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ABSTRACT

This study investigates 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. Educational constructivism is subdivided into the categories of individual, radical, and social, and is described depending on the unique ontological, epistemological, and pedagogical commitments. Two case studies are presented to indicate the change in educational constructivist profiles for these preservice teachers. This study demonstrates that the notion that a constructivist profile could be aligned with conceptions of science teaching and that learning and preservice teachers can develop a constructivist notion of teaching. (KHR)

# Profile Changes for Two Students in a (Mathematics, Science and Technology Education) Preservice Teacher Education Program with Constructivist Views of Teaching and Learning

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# PROFILE CHANGES FOR TWO STUDENTS IN A (MATHEMATICS, SCIENCE & TECHNOLOGY EDUCATION) PRESERVICE TEACHER EDUCATION PROGRAM WITH CONSTRUCTIVIST VIEWS OF TEACHING AND LEARNING

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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, 1997b). 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, we documented changes in these characteristics as preservice teachers completed the university-based course work leading to teacher certification in science. We were also interested in the implications that changes in ontological beliefs and epistemological commitments had on preservice teachers' conceptions of themselves as teachers and their conceptions of students as learners.

This research focuses mainly on educational constructivism which we subdivide into the categories of individual, radical, and social, depending on the unique ontological, epistemological, and pedagogical commitments of each (see Kwak, 2001 for a comparison of versions of educational constructivism). 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 this study we 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.

Before investigating the implications of any version of educational constructivism on student learning, which we believe are inseparable from teaching, we 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 us, a preservice teacher's views of teaching and learning should be founded on these two characteristics. In the section that follows we describe continua for ontological beliefs and epistemological commitments that we will use throughout the remained of this article.

## Theoretical Overview

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, 1997). 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, 1997b; 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, 1997; 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. This position is neutral with respect to the role of reality (Ernest, 1993). 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, p. 149). Radical constructivism denies the possibility of any certain knowledge as a representation of the world, not the existence of a physical world.

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). According to Greeno (1989), 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 we 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 our 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, p. 37). 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, 1997b, p. 190).

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, 1998). 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 our continuum, what we call "Piagetian", emerged from the interview data we analyzed. Piaget admitted that an "external reality is playing a role in constraining and shaping the views we construct about it" (Phillips, 1997b, p. 184), but "nature does not uniquely and unequivocally determine" our interpretations or constructions 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). This perspective on knowledge incorporates participants' statements related to epistemological issues. This Piagetian epistemology preference is well aligned with the position advocated by Piaget's individual constructivism (see Kwak (2001) for exemplary quotes supporting each ontological and epistemological category).

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. We 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, p. 5). 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, p. 5). 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 preservice teachers during the period of this study? That is, do the ontological beliefs and epistemological commitments of preservice teacher's change as a result of coursework in their teacher education program and, if so, how?

A larger study associated with the results reported here investigated change in sixteen preservice teacher's 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's 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, 1997a; Matthews, 1994, 1998) were examined with regard to the philosophical notions of ontological beliefs and epistemological commitments. This, in turn, leads to different pedagogical perspectives (Phillips, 1997a; 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.

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). That is, as 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).

Furthermore, although knowledge is constructed based on experience, these human constructions do not approximate an inherent order in nature. The epistemological commitments

for this version of constructivism emphasize 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). "Many of the constructivist teaching programs, such as Driver's at Leeds University and much of the conceptual change pedagogy, fall within the individual-objectivist" range (Geelan, 1997, p. 21). 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 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, p. 103). 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, p. 149). 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, 1993). 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).

## Methods

To document preservice teachers' understandings of educational constructivism we 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, we 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 teachers in this study were traced over time. We view the process of change in the overall profile in terms of changes in a conceptual ecology--that is, change 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 we will demonstrate the feasibility of analyzing changes in constructivist profiles for preservice teachers and the implications these changes have on their views of teaching and learning.

Constructivist profiles for two students enrolled in the science teacher preparation program are described below. In particular, we sought to identify changes in the ontological and/or epistemological characteristics for each preservice teacher as they completed the university-based coursework for their preservice teacher education program. We also sought to identify the implications of changes in these characteristics on their developing views of teaching and learning. Data were collected over the first three terms (each term lasting 10 weeks) of course work during four in-depth interviews. The interviews were generally open-ended but included interview about instances on science teaching and learning, forced-choice questions containing a priori statements linked to various ontological and epistemological ideas, and the Constructivist Learning Environment Survey (CLES).

Before presenting our analysis of these data we begin by discussing the intent of the science teacher education program as communicated to us by faculty teaching in the program. We then illustrate how data collected from the preservice teachers were used to produce constructivist profiles for the two preservice teachers presented here. Next, we discuss change in these profiles for each preservice teacher. We conclude by discussing the implications that

findings from this study have for teacher education programs that teach constructivism as a significant theme.

Description of the Science Teacher Education Program

The science teacher preparation program we studied resulted in a Master's of Education degree after five terms (ten-weeks each) 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 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.

We concluded this study prior to the student teaching internship, when the influences on our 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 preservice teachers' projected pedagogies. Following them into their student teaching and subsequent induction year(s) was not part of this study, although we recognize the importance of doing so in the future.

Subjects

In all, thirty-four students were accepted into this mathematics, science and technology teacher certification program and they were seeking certification to teach science. All completed the CLES questionnaire. Sixteen of the thirty-four students--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 (see Kwak,

2001). 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 we present profiles for only two preservice teachers--Rob and Ellen. Rob's case was chosen because he was aware that his ontological and epistemological positions should be consistent with his pedagogy. In Ellen's case, although her profile does illustrate significant change, she was not aware of these changes. In one sense, these cases represent the most desirable change in a profile in that they are consistent with the goals of faculty in this teacher education program. This is why they were selected for presentation here--they represent 'best case' scenarios. However, they are not representatives of the entire group since only five out of sixteen preservice teachers showed any change in their profiles.

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. We 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. 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 (or lack of 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, 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). Our analysis was verified through member checks with each participant after an interview. The final analysis included presenting each participant with our analysis of changes in his or her profiles throughout all interviews.

## Findings

Each case study begins with a brief sketch of Rob's or Ellen's past experiences and a brief account of their personal history prior to entering the teacher education program. Subsequent sections elaborate on Rob's or Ellen'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, we discuss the subjects' explanations (i.e., "explainers") for change (or lack of change) in their profiles.

## Rob's Case

### 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).

### Rob's Ontological Profile

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 Figure 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).

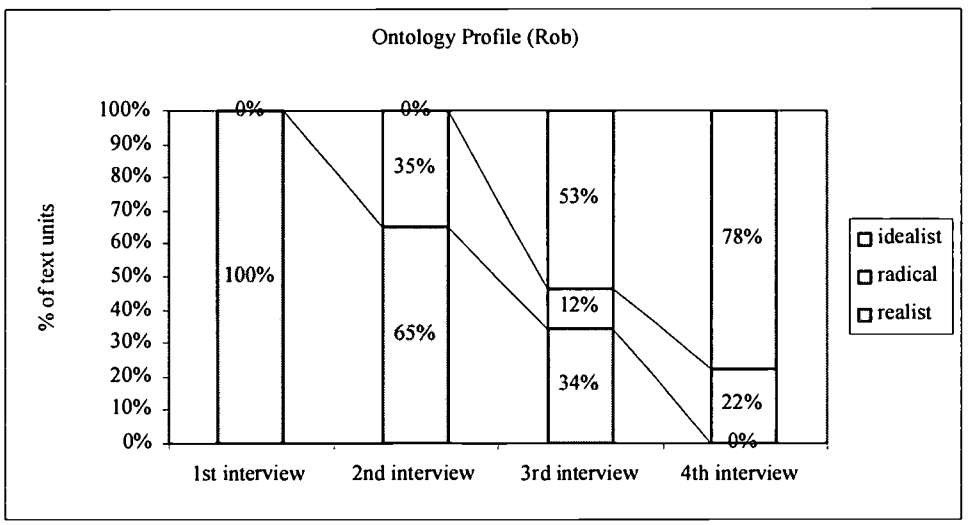


Figure 1: Rob's ontological belief profile

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 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, that's 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 (see Kwak, 2001), 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.

Rob's Epistemological Profile

Text units were coded within subcategories of absolutist, Piagetian, Fallibilism, and relativist for epistemology. Our 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: (a) "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"; (b) However, nature does not "act as a constraint because people speculate and infer beyond what we can see" in nature; and (c) "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."

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).

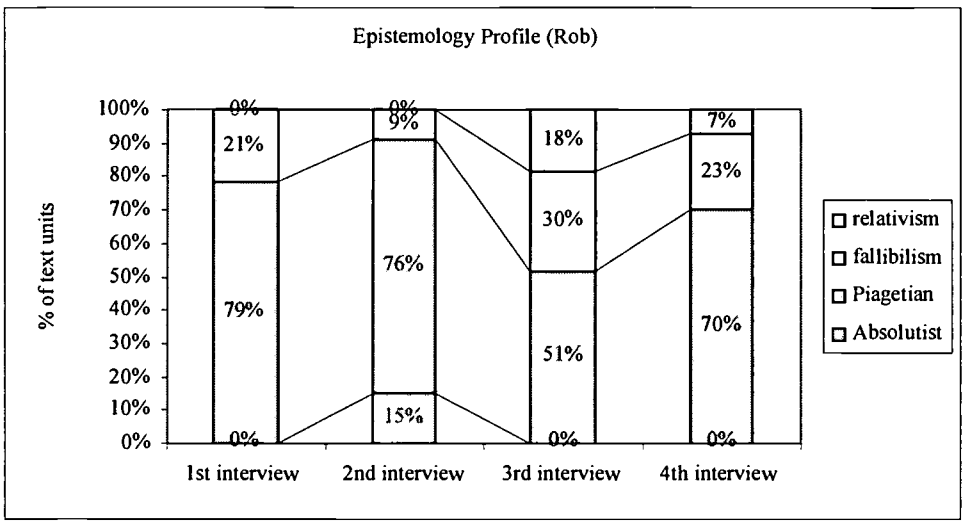


Figure 2: Rob's epistemological belief profile

As was the case for other interviewees, 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 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, we 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.

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).

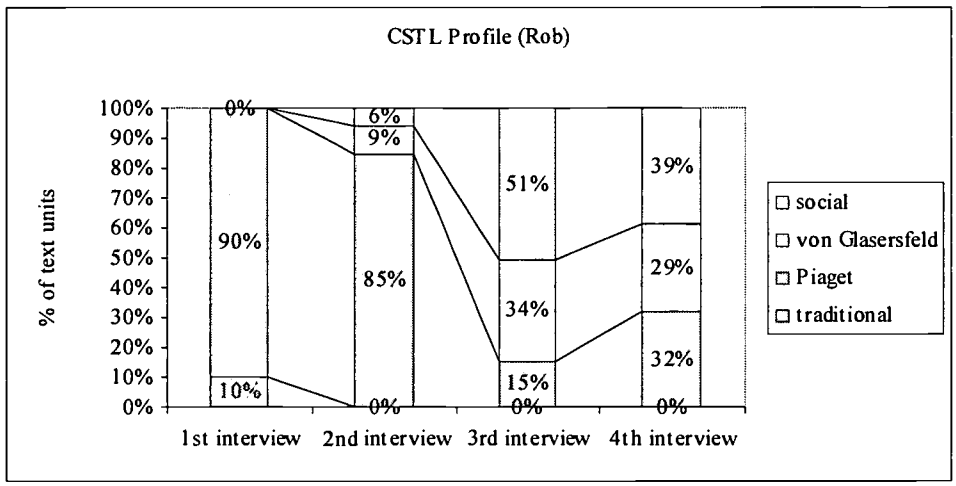


Figure 3: Rob's CSTL profile

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).

General Characteristics of the Explainer Section

At the end of each interview Rob (and Ellen) was asked to explain what was most influential in forming his (or her) 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: (a) whether each preservice teacher was conscious of changes in his or her ontological and epistemological profiles, and (b) 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, our attention will focus first on an analysis of the explainers each preservice teacher mentioned for his or her belief changes, that is, their answers to 'why did your beliefs change (or not change)?'

Rob's explanations for changes

When asked to provide the most influential factors in helping form his beliefs about teaching and learning, Rob offered (a) university coursework--especially field experiences, (b) interactions with other fellow preservice teachers who showed him "there are many different

ways of learning" through group work in the program, and (c) his 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. It's not passive. Learning is not a passive experience. So that would be weak constructivism. And radical constructivism is that plus the second one of somebody's principles, I can't remember what his name is, the guy who has those two principles. And, what was the second principle involved there, I can't 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 that "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).

Ellen's Case

Past Experiences

Ellen is a white American female in her late twenties, requesting certification in Earth Science for grades 7 to 12. Ellen remembered that she was always a good student who "learned by understanding and did what she was supposed to" (Ellen, interview 1). She also remembered she was "infamous for asking 'why' and saying 'I don't understand' when she was a student because she was "unaware that students were just given information and expected to swallow it." To this day, Ellen resented any learning environment in which she was merely provided information because it placed her in a "learning situation where she couldn't learn" (Ellen, interview 1).

Throughout her previous experience as a Peace Corp volunteer and a lobbyist in an environmental group, Ellen discovered, "how much impact she as an individual has on somebody else" and how much she "always wanted to be able to make a difference" in her community. Her experiences with a group of urban Gatos kids in the Peace Corp were "powerful and rewarding", and she could see "what happened when she had a group of kids under her influence, and how she could make them better people." Therefore, Ellen felt that she could utilize "two things that she was good at... an ability to help people feel more confident about

themselves, and an ability to explain complex ideas or difficult ideas simply so people can understand them" (Ellen, interview 1).

Ellen's Ontological Profile

After the first interview, Ellen's ontological belief profile showed realist as the largest component (62% of the total text units) while 38% of her statements were coded as radical. Ellen began with accepting the existence of an external world that constrains what we can believe about it. Typical statements placed in the realist category for Ellen included: "there is a human independent world" and "people have discovered that theoretical objects exist." Ellen also acknowledged that it is possible for us to "totally misinterpret what the scheme of reality is," further explaining this notion as "even though we can describe [the real world] and make sense of it ... [our understanding] might not be right." Statements like these are consistent with the ontological perspective we described as realist in Kwak (2001).

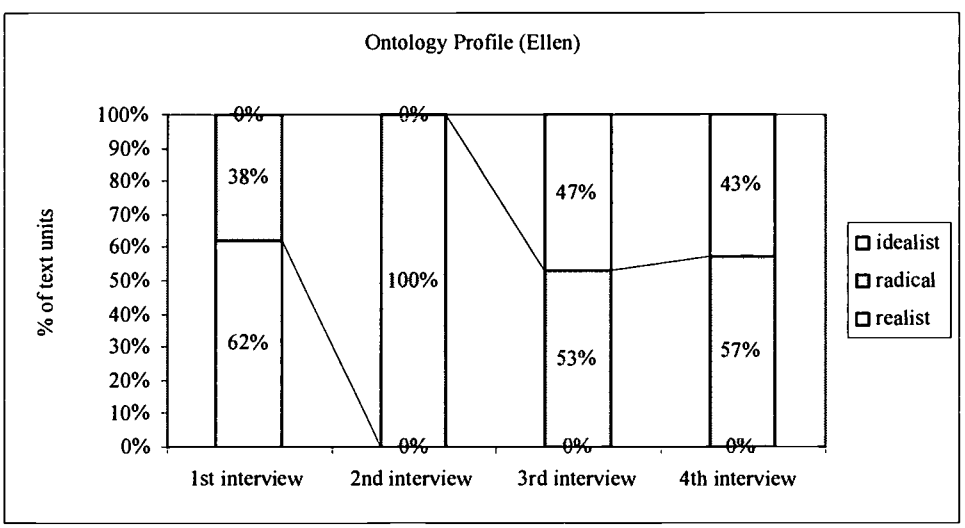


Figure 4: Ellen's ontological belief profile

Asked to select one of the forced-choice items during the first interview, Ellen chose the option representing a radical ontological position--or "a perspectivist" position in Ellen's terminology. Furthermore, Ellen expressed an "anti-realist" position in support for her choice, questioning her access to reality, in the following:

> So I think that our analysis of the real world is not necessarily describing what's actually out there. Even though we can describe it and make sense just like Newton's physics made sense and worked, it might not be right. So [the world of real objects do not exist independently of minds] well, this is a reality and we have an idea of what that reality is to each individual, but do we really see the real reality? Probably not. I am a perspectivist. (Ellen, interview 1)

Ellen contended that our knowledge of reality is never unmediated and that each individual constructs his or her reality mediated by a point of view or a particular set of personal experiences. These statements align with von Glasersfeld's ontological assumptions about reality and were placed in the radical ontology category. When asked about the role of reality, she acknowledged having been "a philosophy major" in her undergraduate years. Overall, as can be seen in Figure 4, Ellen's initial ontological profile features the coexistence of realist and radical ontological beliefs. However, statements referring to the realist category were not identified for Ellen after the first interview.

In the second interview, Ellen aligned her ontological beliefs with those of von Glasersfeld's radical constructivism (100% of text units coded in the radical category). After the first term in the M.Ed. program, when she was introduced to the different versions of constructivist epistemologies, Ellen strongly subscribed to von Glasersfeld's radical constructivism as she specifically referred to his way of describing reality in the following:

> We read a bunch of different articles on constructivism. The one that I most liked was the reasoning and argument of von Glasersfeld's constructivism. I am not sure what the category for that is, but he talked about people's knowledge of reality and everybody constructs their individual reality based on acceptance of their social community, also with an influence of social community. But I don't think

> he was a social constructivist purely. I think he also talked about the individual's being able to be different from what is necessarily just a social construct. I agree with him. (Ellen, interview 2)

When she talked about the role of reality, she replicated von Glasersfeld's argument word for word, including that "there is a reality that exists independently, but nobody has access to it." In addition, she stated that "our theory is the most viable explanation and it fits for our knowledge of our world right now" (Ellen, interview 2). From her standpoint of "perspectivism", Ellen continued to insist that "there is no unmediated access to the real world; therefore, if everyone has their own perspective and everybody constructs their own knowledge, then everybody is not seeing the same thing." Ellen believed that criteria for evaluating our theories should offer a "best fit." That is, "whatever best fits our understanding of the way things work, whatever best fits with the information [we receive] is the best scientific theory" (Ellen, interview 3).

Following the third interview, Ellen's ontological belief profile was 53% radical and 47% idealist. The radical component of Ellen's profile was retained as the largest component in her ontological profile from the second interview on. After the third interview, Ellen revealed a new component to her ontological profile, statements relating to idealist ontological beliefs, as she endorsed the assumption that our perceptions and other representations of the world constitute that reality. In supporting this idealist position, Ellen contended, "just like some parts of the movie, the Matrix," our empirical world could be construction of "these groups of minds" (Ellen, interview 3).

By the end of the fourth interview, Ellen's profile showed the coexistence of radical and idealist ontological beliefs (57% radical and 43% idealist). That is, on the one hand, she took a radical ontological stand when she talked about "no unmediated access to the world, no way to

directly access reality," and evaluating and validating a theory based on its' viability. On the other hand, she took an idealist stand when she viewed reality as being "constituted by our perceptions and other sorts of representations" and multiple interpretations or constructions of reality depending on different cultural groups. During the member check following this interview, Ellen acknowledged, "there has been an evolution" in terms of her ontological beliefs, which has been caused by "readings in class." Whether she achieved consciousness with respect to her profile and was able to recognize the implications of each component will be discussed after reviewing her epistemological profile in the following section.

Ellen's Epistemology Profile

Ellen's epistemological profiles showed more variation than her profile for ontological beliefs. After the first interview, Ellen's epistemological profile was 51% Piagetian, 32% Fallibilism, and 17% Relativism. As was the case for other interviewees, Ellen's epistemology is to some extent related to her ontology (see Kwak, 2001). Aligned with the realist ontological beliefs represented in her first interview, Ellen had the Piagetian position as the largest component of her epistemology profile in the first interview. According to Ellen, this view entailed, "there is a world that someway constrains our creativity or our theories or knowledge" (Ellen, interview 1).

Ellen's Piagetian epistemological component--scientific realism in Ernest (1995) terminology-- showed a gradual decrease, but was maintained throughout all interviews: 30% in the second, 15% in the third, and 17% in the fourth interview. Some typical statements placed in the Piagetian category for Ellen included: "I don't think that our knowledge of the world is passive thinking... we are constructing that knowledge" (Ellen, interview 2). Ellen assumed "an inaccessible world" in which humans are striving to reach a viable explanation or interpretation.

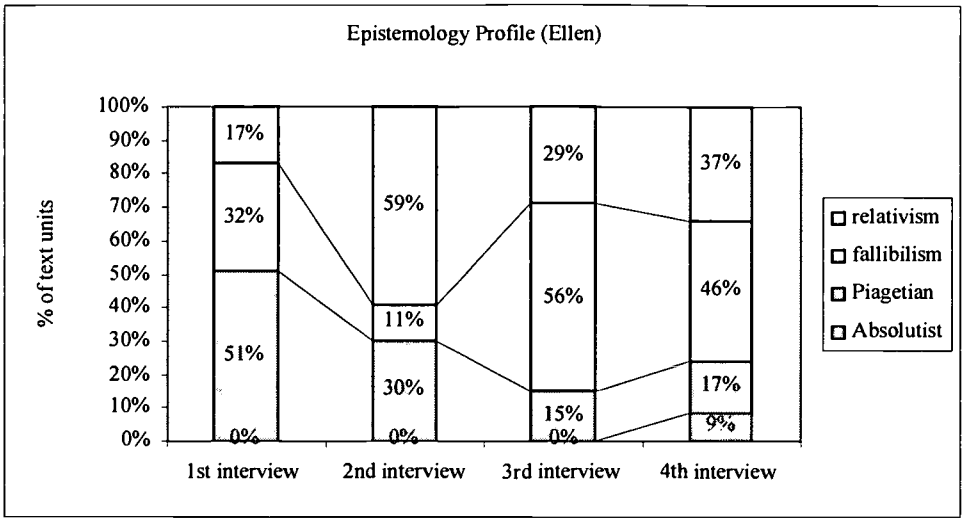


Figure 5: Ellen's epistemological belief profile

During the knowledge construction process, "nature might constrain what we reasonably can believe about it" in that "some theories or concepts are ruled out by our evidence or experience but nature does not uniquely and unequivocally determine" (Phillips, 1997b, p. 170) what we can construct about it. As Ellen put it, "our theories try to be consistent with what we know as reality or what we perceive as reality" and "we judge whether a theory is valid or invalid based on how well it supports the evidence of what we know of the world" (Ellen, interview 3 & 4).

Ellen epistemological profile also contained Fallibilist beliefs in the first interview as she acknowledged the vulnerability of scientific theories to new evidence or interpretation. In accordance with her realist ontological beliefs from the first interview, she stated that we sometimes "totally misinterpret what the scheme of reality is" [and therefore] "all theories are in principle revisable as proven in Newton's physics or probably even in the Big Bang theory" (Ellen, interview 1).

From the second interview on, Ellen subscribed to von Glasersfeld's Radical constructivism. She assumed, "everybody not only constructs his or her individual reality," but also "the individual is able to be different from what is necessarily just a social construct [what is

accepted by their social community]." Ellen strongly emphasized, on the one hand, an individual's active, subjective construction of knowledge where "the knower must infer what he or she was hoping to know" and, as a group of individuals, has revolutionized theories throughout history (Ellen, interview 2). On the other hand, she stated that, "whatever theory that best fits with our understanding of the way things work or the evidence of what we know of the world is the best scientific theory" (Ellen, interview 3). That is, Ellen viewed the validity of a knowledge claim as found in its viability or its non-contradictory fit with what one already knows (von Glasersfeld, 1995). This Fallibilist category was the largest component in her third (56% of text units) and fourth interviews (46% of text units):

> I agree that scientific theories are fallible and liable to refutation. I am thinking of my science, geologic history, how that changes over time. Like the ideas of when life began changes over time. I would agree with that and, I think, most scientists would agree with B, that our knowledge is provisional or is always open to confirmation, elaboration, revision or change. (Ellen, interview 4)

Another feature of Ellen's epistemological profile is that it contained a relativist component from the first interview on. This relativist component was aligned with her initial radical ontological position. That is, she denied any direct or unmediated access to an external reality. From the second interview on, when she endorsed von Glasersfeld's radical constructivist ontological and epistemological assumptions, the relativist component remained as one of the largest components in Ellen's epistemological profile: 59% in the second interview, 29% in the third, and 37% in the fourth. Ellen contended that society not only creates reality but also "creates scientific theory" by validating and accepting "people's knowledge of reality" (Ellen, interview 1 & 2). When asked to select the forced-choice item consistent with her epistemological beliefs, she consistently chose the relativist option throughout all interviews.

An assumption implicit in Ellen's approach to truthfulness in science is that each individual constructs scientific knowledge that should "corresponds with the accepted version of the world and how the scientific community has agreed to explain something" (Ellen, interview 4). In other words, although "there is no real reality" that can validate one individual's construction over that of another, individuals should construct their own knowledge "corresponding to how the scientific community has agreed to explain something or corresponding with the accepted version of the world" (Ellen, interview 4). Moreover, to be accepted by the community to which they belong, each individual should be "able to explain that theory in a similar language" (Ellen, interview 4). During the member check, Ellen continued to be fascinated by ideas advocated by von Glasersfeld, especially his emphasis on the individual's reality followed by his or her knowledge construction.

In sum, the proportion of text units in the Piagetian category gradually decreased for Ellen's epistemological profile and was replaced by text units representing Fallibilism and Relativist components. This change in Ellen's epistemological profile fit with her ontological belief shift from realist to radical and idealist. That is, as she displaced the notion of an independent existence of the external world with no direct access to reality (i.e., von Glasersfeld's ideas) and, furthermore, multiple realities constructed by people "in a different epistemic community, her epistemological profile shifted from Piagetian to relativist.

One important issue regarding changes in Ellen's ontological and epistemological profiles is how she could transfer her ontological and epistemological beliefs to her views of science teaching and learning. That is, whether or not she recognized that changes in her ontological beliefs and epistemological commitments were impacting her views of science

teaching and learning. This issue is discussed in the explainer section that follows her CSTL profile immediately below.

Ellen's CSTL

After the first interview, Ellen's CSTL profile was determined to be 50% traditional and 50% individual. The traditional component of Ellen's profile initially reflected her beliefs about the nature of teaching based on her prior experiences as a student, where she "was a good student who did what she was supposed to" (Ellen, interview 1). Ellen's self image as a teacher that she brought to the M.Ed. program was constructed based on her prior experiences as a student, "assuming that her students will possess learning styles, aptitudes, interests, and problems similar to her own" (Kagan, 1990, p. 145). Having observed both positive and negative teaching models, Ellen's initial CSTL was aligned with her traditional views, where "teaching is transferring knowledge or skills or concepts from one person or thing to another or to yourself [and] learning is receiving the same things, information, and concepts" (Ellen, interview 1).

As a preservice teacher, she perceived "what will be expected of me as a teacher is to steer or funnel the students towards accepted scientific interpretation or solution," whereas students "will learn it if they are paying attention" (Ellen, interview 1). However, it was rare to locate this traditional component in Ellen's profile from the second interview, where she contended that it is possible "to lecture or introduce ideas from an external authority without pressing to accept that authority, if you choose not to" (Ellen, interview 2). She went on to say that, as a teacher, "if I am going to introduce another position [accepted scientific interpretation or solution], I better have a good way to justify or explain it."

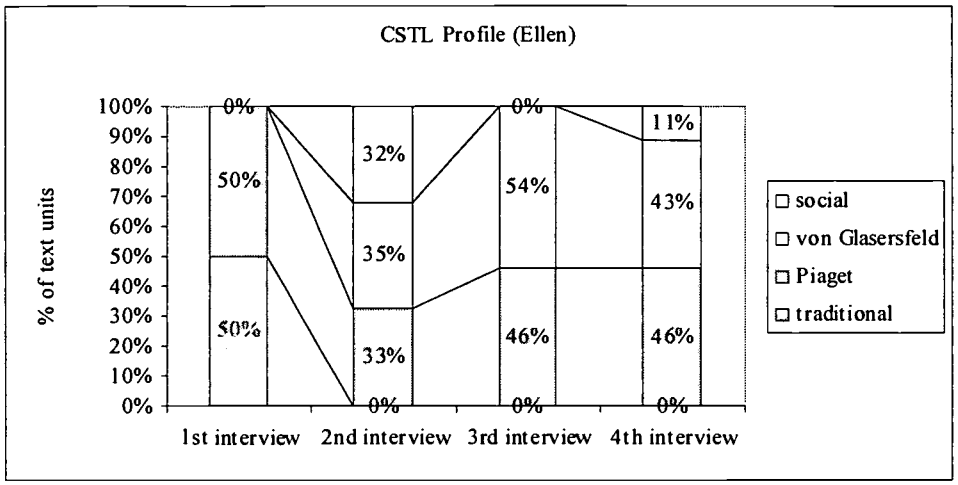


Figure 6: Ellen's CSTL profile

In her first CSTL interview, Ellen aligned her views of teaching with ideas like those of individual constructivism. According to Ellen, teachers should compare the students' and the accepted science points of view for the learner in the following:

> Because of their [teachers'] duty, I think I believe B, but the sentence ['the teacher must not evaluate the students' contributions...'] I think that I couldn't do that. I think I would say, "Oh that's a very good idea. How about blah, blah, blah" or I would definitely guide the situation toward the expected interpretation, standard interpretation, or whatever we're trying to learn. (Ellen, interview 1)

Ellen stated that teaching science involved socializing students into particular ways of viewing the world. This Piagetian component in Ellen's CSTL profile remained the largest or second largest component throughout all remaining interviews: 33% in the second interview, 46% in the third, and 46% in the fourth interview.

According to Ellen, one of her main rationales for science teaching was to have "students understand a best approximation of accepted scientific ideas" and "it is the teacher's responsibility to expose students to the accepted scientific interpretation" (Ellen, interview 2). She went on to say, "the method of doing that can be constructivist and doesn't necessarily have to be through traditional teaching." "In order for children to really understand what's going on,"

Ellen stated, students need to "go through some sort of conceptual change.... misconceptions need to be restructured" (Ellen, interview 2). Although Ellen was initially unsure of "whether she can be that kind of teacher or not," she was inspired by the learning reported in Sister Gertrude Hennessey's (1991; 1992) science classroom stating that "[Sister Gertrude] was able to introduce the interpretations of the scientific community without necessarily imposing those perspectives on her students as an authority" (Ellen, interview 2).

Ellen's CSTL profile changed to 33% individual, 35% radical and 32% social after the second interview, and to 46% individual and 54% radical after the third interview, when the social component disappeared all together. In the second interview, Ellen was fascinated by social constructivists' ideas such as the notion that students develop common perspectives with regard to objects and events in the world through communicating among themselves (Prawat, 1996). However, Ellen's view of herself as a teacher always reverted to enculturating students into the conventions of the science community. According to Ellen, "students' creating their own knowledge is not necessarily practical in the schools" (Ellen, interview 3). Whenever asked to choose one of the preferences that most aligned with the ways she thought about science teaching and learning, she chose an individual constructivist perspective to "compromise what she was supposed to be doing as a teacher in classrooms."

> I think practically, the kind of teacher that I probably would be is most likely E [the individual constructivist option]. I like B [the social constructivist option] but it seems like it might take too much time... sort of like you would be unable to do it as a teacher with fifteen learning objectives that you are required to go over throughout the year. (Ellen, interview 4)

Ellen also stated that "students' own interpretations of ideas in their own heads, or their own ideas constructed for themselves, may not be consistent with what the teacher intended for them to learn" (Ellen, interview 4). Thus, she emphasized, "teaching must involve a process of

regular feedback and checking [with the students] to identify the reasoning students are using." In effect, she would check with her students to understand how they are justifying and explaining their interpretations. In sum, Ellen perceived her role as "teach[ing] an agreed-upon, accepted scientific knowledge" (Ellen, interview 3). Ellen wanted to deliberately encourage "the scientifically acceptable viewpoint" in that "it was to the student's benefits to know the established beliefs and knowledge that a scientific community has agreed upon" (Ellen, interview 4).

After the fourth interview, Ellen's CSTL profile changed to 46% individual, 43% radical and 11% social. The social component first emerged in the second interview (32% of all text units) when Ellen stated that teachers "have to guide institution of scientific activities in the classroom" (Ellen, interview 2). To achieve this goal, she, as a teacher representing the scientific community, would model "how to think scientifically, to analyze, to act, and to reflect" according to the rules of canonical science (Ellen, interview 2). However, she was unsure "if she [could] implement scientific methods and scientific traditions in her classroom" and, in turn, had to compromise her ideal approaches to teaching and learning because of external time constraints and the amount of content she felt required to be covered.

On the other hand, Ellen always maintained an emphasis on subjectivity. She continued to be fascinated by "individual's being able to be different from what is necessarily just a social construct" (Ellen, interview 2). With her emphasis on subjectivity, Ellen described learning as a highly individualistic process whereby an individual constructs knowledge in the process of making sense of his or her experiences. This fits well with von Glasersfeld's notion of radical constructivism and, as can be seen in Figure 6, Ellen maintained this radical constructivist perspective as follows: 35% in the second interview, 54% in the third, and 43% in the fourth

interview. However, "everybody constructs their individual reality based on the acceptance of their social community... with the influence of social community" (Ellen, interview 2). That is, in the process of an individual student's constructing knowledge, Ellen acknowledged, "social communities" as well as "our prior understanding" act as constraints (Ellen, interview 4). Accordingly, Ellen believed that her role was to "have students learn what the current society regards as having the greatest viability" (Ellen, interview 4) and that a teacher must be concerned with what goes on in the student's head if she hopes to change the student's conceptual structures. Moreover, Ellen stated, "as a subjective sense making activity, learning goes through some sort of conceptual change where misconceptions need to be restructured in order, for children, to really understand what's going on" (Ellen, interview 4). A consistent rationale for Ellen's science teaching was for her to lead students towards conventional science ideas, because that is "what the current society regards as having the greatest viability" (Ellen, interview 4).

In sum, Ellen "rejected traditional pedagogy, which would be a traditional lecture format and traditional test" after having "been exposed to different ideas of how to teach and the responsibilities of teaching" (Ellen, interview 4). She was greatly influenced by the epistemological and pedagogical perspectives proposed in von Glasersfeld's radical constructivism. She "incorporated the ideas about children as individuals with different perspectives as valid" and she speculated that she would "address different learning styles or different strengths of the individuals and help them come about making links between their conceptions and the science view" (Ellen, interview 4). When talking about her goals for teaching science, Ellen's focus was on students' knowing "the expected interpretation, standard interpretation" (Ellen, interview 1), "thinking scientifically using a scientific method to explain

how the world works" (Ellen, interview 2), and "having an appreciation for science" (Ellen, interview 4).

Ellen's explanations for change

Asked to provide the most influential factors in helping her change her beliefs about teaching and learning, Ellen indicated that "the structured coursework" of the MSAT M.Ed. program was the most influential factor. This coursework helped her see "what the alternatives were in terms of different learning theories" (Ellen, interview 4). Ellen stated that she came into the program "with a certain perspective and it has been enlightened and enlarged, but not changed dramatically." From the beginning of the program, she argued, she could "teach right now in a lecture format. You can always get in front and you can lecture. That's not the problem. The problem is trying to make it engaging so that kids will actually learn something" (Ellen, interview 4).

What she wanted to know from the teacher education program was "how we might implement something else" and "alternative points of view, particularly in terms of talking about integration and constructivism and active hands-on learning." Ellen also stated, "I really don't think the M.Ed. program has influenced my beliefs about teaching and learning very much." While the M.Ed. program helped her to "put some vocabularies to it, like constructivism, but in general my ideas about what students should get from a science classroom and what a teacher should be doing to facilitate haven't really changed." The program, she argued, may have helped her put her ideas in "a little bit more concrete ways because of readings that I did and learning what other people believe, whether it's my peers or Piaget or even the self-reflections that we have been asked to write" (Ellen, interview 4).

Additional factors that influenced her CSTL included "group discussions with her peers where problems and ideas were discussed, and actually being in schools talking to teachers, and teaching myself through field experiences" where she could observe "a bunch of different teachers." She also suggested, "the most practical way to learn as a teacher is to combine coursework with teaching or observing experiences." In this way she thought she could apply theory to practice. In addition, when asked to reflect on any significant changes in herself as a teacher throughout the M.Ed. program, Ellen commented that she "incorporated a lot of different ideas of how to teach and my responsibilities of teaching, and learned how to address different learning styles."

Asked to explain the belief changes represented in her profiles, she commented, "there has been an evolution" in that she moved away from the "traditional pedagogical perspective and from the realist ontological perspective" and toward von Glasersfeld's perspective.

Regarding the extent to which she was conscious of the relationship between her ontological or epistemological beliefs and CSTL, she stated, "there is a link to that [how ontological perspective might influence on her pedagogical perspective]." Ellen's alignment of her ontological and epistemological beliefs with those informed by von Glasersfeld's radical constructivism mapped onto her preferred "pedagogies based on a radical constructivist perspective." Accordingly, she identified "knowledge as a subjective sense-making activity for learners. When asked to comment on how her strong endorsement of von Glasersfeld's perspectives would influence her teaching, Ellen said, "hopefully that goes into my ideas about children as individuals with different perspectives and a lot of their opinions are valid" (Ellen, interview 4).

Ellen wanted students to learn accepted scientific knowledge because, she thought, that knowledge was what the current society regarded as having the greatest viability at this particular time. Although Ellen was aware of "what the idealist and relativist would say" in terms of the role of reality in knowledge construction, she wanted to deliberately encourage students "to learn the theoretical ideas and conventions of the science community" in her science classroom. Knowing the "established beliefs and knowledge that a scientific community has agreed upon," Ellen contended, "her students, who are members of this Western scientific community, would benefit" (Ellen, interview 4). It is important to note that Ellen was also aware that each student constructs reality, as well as scientific knowledge, in different ways depending on his or her everyday culture or experiences. However, as a science teacher in a Western community, Ellen would give preference to the view adopted by the science community so her students' could function and survive in their Western scientific traditions.

Regarding her overall CSTL profile, Ellen maintained the Piagetian as the largest component, and von Glasersfeld's radical constructivist component from the second interview on. It was just prior to this interview when she was introduced to various versions of constructivism in the M.Ed. program. Ellen's emphasis on individualism in knowledge construction as well as science learning led her to recognize that students would "interpret the lecture to fit his or her own knowledge framework. Therefore, what they learn might not necessarily be the information that the teacher is imparting to them" (Ellen, interview 2). Ellen also showed a gradual decrease in the social component of her CSTL profile as she was frustrated by the amount of lecturing she observed and content she felt required to cover during her field experiences:

> I will be constrained by the fact that I will have thirty kids per period, one hundred and fifty kids per day with a course of study that covers multitude of

> topics. It's also my responsibility to prepare these children for [state mandated] proficiency tests or to get to them more information than just scientific methods. Even though how to think in a scientific fashion or how to be reflective is important to me, and that's part of what science is about, obviously I have to teach more than that to my students. I have to have content that goes beyond pure constructivist's discovery methods or whatever. (Ellen, interview 4)

In conclusion, other than the disappearance of traditional pedagogical beliefs, Ellen maintained a consistent CSTL profile without showing any radical change.

## Conclusions

The two case studies presented here indicate that there was change in the sub-components of the educational constructivist profiles for these preservice teachers. This study 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. It also demonstrated implications that changes in components for an educational constructivist profile have for a preservice teacher's view of themselves as teacher. However, changes in ontological and epistemological beliefs are not easy, nor are they easily internalized (Chinn & Brewer, 1993; Chi, 1992). While the possibility that change can occur in two preservice teacher's profiles was documented, only five of 16 participants involved in the larger study showed any change. On the positive side, when change did occur, these changes were attributed to the coursework associated within this preservice teacher education program. Teaching about constructivist philosophies, as this program did, helped some preservice teachers develop conceptions of teaching and learning that were well grounded philosophically.

The overall conclusion drawn from this research is that preservice teachers can develop 'constructivist' notions of teaching that are consistent with and founded upon philosophical principles. For teacher educators attempting to change preservice teachers views on teaching, preservice teacher education programs should challenge their student's 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.

## Implications for Further Research

Constructivist-oriented preservice teacher education programs can help preservice teachers change their constructivist 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. Questions that arise for us are: how will these participants' profiles change as a result of their student teaching, and when they enter the first few years of teaching? That is, longitudinal studies of profile change should be conducted. To address this question, as Richardson (1996) contends, we propose further research that "moves beyond descriptions of preservice teachers' beliefs and conceptions and toward the observation of teaches' actions in the classroom" (p. 114).

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 MSAT program. In other words, above anything else, these exemplary teacher educators left a deep impact on preservice teachers' formation of their beliefs towards a constructivist learning and teaching framework. Accordingly, further research on the personal and professional characteristics of exemplary science teacher educators is needed.

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