not a new idea that people can have different ways of seeing and representing their world (Mortimer 1995), Rob's conceptualization of reality shifted dramatically from the first interview to the last. For example, when he talked about the existence of electrons, tectonic plates, and black holes, his ontological beliefs were grounded in a realist position. However, when asked to align his ontological beliefs with exemplary statements of realist, radical, and idealist positions through forced choice questions, his comments revealed a coexistence of different ontological assumptions and beliefs. Rob's perceptions of reality moved from one category to another depending on the contexts and contents of the situation. Over the four interviews, his profile changed from solely realist to including varying proportions of radical and idealist ontology by the third interview. As

Mortimer (1995) suggests, reasons for these changes can be found in the different prior experiences Rob received as a learner and in his distinct socio-cultural background. Factors that explain Rob's reasons for change in his ontology are discussed after analyzing his epistemological profile in the following section.

3. Rob's epistemological profile

Text units were coded within subcategories of absolutist, Piagetian, Fallibilism, and relativist for epistemology. My focus when analyzing the interviews was to determine the foundations for Rob's views on scientific knowledge and truth. Rob was asked to discuss his ideas and to comment on forced-choice options describing different epistemological standpoints. As can be seen in Figure 2, Rob maintained a preference for a Piagetian epistemological position as the largest component throughout all interviews: 79% in the first interview, 76% in the second, 51% in the third, and 70% in the fourth interview. Statements indicating Rob's Piagetian position included: (1) "nature does play a role in shaping what we know about it because we base ourselves on phenomena that we observe [in nature] to create laws and explanations"; (2) However, "nature does not act as a constraint because people speculate and infer beyond what we can see" in nature; and (3) "I don't think there is ultimate scientific truth [although] 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" (Rob, interview 4). Rob rejected the possibility of obtaining "ultimate scientific truth" although he indicated that human beings are striving for it in our attempt to "come up with a dictionary of explanations for things that are happening" (Rob, interview 4). According to Rob, because "these [scientific theories and explanations] are all our inferences, we don't really know what happens and we don't know if we can get to a true picture of reality and there is no final answer" (Rob, interview 4).

After the first interview, Rob's epistemological profile was 79% Piagetian and 21% Fallibilism. Rob maintained the Fallibilist epistemological component in his profile throughout all interviews as follows: 21% in the first interview, 9% in the second, 30% in the third, and 23% in the fourth interview. According to Rob, "the world is always interpreted through your mind" (Rob, interview 2), and as "subjective beings [we] tend to interpret things subjectively· so objectivity is tough one" to achieve in science (Rob, interview 4). Accordingly, he acknowledged that "scientific truth is fallible and controvertible" (Rob, interview 3) and that "science should always be open to revision" (Rob, interview 4).

As was the case for other interviewees in the larger study, Rob's epistemology was closely related to his ontology. For example, Rob had an absolutist epistemological component (15%) that matches logically with his realist ontological beliefs after the second interview (15% absolutist, 76% Piagetian, and 9% Fallibilism). He stated that "[nature] does

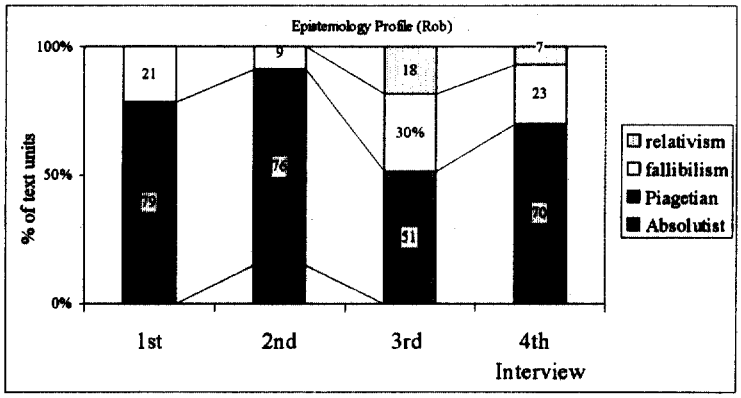

Fig. 2. Rob's epistemological belief profile

exist independently [and that] knowledge and those concepts are there regardless of whether we appreciate them or not" (Rob, interview 2). On the other hand, in accordance with statements about an idealist ontological perspective, Rob revealed a relativist epistemology during the third interview. In the third interview, I found apparently contradictory Piagetian and relativist epistemological positions coexisting in Rob's epistemological profile: 51% Piagetian, 30% Fallibilist, and 18% Relativist. From his relativist epistemology, Rob acknowledged that different socio-cultural communities (e.g., a Western community or an Amazonian native community) construct different realities. The acceptance of knowledge claims for people in these communities "depends on the culture and society within that community" (Rob, interview 4). Alternatively, according to Rob, a reality constructed by "someone who is a creationist with religious beliefs that are not accepting of evolution" would view the world differently from Rob's reality, his being one that is accepting of evolution (Rob, interview 4). Rob went on to say, "those are different realities and that cultural differences [affect how] people see things" (Rob, interview 4). After the fourth interview, Rob maintained his relativist epistemological position but to a lesser extent than in the previous interview. Following the final interview, Rob's epistemological profile featured the coexistence of three different epistemological positions: 70% Piagetian, 23% Fallibilist, and 7% Relativist.

In conclusion, Rob consistently maintained two components to his epistemological profile- Piagetian and Fallibilist. However, some of Rob's statements were coded in the relativist epistemological category. One important issue regarding changes in Rob's ontological and epistemological profiles is that he could transfer his ontological and epistemological beliefs to his views of science teaching and learning. That is, he was aware that changes in his ontological and epistemological beliefs did have implications for his actions as a teacher of science. His view of himself as a teacher will be discussed in the explainer section after

discussing changes in his CSTL profile in the following section.

4. Rob's CSTL profile

A Conceptions of Science Teaching and Learning (CSTL) profile was constructed using categories of traditional, Piaget's Individual, von Glasersfeld's Radical, and Vygotsky's Social pedagogy. After the first interview Rob's profile was: 90% Piagetian and 10% traditional. Overall, he viewed the teacher's task as introducing "a certain core body of knowledge and certain standards" to students so they could construct meaning within the bounds of "certain standards" (Rob, interview 1). During the first interview Rob amplified his views of a good science teacher stating that a good teacher shows "enough connections between what students have learned in the science classroom and what they would see when they're walking outside of the classroom." This was necessary, according to Rob, "so students would see relevance to the subjects or applicability [to their lives]." Rob felt that it was important for his instruction to create strong connections between science and students' everyday lives, connections that would "make students think and stimulate students interests [in learning]."

Following Rob's second interview his CSTL profile was 85% Piaget's Individual, 9% von Glasersfeld's radical, and 6% Vygotsky's Social. Having been introduced to different theoretical works on constructivism by faculty in the teacher education program by this time, Rob's profile changed such that he eliminated the traditional pedagogical perspective identified after his first interview. According to Rob, this change was due to discussions of conceptual change teaching and learning presented during the coursework in his teacher education program. Accordingly, his view of the role of a teacher shifted to: "see what's already there, what of the [students' ideas] that are there might not be what the teacher considers correct. You have to work with those preconceived notions and naïve conceptions, and build on those. If I can help direct them in a certain direction to get over certain hurdles" (Rob, interview 2). Rob wanted to "more or less direct students or put them on shortcuts that would avoid a lot of dead ends." He stated that not to do so would result in "you as a teacher doing them a disservice" (Rob, interview 2). Grounded in his epistemological beliefs that "knowing is a subjective sense making activity," Rob expected his students to "try to make sense of what they see, hear, smell, or what somebody tells them" (Rob, interview 2). Along this line, "the teacher must structure and facilitate learning environments with as wide a range of experiences as possible" to reach as many students as possible. In order to accomplish these instructional goals "he wouldn't necessarily completely exclude the lecture method because there are some people who [learn] better with that method" (Rob, interview 2).

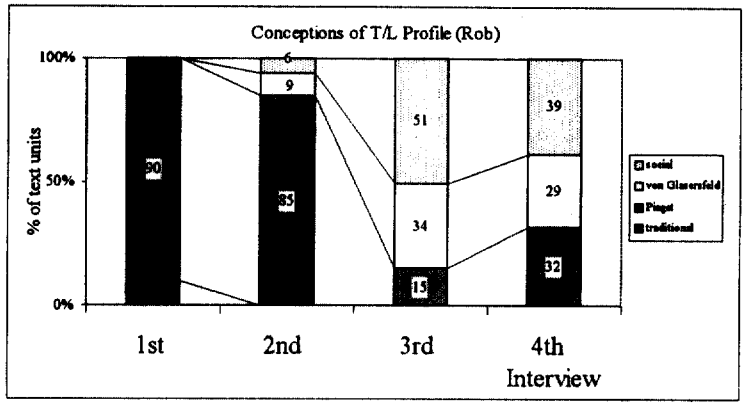

Fig. 3. Rob's CSTL profile

At this time, Rob's view of teaching mainly focused on "making students see a relationship between science or whatever concept I am teaching them at the moment. And how that might apply to everyday situations or their lives." According to Rob, students "can find some interests or some applications which might help to make it more appealing to them and then get them to ask questions" (Rob, interview 2). An ultimate goal of Rob's science teaching was for students to understand "what is considered acceptable and not acceptable, how to present information, and how to express themselves." It was Rob's belief that this is "what students are going to be doing eventually when they are not in school anymore" (Rob, interview 2).

After the third interview, Rob's CSTL profile was 15% individual, 34% radical and 51% social. Although Rob still stated that "learning is subjective and a process of self-organization", he now included more emphasis on the importance of students reaching consensus in terms of their learning. That is, as a teacher, he would "tell students what the society [whatever society you are in] thinks is the best explanation. However, it's up to them [the students] to decide whether or not it is the best explanation for them" (Rob, interview 3). Moreover, for Rob, established scientific theories were no more than "a structure or a framework which makes it easier for you to relate to the world around you" (Rob, interview 3). Rob's view of science teaching shifted from having students 'exchange' their preconceptions with accepted scientific concepts, to having them know that "they can believe whatever they want to believe as long as they are open to other people's explanations and they can come up with justifications and rationale for their point of view" in the third interview (Rob, interview 3). To reach his goals, Rob's teaching would emphasize "on-going dialogue as opposed to conflict or an argument." He described himself as a "facilitator and supporter" who is "interacting with people, reaching consensus, and encouraging students to explain why they believe something and to justify their

interpretations" (Rob, interview 3). When asked to state his instructional goals Rob mentioned: "To communicate the messages. To provide shortcuts. To give students a wide selection of things from which they choose what they personally find enjoyable or productive or useful, depending on what they want to pursue. To get kids to think for themselves, and to value and incorporate students' prior knowledge or what they bring with them to the classroom" (Rob, interview 3).

Following the fourth interview, Rob's CSTL profile was 32% individual, 29% radical and 39% social. Analysis of this interview showed a reappearance of an individual component in Rob's profile. Although Rob still believed, "teachers facilitate and support students to construct their own ideas," he firmly realized that "as a teacher his role was to link students and the scientific community. In a way, you help them interpret things from a scientific community back and forth until students have enough of a conceptual framework to do their own interpretations and go off on their own." Rob stated he still wanted "to clear up possible naive conceptions that students may have, to teach students to be independent thinkers, to have them question most things that they see and hear, including what the teacher tells them" (Rob, interview 4). This notion is also stated in the following:

> To facilitate, support students and help them to create their own ideas or their own interpretations and then kind of direct those interpretations a little along established lines·. [to] encourage your students somehow directed so that they reach that the same consensus reached in the general scientific populations. If they reach a completely different consensus then you have problems because there are certain accepted consensuses [sic]. (Rob, interview 4)

In the end, Rob's CSTL was consistent with his beliefs about the nature of scientific knowledge (i.e., his epistemological profile). That is, Rob contended, "you never know if [new information] will change what we are discussing, so you want to always leave them with an open mind to accept that there is nothing that is absolute or set in stone. [Science ideas] should be subject to further questioning and possible modification" (Rob, interview 4). As a teacher, Rob believed that "the learning environment should include a range of experiences so that students know what is the most accepted theory but also know what are some of the alternative theories or alternative explanations" (Rob, interview 4). Rob also stated that "learning is a process of self-organization and knowledge is our attempt to explain what we observe" where "everybody brings their own experiences which we can't really share" (Rob, interview 4). According to Rob, "everybody's own experiences create that person [by] building plans in their head. Then they try to relate things in their head to the outside world based on the plans that they make" (Rob, interview 4). Grounded in his individualistic ontological beliefs (recall the Radical position for Rob described above) and

his awareness of the fallible, tentative nature of knowledge, one of rationales for science teaching was to have students "understand why a certain interpretation is the most accepted and why it has the most evidence in favor of it." Furthermore, Rob "definitely wanted to encourage your students to explain and justify [their positions]. Whenever a person tells you some belief, you want them to justify, support it somehow, and articulate [the reasons for] it." Rob wanted students to leave his science class with knowledge of the criteria used to judge the validity of information - "how to explain for themselves and justify their positions" rather than with propositional knowledge of specific science content (Rob, interview 4). In the final analysis, he insisted, "the teacher must definitely know what is going on in the student's head and try to understand what the student understands" (Rob, interview 4).

5. Rob's explanations for changes

At the end of each interview, Rob was asked to explain what was most influential in forming his beliefs about teaching and learning, and what was most significant about the teacher education coursework or experiences during the program. Analyses of data in this section focus on: (1)whether each preservice teacher was conscious of changes in his or her ontological and epistemological profiles, and (2)the extent to which each preservice teacher was conscious of the relationship between his ontological/epistemological beliefs and CSTL. It is important at this point to reemphasize that there are significant differences at the epistemological and ontological level for different versions of educational constructivism - individual, radical, and social constructivism. These differences should, in turn, result in different conceptions of science teaching and learning. To that end, my attention will focus first on an analysis of the explainers Rob mentioned for his belief changes, that is, his answers to 'why did your beliefs change (or not change)?'

When asked to provide the most influential factors in helping form his beliefs about teaching and learning, Rob offered (1)university coursework - especially field experiences, (2)interactions with other fellow preservice teachers who "showed him there are many different ways of learning" through group work in the program, and (3) is family and other living situations wherein he "had a chance to hear and talk to them about how they teach and what their opinions are" (Rob, interview 4). What he has learned most throughout the university coursework is that "there are many different ways of learning and therefore there should be many different ways of teaching." This is quite different from "the [memorization type of teaching] he experienced as a learner" (Rob, interview 4).

A member check confirmed that Rob was not conscious of changes in his ontological and epistemological profile changes throughout the program. However, when reflecting upon his profiles after the last interview, he explained that his ontological beliefs "shifted towards the

social sector", as a result of "interactions with peers and interactions in the classroom." Rob stated, "passing through radical would not necessarily be the way to get from realist to social [idealist] zone." Aligned with his strong commitment to a Fallibilist epistemology, he stated that his "profile is dynamic" and "is probably going to continue to change constantly since it has obviously changed [since starting this teacher education program]" (Rob, interview 4).

He also acknowledged, "there is concordance between ontological and epistemological beliefs, and that is reflected over pedagogical beliefs as well." However, he didn't provided specific instances of this concordance. Likewise, when questioned about his awareness of different versions of constructivism he could not distinguish various versions of "weak, radical, and social" (Rob, interview 2). However, he clearly remembered that "social constructivism was Vygotsky perspective that would be that things are determined by the social context and you are going to learn based on the society in which you are developing" (Rob, interview 2). He expressed his understanding of different versions of constructivism best in the following:

> The ones I remember are weak constructivism, radical, and social. The weak, I believe, the only principle that they say is that learning has to be like a proper experience. It has to be something that happens to you. Its not passive. Learning is not a passive experience. So that would be weak constructivism. And radical constructivism is that plus the second one of somebodys principles, I cant remember what his name is, the guy who has those two principles. And, what was the second principle involved there, I cant remember right now what the second principle was. (Rob, interview 2)

Rob's ontological and epistemological beliefs were also consistent with how he viewed teaching and learning. Throughout all interviews, Rob moved away from realist ontology and towards idealist ontology. In doing so he insisted on a socially negotiated, culturally bounded representation of reality. Aligned with his radical/idealist ontological beliefs, Rob's epistemological beliefs were firmly grounded in the notion of "no ultimate truth" and no immediate access to the real world because of constraints on our perceptions, and culturally determined criteria of truthfulness. According to Rob, "human beings are trying to come up with, say, a dictionary of explanations for things" that "we are constantly editing based on things that are happening" (Rob, interview 4). In another statement from Rob, "we are trying to collect pieces for a puzzle, or many puzzles maybe, and you're trying to collect pieces that make of these different puzzles [many different interpretations and explanations depending on the society and culture you belong to] (Rob, interview 1).

Since Rob believed in the tentative nature of scientific knowledge, as a teacher he

wanted to be a "link between students and the scientific community" (Rob, interview 4). Accordingly, he would present "what the society thinks is the best explanation, certain principles about which there has already been a consensus in the general scientific community." However, he also maintains, "it is up to the students to decide whether or not it's the best explanation for them." This statement reveals a radical characteristic in his epistemological beliefs that can be summarized as "everybody's own experiences create that person· students should know what is the most accepted scientific theory but also knows what are other alternative possible theories to something or alternative explanations." In the end, Rob indicated that his teaching needed to introduce students to "a consensus reached in the general scientific populations or how to do scientific inquiry or investigation" using "the accepted model for how to do things" because otherwise "students have problems in surviving and continuing as members of a specific community - in this case, the contemporary Western [scientific] community" (Rob, interview 4).

V. Conclusions

Changes in sub-components of the educational constructivist profiles for a preservice teacher were illustrated in this study. This study also demonstrated that the notion of a constructivist profile containing ontological beliefs, epistemological commitments, and pedagogical beliefs could be aligned with conceptions of science teaching and learning, and that these changes have implications for a preservice teacher's view of their role as teacher. However, the changes in ontological and epistemological beliefs noted in this study were not accomplished easily for the student, nor are they expected to be easily internalized (Chinn & Brewer, 1998). While the possibility that change can occur in a preservice teacher's profiles was documented, only five of 16 participants involved in the larger study showed any change (see Kwak, 2001). On the positive side, when changes did occur, these changes were attributed to coursework associated within this preservice teacher education program. The teaching about constructivism that this program did helped some preservice teachers develop conceptions of teaching and learning that were well grounded philosophically.

Finally, as noted earlier, the participants involved in this study attributed the most influential factor in developing a constructivist perspective on teaching and learning to one or two faculty members of the preservice teacher education program. In other words, beyond all other reasons, the exemplary practices from one teacher educator left a deep impression on these preservice teachers' beliefs about constructivist learning and teaching that is consistent with those beliefs. Further research on the personal and professional characteristics of exemplary science teacher educators is needed.

The overall implication drawn from these case studies is that preferences for

'constructivist' notions of learning can (and should) be consistent with and founded on philosophical principles. If teacher educators seek to change preservice teachers' views of teaching, preservice teacher education programs must challenge their students' ontological beliefs and epistemological commitments if they expect to see changes in how science is taught and learned. For researchers, this study offers insights into the reasons that preservice students give for changes in their thinking about learning to teach.

Constructivist-oriented preservice teacher education programs can help preservice teachers change their profiles when those programs are firmly grounded in epistemology. Continued examination of changes in preservice teachers' beliefs towards educational constructivism, or any other version of constructivism, would provide important information about the extent to which these views can be applied in their science classrooms. Therefore, further research is needed to know if (and how) the changes observed in this study are effected by the contexts and dynamic interactions that occur when these students are no longer exposed to university faculty. Longitudinal questions that arise for me include: how will these participants profiles change as a result of their student teaching experience, or after the first few years of teaching? As Richardson (1996) suggests, I propose further research that "moves beyond descriptions of preservice teachers' beliefs and conceptions and toward the observation of teachers' actions in the classroom" .

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Appendix A: Analytical framework for the comparison of three versions of constructivist paradigm

Characteristics / Version of Constructivism	Ontological beliefs: Realist, Radical, or Idealist	Epistemological commitments: Absolutist, Piagetian, Fallibilist, or Relativist	Conceptions of Science Teaching and Learning (CSTL): Pedagogical implications in light of educational theory: individual focus or social focus
Individual constructivism (Also known as Cognitive; Cognitive-developmental; Piagetian; Personal; Trivial; or Weak constructivism)	[Realist] Piaget contends, we only construct those that are in some logical sense isomorphic with nature. Accept the ontological reality of the external world (Phillips, 1997).	[Piagetian] The adaptive function of cognition. The person exists as a real biological entity in a real physical world. Locate knowledge within the cognizing individual	[Individual focus alone] Learning is knowledge-dependent; emphasizes the active engagement of the students and the importance of prior knowledge. [Science learning] Learning as the accommodation processes. A process of enculturation into the science community (Driver *et al.*, 1994). Learning as conceptual change.
Radical constructivism	[Radical] The world is created by and dependent upon human thought (Matthews, 1994). There is no rationally accessible, extraexperiential reality.	[Fallibilist] Knowledge, as an adaptive function, is the appropriate ordering of an experiential reality. [Instrumentalist] or pragmatists theory of knowledge.	[Individual focus alone] Emphasize the adaptive function of cognition in relation to the experiential world. [science learning] Learning as a subjective sense-making activity for the purpose of enhancing survival, located in learners minds
Social (contextual) constructivism	[Realist: weak form] Presume a persistent reality (e.g. Solomon, Tobin, & Vygotsky). [Idealists: strong form] Knowledge is constructed within a particular community (e.g., Gergen, & Harry Collins).	[Relativism/ Fallibilists] Conventional knowledge as socially accepted, lived and fallible. Socio-political processes [social negotiation] are the main factors in the scientific knowledge construction.	[Social focus] [Vygotskian tradition] Learning is coparticipation in culturally organized practices; cognitive apprenticeship; legitimate peripheral participation; or the negotiation of meaning in the construction zone. [Sociolinguistic tradition] Learning science as an initiation into the culture of doing science; students learn to act in accord with the normative rules.
Behaviorists perspective (Also known as Objectivism; Positivism)	[Naive Realism] Objective external reality; a human-independent world.	[Absolutism] Knowledge as a representation of the real world.	[Behaviors learned through reinforcement] Learner as the recipient of knowledge. Knowledge is to be transferred by means of words.

Appendix B: Structure of analysis scheme: Definitions of coding categories and exemplary quotes for each category

Coding Category	Definition
Ontological Beliefs	Any statements related to the status of the mode of existence of types of entities in the world, any comments concerning the issue of the relation between our ideas and the nature behind them (Phillips, 1997, p. 176) and any philosophical claims about reality.
Realist: an ontological position advocated by Piaget	The material world (e.g., objects of knowledge) 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).
Exemplary Quote:	[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: advocated by von Glasersfeld	Acknowledges a reality but there is no way to directly access that reality (no extraexperiential reality). Denies the possibility of certain knowledge as a representation of the world, not the existence of the physical world; therefore, an ontologically neutral position (Ernest, 1995).
Exemplary Quote:	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: advocated by social constructivists	Statements indicating that either there is no world outside of human experience or that such a world, including human experience, is all ideational and constituted by our discourse and theorizing.
Exemplary Quote:	I think that we are determined more or less by our social interactions, by environments that we grow up in· 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	Statements revealing the relationship of epistemological commitments to each version of constructivism.
Absolutist (also known as Objectivism or Foundationalism)	Statements indicating that, over the course of history, science progresses towards Truth. That is, replacement of old scientific theories by new ones is a progressive step toward ultimate Truth about the world and how it works (Ernest, 1995).
Exemplary Quote:	I would say that there is some absolute truth that we are slowly but surely discovering·. It seems like we are getting a little closer to whatever reality is. I think on the grand scheme of things, like humans as a whole would be striving closer and closer to this truth. (Young 4)
Piagetian: advocated by Piagets individual	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 Quote:	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 nature plays a role in 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. We have to cross things out or we have to add parentheses and put something more in there or maybe we have to put a little drawing of something new that has come about. So it's kind of like a book that we are constantly editing. (Rob 4)

Fallibilist	[A]n epistemological position that is opposed, on the one hand, to relativism and, on the other hand, to absolutism (Matthews, 1994, p. 37). Statements' indicating that scientific knowledge is fallible, controvertible or tentative and open to confirmation, elaboration, revision or change.
Exemplary Quote:	We should not stick to something and say this is never going to change·. So you want to always leave [students] 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: advocated by social constructionism	Statements indicating that knowledge is constructed within a particular community, no reliable comparisons can be made between competing views since communities construct different paradigms about the natural world. At one extreme end of this position, some strong social constructivists would contend that the natural world has a small or non-existent role in the construction of scientific knowledge (Phillips, 1997, p. 190).
Exemplary Quote:	I think that's true for the scientific community·. it would have to be the scientific community that decides the acceptance of every knowledge claim ·. The non-scientific community doesn't necessarily always agree with the scientific community. (Rob 4)
CSTL/Options	Driven by ontological and epistemological perspective, individual, radical or social constructivists have different views of science teaching and learning, views that should guide their instruction.
Traditional	Statements indicating an authoritarian, teacher-centered, transmission model of science instruction, so called banking model of education (Matthews, 1994, p. 138).
Exemplary Quote:	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)
Piagets Individual	Statements indicating some obligation on the part of the teacher to acculturate students into scientific ways of knowing of the wider community because most ideas in science are beyond the experience of students or the capabilities of school laboratories to demonstrate (e.g., the cellular, molecular, atomic, and most of the astronomical realm).
Exemplary Quote:	I guess the focus of my science class would be on conceptual change· 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 my classroom I would want their ideas to be closer to the accepted norm of the scientific community. (Young 4)
von Glasersfelds Radical	Statements indicating that a student generates schemes to guide their actions. The teacher, representing society, structures and facilitates learning experiences so students learn what current society regards as having the greatest viability.
Exemplary Quote:	The teacher is putting out the accepted scientific values so students come to learn what current society regards as having the greatest viability but emphasizing that [knowledge] changes all the time. Students' ideas are just as valid as other ideas as long as they are put to the same sort of criteria that we put scientist to. (Young 2)
Vygotskys Social	Statements indicating that 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 in light of their own standards, and students are viewed as being scaffolded or apprenticed as they gain understanding of scientific ways of knowing.
Exemplary Quote:	I am there to link students and the scientific community, between students and the public standard. In a way I 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)