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PROFILE CHANGE IN PRESERVICE SCIENCE TEACHER'S EPISTEMOLOGICAL AND ONTOLOGICAL BELIEFS ABOUT CONSTRUCTIVIST LEARNING: IMPLICATIONS FOR SCIENCE TEACHING AND LEARNING

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By
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* * * * *

The Ohio State University
2001

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ABSTRACT

This study investigated preservice teachers' understandings of the ontology and epistemology underlying constructivist notions of learning, and 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. Multiple views of constructivism formed the basis for much of the instruction that was presented throughout these preservice teachers' education program, as revealed by faculty interview data. For the 16 preservice teachers included in this study, the epistemological and ontological characteristics for each teacher's developing views of learning were identified through four in-depth interviews. Data from interviews were used to construct a constructivist profile for each preservice teacher's views of learning (i.e., a profile containing ontological beliefs, epistemological commitments, and pedagogical beliefs). Changes in the profiles for each individual were documented over the time span of this study. Of the sixteen participants in the study, five significantly changed ontological and epistemological beliefs and eleven did not. Profile changes for the five who did change also resulted in changes in their conceptions of science teaching.
This study demonstrated that the notion of a constructivist profile could be aligned with CSTL. 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. On the positive side, when change did occur, these changes were attributed to the coursework associated within this preservice teacher education program that attempted to advance constructivist philosophies—or a program designed to develop a constructivist perspective on teaching and learning. 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 teachers give for changes in their thinking about learning to teach.
Dedicated to my brother, Younghwan Kwak
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Thanks also to my fellow students, and the many other faculty of OSU; my years in OSU have been a wonderful time with your help.

And to my family, my mom, daddy, Taeyoung, Nanyoung, and my niece Jaewon and Jaeha for holding and calling me with a 14 hours of time gap between Columbus and Seoul.

And to my big brother Younghwyan in the other world, who have made me what I am and will be, and will be with me forever.
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CHAPTER 1
INTRODUCTION

The purposes of this section are to (1) draw boundaries to limit the meaning of constructivism used in this research context, (2) describe the problem to be researched, and (3) provide a rationale for the study.

Background to the Investigation:

Confining Constructivism to a Pedagogical Version

Constructivism is the contemporary overarching paradigm\(^1\) and one of the major influences in present day science teacher preparation. That is, in all the varieties of constructivism (e.g., "constructivist theories of learning, constructivist theories of teaching, and constructivist epistemologies") and even misinterpretations or misusages of the term, there is little argument that constructivism is the contemporary overarching paradigm in science education (Matthews, 1994, p. 1). Sharing the metaphor of carpentry or architecture, constructivism ranges from (in a broad sense) a research paradigm, which is composed of both a way of thinking about the world and a methodology for investigating the world, to (in a narrow sense) an individual student’s understanding of

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\(^1\) In this context, a paradigm refers to a comprehensive entity including conceptual, theoretical, instrumental, methodological, and even a metaphysical worldview\(^1\) in the Kuhnian sense.
his surroundings through his own configuration. As a research paradigm, constructivism offers accounts of the epistemology of science, inspires science education curriculum reform programs, underpins major research programs in science education, and is also "the foundation of many science-teacher training programs where constructivist teaching methods are widely advocated" (Matthews, 1992, p. 183). Having its origins in "the Piagetian-led cognitive revolt against behaviorist theories of learning" educational constructivism, regardless of its theory ramification, shares a view that students build up their own knowledge as they are engaged actively in the learning process. The following diagram depicts the location of educational constructivism within a broad range of interpretations (e.g., constructivist research paradigm, sociological constructivism, and philosophical constructivism), primarily based on Phillips’s (1997), Ernest’s (1995), and Matthews (1998) classification schemes. The other main categorization, philosophical constructivism, underlies and permeates all the other kinds of constructivism by encompassing and supporting all the common epistemological and ontological presuppositions.
Philosophical Constructivism (Constructivism in the Philosophy of science): instrumentalist philosophy, the human dimension of science, etc.

Constructivism

Naive Empiricism or Classical Behaviorism

[Research Paradigm]
Interpretative or Constructivist Paradigm

[Neopositivistic Paradigm] with its emphasis on quantitative methods

[Critical Paradigm] based on critical theory, concerned to promote social justice and social change

[Constructivism in the Sociology of Science]
Social Constructivist: Socio-political construction of public bodies of knowledge

Social Constructionism

[Educational Constructivism]
Psychological Constructivism

[Social Constructivists]

[Critical Constructivists]

[Radical Constructivists]

[Individual Constructivists]

Figure 1.1: A taxonomy of various versions of constructivism (Kwak, 1999).

Among the various usages and interpretations of constructivism, one is constructivism as a research paradigm, that is, the interpretative (or constructivist) paradigm. Since the demise of logical positivism and logical empiricism in the 1950s, as one of the alternative paradigms of postpositivist approaches, the interpretative or constructivist paradigm is concerned with identifying underlying structures that cannot be observed or collected, but must be constructed using personal theoretical frameworks. This constructivist research paradigm emphasizes qualitative methods, particularly ethnographic techniques aiming at thick description where the first objective is to describe complex contextual factors such as the subject’s conceptual ecology and the
local social-cultural milieu of each study. From this interpretative research perspective, readers also will reconstruct reported qualitative data and work using what they personally know and value, referring to thick description—recordings of the circumstances, meanings, intentions, strategies, motivations, and so on that characterize a particular episode, whereby readers can understand the details of the contexts in which the researcher's interpretation is grounded (Tobin, 1993; Cobern, 1993; Matthews, 1997; Ernest, 1995).

A second version of constructivism, constructivism in the sociology of science, has been adopted by many social or sociocultural constructivists. The contemporary sociology of scientific knowledge has its value in pedagogy in terms of providing science education with another perspective from which to see science as socially constructed through negotiation in the social milieu. On the other hand, before accepting its extreme position of epistemological relativism in constructivist sociological theories that consider science as not essentially being different from other merely social practices, we, as science educators, should reconsider the foundation and rationale of science education (Slezak, 1994). These versions of constructivism are not considered germane to this study.

The third variety is educational constructivism, which is also labeled as psychological constructivism (Phillips, 1997b). Educational (psychological) constructivism, "which can be found in the educational literature" (Matthews, 1994, p. 148) as an alternative epistemology to naive empiricism or classical behaviorism, is differentiated from constructivism as a research paradigm and constructivism in the sociology of science. It is a philosophical perspective interested in the ways in which
human beings, especially children, individually or collectively interpret or construct the social and psychological world in specific contexts. Beyond its original consideration of learning theories and theories of pedagogy, educational constructivism has expanded its boundary by linking its position to issues of empowerment and emancipation in its critical theory version (Matthews, 1998).

Constructivism, on its normal science stage in the Kuhnian sense, itself goes through a theory elaboration process upon meeting challenges from inside such as wanting internal consistency or generalizability of a theory, as well as from external dimensions (social desirability) such as contemporary widespread issues of cultural studies including the multicultural education movement and the sociology of science (theories of sociology of scientific knowledge). Frequently, theory elaboration entails building exceptions into the paradigm to avoid seeing anomaly as anomaly (Kuhn, 1970). Thus, as an evolving paradigm, educational constructivism along with the other varieties of constructivism, experiences meaning construction processes to better describe the broad range of phenomena involved. In this theory elaboration process, philosophical and sociological perspectives as backdrops exert external demands on educational constructivism (Ernest, 1995). Along this line, while drawing upon the other constructivist traditions, my research mainly focuses on educational constructivism which itself has such various subdivisions as individual, radical, and social constructivism, depending on unique ontological, epistemological, and pedagogical commitments of each version.
Rationale for the Investigation

Against this background, over the last three decades there has been significant elaboration of constructivist pedagogy in terms of its theoretical background, which has incorporated individual psychological inner dimension as well as social dynamics in interpsychological dimension, and, to a lesser extent, theory into practice. The shared, undifferentiated grounds of conceptual change or sociocultural perspective are to actualize the constructivist ideology: to make science (instruction) meaningful in both individual and social dimensions through appropriate intra- and interpsychological intervention.

On the other hand, this blending of individual and social constructivisms has resulted in some criticisms. That is to say, through dialectical interaction in diverse forms of constructivism, particularly individual and social components, critics try to reach complementary cooperation whereby individual and radical constructivism is adapting to incorporate social dimension, and vice versa. As Ernest (1995) put it, "the majority of authors and commentators stress the need for constructivism to accommodate the complementarity between individual construction and social interaction" (p. 483).

After all these years, it's worthwhile to contemplate the path of constructivist epistemology before we move on to another decade and blending movement in various versions of constructivism. Before investigating the influence of constructivism on students' learning, which is inseparable from teaching, we need to look at the extent to which teachers can internalize constructivist epistemology. Based on this internalized constructivist epistemology, teachers can at least try to implement or act in accord with constructivist pedagogical implications such as sensitivity to learners' previous
constructions, diagnostic teaching, attention to metacognition, and so on. On the one hand, exposure to teaching about constructivist ideas can provide preservice teachers with appropriate language (terminology) with which they can describe their previously unconsciously held ideal pedagogy. On the other hand, in order to realize a constructivist learning environment in science instruction, teacher educators must examine how preservice teachers cope with constructivist epistemology that could contradict their own life long experience that “has usually been composed primarily of exposure to traditional science instruction” (Stofflett, 1991, p. 5). Considering that “teachers can not be expected to learn effective science pedagogy on their own,” teacher educators are mainly responsible for “preparing them to meet this challenge” (p. 11) and teacher education programs should address the issue of preservice teachers’ pedagogical knowledge (Shulman, 1986). Along this line, the development of a solid base of knowledge about preservice teachers pedagogical perspective changes will be instrumental in “providing a framework for considering both the learning processes involved in changing their conceptions, as well as providing a framework for designing instruction that facilitate those changes” (Hewson & Kerby, 1993, p. 5). That is, such knowledge is “fundamental to efforts to design preservice models that will be successful in helping individuals acquire more appropriate conceptions of science teaching” (p. 6).

Research Purpose and Questions

I will investigate preservice teachers’ meaning construction about constructivist epistemology itself in terms of each individual’s occupied niche in conceptual ecology and social and physical milieu. Throughout their preservice teacher education program, what impact does the Math, Science, and Technology Education (MSAT) Master of
Education (M.Ed.) preservice teacher education program—which employs constructivist aspects of teacher education and generates applications of constructivism to the practice of teaching—have on preservice teachers’ conceptions of teaching and learning? I focused on the span of time, from when preservice teachers were first introduced to constructivism (or to the terminology itself) to the end of their university coursework of the M. Ed. program, just prior to their internship as student teachers. The purpose of my study is to examine how preservice teachers respond to the constructivist epistemology that is an overarching theme in their M.Ed. program, and why they respond as they do. Then I will use these answers to make recommendations for science teacher education programs. Furthermore, through this investigation I might predict the future of constructivism, which is reflected in preservice teachers’ responses to constructivism along the time line. It could be a deep impact in either a positive or negative meaning, just a renaming of their imagined or dreamed ideal teaching pedagogy, or nothing different than before for them.

My assumption is that, with a rare exception, transitional stages could be located in preservice teachers’ pedagogical perspective shift, mainly influenced by constructivism. Transitional stages, here, mean preservice teachers’ acceptance of constructivist epistemology along the line of the general trend in the historical development of constructivism. That is to say, as time goes on, an individual preservice teacher could go through her own processes of elaborating her pedagogical perspective with regards to constructivism, from personal-objectivist realm to social-relativist realm as represented on Geelan’s (1997) rectangular coordinates.
On the other hand, it is hard to expect a radical or thorough and through shift in preservice teachers’ perspective—hypothetically from traditional pedagogy, via individual and radical, to social constructivist pedagogical perspective—upon their confronting theories of constructivism, for a number of possible reasons. First, teachers’ perspectives are often held unconsciously (Kagan, 1990), which hampers recognition of anomaly as well as differentiation of their own position from others’ positions. Second, some theoretical backdrops of different versions of constructivism, such as ontological beliefs and epistemological commitments, are very hard to change because these deeply entrenched beliefs are “remote from experience” (Chinn & Brewer, 1993, p. 17). Moreover, the discrepancy between preservice teachers’ previously-held ontological or epistemological beliefs and those of a specific version of constructivism not only lead preservice teachers “to reject” that specific constructivist idea (perspective) but also make it difficult for the preservice teachers “even to comprehend” that specific constructivist perspective, that is, the initial failure of intelligibility of constructivism in light of conceptual change conditions (Chinn & Brewer, 1993, p. 17). Third, the preservice teachers enter the M.Ed. program with “well-established preconceptions about good teaching” (Kagan, 1990, p. 426) based on their schooling experiences. These preconceptions often resist change. Therefore, teachers’ perspective change toward constructivism also depends on the complicated dialectic relationship between the status of theories, each teacher’s conceptual ecology, and social-physical milieu of the theory and an individual (from intra- and interpsychological desirability). If there is change, however, in this perspective change there can be located the internal and external causes or driving forces which enable the change, in terms of the necessity in both dimensions:
the necessity of an individual's personal cognitive activity and the necessity of a particular version of constructivist theory.

Another critical assumption of mine is that some of these change trials are seriously hampered by the lack of each preservice teacher's background knowledge. Access to this knowledge would enable them to recognize anomalies in extant perspectives as anomalies which are in need of validation or refusal. Like many examples from the history of science, if an individual fails to see anomaly as anomaly she keeps expanding and building exceptional hypotheses into her extant theory on a false ground to subsume more cases, explain away imminent contradictions and ultimately avoid the crisis of paradigm change, which is a revolutionary process. According to Kuhn (1970), there could be three directions of response when anomaly shows up in a normal science stage: (1) trying to fit it in via making elaboration of theory such as Ptolemy's adding enormous epicycles to explain away the motions of heavenly bodies, (2) ignore it if it does not fit in, or (3) building exceptions into the paradigm.

Regardless of widespread use of constructivist terminology, preservice teachers could slip through their teacher education program without being impacted by constructivist epistemology/ontology, which will be quite counter-intuitive to their time honored transmission-absorption views of epistemology. There are various other possible responses: preservice teachers could be rearmed with their previous pedagogy in the name of constructivism; they could assimilate the constructivist pedagogy into traditional teaching modes; there could be "an undisturbed outcome, i.e., lack of any change"; or "a two perspectives outcome" whereby preservice teachers are able "to successfully
complete all the assignments given in class, while continuing to maintain” their inadequate traditional views of pedagogy (Stofflett, 1991, p. 152).

In sum, the study will seek to answer the following questions:

1. What are the developing notions of constructivism in light of ontological, epistemological or pedagogical commitments during the period of this study? What are the epistemological and ontological characteristics for each teacher’s developing view of learning with the influence of constructivist epistemology taught in the core MSAT M.Ed. courses?

2. What activities and experiences prior to or within the program, contributed to the development of ontological and epistemological views that are consistent with constructivist views of teaching and learning? That is, why do some preservice teachers capture and subsume constructivist epistemology/ontology while others ignore these philosophical positions on learning in favor of retaining their previous views of learning?

3. How did changes in the ontological and epistemological beliefs help preservice teachers to understand the concepts--constructivist epistemology--better and, in turn, to change their views of how to present science teaching and interpret student learning?

From a constructivist point of view, it is reasonable to argue that preservice teachers build their pedagogical perspectives as they incorporate instructional concepts of learning/teaching methods courses, socially approved behaviors, interpretations of their experience concerning science teaching and learning, and other internal and external
needs and demands from intra- and interpsychological dimensions in particular contexts in which they are grounded.

Upon probing the first question, based on one of my assumptions that the situation in which preservice teachers encounter the constructivist epistemology is similar to confronting an uneasy, contradictory ‘anomaly’, on the condition that they can perceive anomaly as anomaly. That is, in light of their preconceived paradigm, in which they have been located in a stable and long-term niche throughout their own schooling, the constructivist epistemology should be anomalous to them. In this regard, preservice teachers’ possible psychological response to anomalous data can be either (a) no meaningful response toward the constructivist epistemology (or, outright rejection), (b) capture of the constructivist epistemology by incorporating that into their profiles, or (c) exchange for the constructivist epistemology, which might be rarely found with stark revolutionary processes (Chinn & Brewer, 1993; Chinn & Brewer, 1998; Hewson, 1981).

Either direction of change, preservice teachers’ perceptions or position-statements can be traced over time even though that change could be extremely slow and steady-paced. Note that, in the first question, my basic assumption is that the fundamental ways whereby the human collaborative society has dealt with a certain theory evolution throughout history are similar to the ways in which each individual makes perception shift toward that certain theory.

In tracing preservice teachers’ pedagogical perspective changes, I postulate there will be evolutionary conceptual capture processes, rather than revolutionary conceptual exchange processes. That is, washing out their previous paradigm and replacing it with a constructivist epistemology. As Mortimer (1995) contends, there can be found some sort
of conceptual profile change while pre-instructional paradigm and constructivist epistemology coexist with different extents and occupy different amount of niches in each individual’s conceptual ecology through a reorganization of the conceptual structure.

For the second question, the conditions of a variety of responses, I will examine components of each individual’s conceptual ecology, which either help or block change toward constructivist epistemology. In this context, Chinn and Brewer (1993) enumerated “factors that influence how people respond to anomalous data” can be located under appropriate conceptual ecology components. For example, characteristics or quality of the new theory can be matched to ‘epistemological commitments to internal consistency’ in conceptual ecology in that high quality of a new theory appeals more to individuals who pursue more perfect theory. That is to say, in a rather aesthetic sense, it is more likely to be accepted if an alternative paradigm has such characteristics as accuracy, accountability of broad scope of data, internal/external consistency, simplicity, and fruitfulness (Kuhn, quoted in Chinn & Brewer, 1993, p.22). For example, some of the preservice teachers could give more weight to social constructivism than individual constructivism over the time span in their M. Ed. program in that social constructivism is in accordance with concurrent external social needs, such as multicultural education and the impact of culture. Thus, for them, social constructivism has more power than individual constructivism in explaining and coping with external, social movement and need.

To investigate the second question, my basic framework is two sets of categories that may produce the needs of change (or lack of change): demands from personal level
versus demands from theory level, and internal versus external demands. The first category (personal versus theory) locates an individual’s personal need and a theory’s need—mainly caused by the lack of explanatory power—as the sources of change. The second category (internal versus external) probes the demands of change in terms of each cognizing subject’s conceptual ecology and social & physical milieu, in which each person resides and is shaped as a social member. The two sets of categories can be arranged along vertical and horizontal axes to form a matrix like the following:

<table>
<thead>
<tr>
<th></th>
<th>Internal demands for change</th>
<th>External demands for change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each Individual’s Personal aspect</td>
<td>(1) Within conceptual ecology components:</td>
<td>(2) Past experience in conceptual ecology</td>
</tr>
<tr>
<td></td>
<td>- Metaphysical beliefs and concepts (Ontological belief)</td>
<td>- Social &amp; physical milieu</td>
</tr>
<tr>
<td></td>
<td>- Epistemological commitment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Anomalies (Dissatisfaction)</td>
<td></td>
</tr>
<tr>
<td>Theory of constructivism</td>
<td>(3) Characteristics of theory in terms of conceptual ecology: Conceptions of Science Teaching and Learning (CSTL) driven from Constructivist Epistemology</td>
<td>(4) Social &amp; physical milieu</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Other knowledge (or background knowledge)</td>
</tr>
</tbody>
</table>

Table 1.1: Analytical framework: conceptual ecology and social & physical milieu

In this context, cells (1) and (3) in Table 1.1 can be explored through an analysis of statements related to components of the conceptual ecology. For example, cell (3) can be inspected in terms of a property of theory itself in terms of explanatory power and its consistency with other established theories as well as internal and logical consistency.

Cell (2) will be reflected in statements related to each individual’s background knowledge, which preservice teachers bring into the M. Ed. program. In each individual’s background knowledge construction, social and physical milieu is also embedded. That
is, each individual’s extant background knowledge is the survived results throughout the interactions of the social and physical milieu and each individual’s cognizing activity that brought each individual to his or her current beliefs about teaching and learning.

Cell (4) can be traced to the evolution of a theory itself by the impact of social and physical environment changes. That is, even within the constructivist epistemology, constructivism itself went through on-going meaning construction processes whereby the theory has been elaborated and broadened or, sometimes, various versions of constructivism have resulted—proliferation of theory in the Kuhnian sense--such as trivial, sociocultural, contextual, radical, social constructivism, and social constructionism. In other words, upon meeting challenges from outside of a theory, theory itself goes through inside modification processes to respond to the demands from outside or to cope with environment changes.

In this context, the biggest assumption of this study is that preservice teachers possess, a level of background knowledge sufficient to interpreting and understanding what constructivist epistemology is about. That is, the constructivist epistemology should be intelligible to preservice teachers even though they do not believe it as true (plausible) or act on it as part of their beliefs system. Without the necessary background knowledge, preservice teachers may not even be able to understand the difference between their preinstructional concept (usually traditional pedagogy) and the constructivist epistemology, nor the difference between individual (or trivial) constructivism and social constructivism. In addition, if an alternative theory of higher quality is to be acknowledged as having value, the cognizing individual should have at least epistemological commitments to internal consistency or explanatory power of a theory as
a component of his or her conceptual ecology. The overview of my analytical framework is summarized in Table 1.2. Before assigning an overall response in terms of each conceptual ecology component, each preservice teacher's statements will be classified according to three codes: Resistant To Change or Outright Rejection; Capture of Constructivist Epistemology (CE); or Exchange for CE—Due to X (Explainers). Therefore, each cell of the table could have any of these three codes representing sample statements as well as the frequency of statements identified by a code.

<table>
<thead>
<tr>
<th>Conceptual Ecology</th>
<th>Constructivism</th>
<th>Explainers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response</td>
<td>Ontological beliefs</td>
<td>Epistemological beliefs</td>
</tr>
<tr>
<td>Outright rejection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capture of CE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exchange for CE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.2: Analytical framework: Factors that influence how preservice teachers respond to constructivist epistemology (CE) versus possible responses

Overview of the Research Methods

This qualitative case study included MSAT M.Eds who were getting their certification in an area of secondary science and who volunteered for the interviews. The primary method of data collection was in-depth, guided interviews. The preservice teachers also responded to a questionnaire (the CLES—Constructivist learning
environment survey) examining teachers’ projections of the ideal classroom learning environment. Themes and categories emerging from the data analysis, as well as interpretation of the data, were discussed with three peer debriefers. Accuracy of the participants’ meaning and the proffered interpretations was verified through member checks with each participant.

Scope and Limitations of the Investigation

This investigation is fundamentally descriptive in nature. The most specific purpose of this study is to describe the nature of preservice teachers’ pedagogical perspective changes upon meeting anomalous (anomalous to their previous pedagogical beliefs which is grounded in the traditional pedagogy) constructivist epistemology. The study aims to use categories derived from the conceptual ecology to describe and interpret preservice teachers’ perspective changes toward constructivist epistemology throughout three-quarters of university-based portion of their preservice program. By limiting the time frame to the theoretical part of the university coursework, the study aims to examine ‘theoretical impact’ of constructivist epistemology on preservice teachers’ pedagogical perspective changes. That is, by excluding the practicum period (student teaching experience or internship), I also exclude other social, political and pedagogical variables (i.e., “the nature of pupils, principal’s beliefs, parental attitudes, availability of materials, communication between school and university personnel, attitudes of mentor teachers in a school, and the personal relationships that develop between a novice and his or her cooperating teacher” (Kagan, 1992, p. 150)). Before we examine the ‘theory into practice’ stage, it is desirable to investigate how constructivist epistemology reified in a
preservice program is interpreted by each preservice teacher, and to what extent a preservice teacher has internalized constructivist epistemology as his or her own. Although “the effects of a teacher education program appear to be erased by classroom practice” (Kagan, 1992, p. 146), it is important to provide preservice teachers with a coherent knowledge base underlying their professional development at this stage. Unless preservice programs can make pedagogical perspective changes firstly at a theoretical level, it is hard to expect preservice teachers to implement a constructivist epistemology in their classroom teaching practices. This would be far more complicated with other contextual dilemmas, given the stress of daily of student teaching. That is, to try to realize constructivist pedagogy in the classroom, preservice teachers should know what constructivist epistemology is, and how it is different from their own previously held beliefs at the theoretical level first. Implementation or realization of their ideal pedagogy in daily practice is then the next step.

Finally, to more clearly delimit the questions of interest in this investigation, the followings are suggested as questions for subsequent study:

1. Is the constructivist pedagogy, which is adopted by preservice teachers throughout a preservice program, really erased by classroom practice?
2. What are the barriers to rooting constructivist pedagogy in practice?
3. Can preservice teachers attempt to implement constructivist pedagogy in practice?
4. If so, do they facilitate students’ learning as the constructivism suggests they should?
5. If so, is there any relationship between the use of constructivist pedagogy and subsequent students’ learning including students’ attitude changes?

These are questions for which the present investigation will provide a necessary, and valuable base.
CHAPTER 2
LITERATURE REVIEW

Overview of the Chapter

Considering the goals of this study, a review of relevant literature that represents philosophical background and commitments of different versions of constructivist paradigm is presented here. This review acts as the theoretical foundation for subsequent arguments as well as provides a rationale for the analytical framework. The purpose of this chapter is not only to provide a theoretical context within which this research is situated and the analytical framework for this research emerged, but also to help the reader understand this study. The first section of the following review presents philosophical commitments of three versions of educational constructivist paradigms. Then research that has referred to and expounded on the conceptual change model’s conceptual ecology is reviewed. Finally, a brief review of past research on preservice teacher education programs that incorporated constructivist pedagogy is included.
As stated in Chapter 1, 'educational constructivism' is differentiated from other constructivisms and located along a continuum, from a research paradigm to a view of learning. Although a variety of positions within educational constructivism share interests in pedagogy and improved classroom practices, each version of educational constructivism assumes different philosophical position in terms of ontological, epistemological, and, consequently, the details of pedagogical implications. Thus, educational constructivism (or psychological constructivism) is further divided into three distinct versions: individual, radical, and social. Sections of this chapter that follow focus on the implications each form of educational constructivism has for understanding instructional practices and student learning.

Main tenets of each version of educational constructivism are examined with regard to philosophical perspectives, mainly ontological and epistemological commitments that should lead to different pedagogical perspectives. That is, depending on the role that the external world of nature plays in our knowledge constructing activities—one's ontology—and "what counts as knowledge as well as how this is produced and justified" (Phillips, 1997b, p. 162)—one's epistemology, each version of educational constructivism can be identified. Each version of educational constructivism (i.e., individual, radical, or social) acts as a research paradigm in that each provides "an overall theoretical research perspective" (Ernest, 1995, p. 465) as well as philosophical foundation for teaching practices for those who adopt it. Paul Ernest (1995) expounds on these different
constructivist positions using a classificatory scheme composed of ontology, epistemology, methodology, and pedagogy. In the analysis that follows, I adapted Ernest's components of educational paradigms to focus on the philosophy of science and practical pedagogical components in order to highlight main tenets of educational constructivism.

In sum, I adapted three components as my analytical framework to distinguish different versions of educational constructivism: ontological commitments, epistemological commitments, and conceptions of science teaching and learning. Each of these includes implications for pedagogy or teaching practice. After expounding on the three components in my analytical framework, I provide an overview of constructivists' philosophical and epistemological background before giving further details about three different constructivist paradigms in light of the three components: ontological commitments, epistemological commitments, and conceptions of science teaching and learning (CSTL).

Ontological Commitments: Nature of Reality

Addressing growth in scientific knowledge, philosophers of science strive to explain the objects of human thought processes, namely, the material existence of the world and objects in it (ontology). Ontological commitment can be divided into two opposing positions: Realism and Idealism. According to realism, there is an existing material world apart from, and independent of, human experiences and human mental activity. Realists 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). This ontological position is in contrast to idealism which maintains that either there is no world outside of human experience or that such a world, including human experience, is constituted only by our discourse and theorizing. Along this line, in some forms of idealism, scientific knowledge is tested against social interaction with others, depending on consensus or dissensus within a community of scientists, neither against observation nor reality. According to idealism, our representations, regardless of their individual or social origins, are all we really have (Matthews, 1994; Nola, 1997; Bickhard, 1997). It is thus a rather extreme version of empiricism, which is “skeptical of any claims that we can know anything beyond experience” (Nola, 1998, p. 32). Furthermore, idealism in turn leads to a relativist epistemological position in that there are no rational criteria whereby comparisons or judgments of whether some ideas are correct and others incorrect can be made between competing theories or views (Matthews, 1994; Bickhard, 1998).

**Epistemological Commitments: Nature of Knowledge**

Epistemology is about “how the epistemic agent--the knower--knows about the world” and it is a theory of the nature, genesis, and warranting of subjective [or shared human] knowledge as well as a theory of truth” (Ernest, 1995, p. 465). According to Greeno (1989), thinking and learning are influenced by an individual’s beliefs about the
Fallibilism maintains that "Humans can have knowledge of the world even though such knowledge is imperfect. Therefore, reliable comparisons can be made between competing theories or opinions" (Matthews, 1994, p. 37). Fallibilism is "an epistemological position that is opposed, on the one hand, to relativism and, on the other hand, to absolutism" (p. 37). Relativism, following from Kuhn's (1970) views of science, holds that no reliable comparison can be made between competing views since different paradigms construct different natural universes. In contrast, absolutism (also called objectivism as analogous to foundationalism) holds that "current theory constitutes absolute, unimprovable knowledge" (p. 38). As the opposite of relativism, objectivism (or foundationalism)—both rationalist and empiricist epistemologies—seek permanent, indisputable criteria whereby the nature of rationality, knowledge, truth, reality, goodness, or rightness can be ascertained.

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

Ernest defines pedagogy as "a theory of teaching—the means to facilitate learning according to the epistemology" (p. 466). In this interpretation, constructivist premises about knowledge and knowers acknowledge learners as active knowers. According to Tobin (1993), metaphors as personal referents can be used to make sense of concepts associated with science and the teaching of science. On the assumption that one's metaphors are consistent with one's personal epistemology, the metaphor is not only "a
verbal device used to communicate teaching and learning practice” but also “an organizer of beliefs and practices” (p. 221). In other words, a teacher’s beliefs and her associated classroom practices are embedded within a metaphor, which subsequently, constrains “what a teacher would do to her students” (p. 221). Furthermore, “if metaphors constrain the actions of teachers, it is imperative that teachers are conscious of their metaphors, and consider alternatives and the consequences of adopting alternative conceptualizations of teaching roles” (Coben, 1993, p. 225).

Three versions of constructivist paradigms were considered in this study—individual, radical, and social constructivism. Like Ernest, I focused on practical pedagogical aspects of constructivism in science education to (1) identify each paradigm’s epistemological commitments, (2) illustrate findings of empirical research in light of underlying epistemological or other paradigmatical components, and (3) outline practical pedagogical implications in light of teaching and learning science.

There is a minute but hard-to-ignore difference in the perspective-taking and interpretation of constructivist paradigms between mathematics education and science education. That should be noted before continuing this review. The primary viewpoint taken here is from science education rather than mathematics education, sociology of knowledge, or ethnomethodology. The other boundary defining this literature review is the psychological constructivist perspective, rather than the radical sociological constructivism. In some extreme forms sociological constructivism claims that “science is nothing but a form of human cognitive construction comparable to artistic or literary
construction, and having no particular claim to truth" (Matthews, 1994, p. 138), which will be excluded from my study.

**Common Philosophical Grounds of Various Versions of Constructivism**

Constructivism is differentiated from empiricist, inductivist or positivist images of science by assuming a social or philosophical view of scientific knowledge and the nature of learning. The constructivist perspective presents science as non-objective and non-authoritarian. Moreover, it offers personal ownership of knowledge, not through hard work in compromising with other people's established ideas, but through a learner's construction of understanding through experiences mediated by 'a cognitive lens' (Confrey, 1995; Ogborn, 1997). Geelan (1997) contends, "No constructivist perspectives are entirely objectivist" (p. 20-21). According to Geelan, some of them do less to "problematize" traditional correspondence theories of truth, as representations of an independent reality. In a like manner, individual constructivists "have often explicitly recognized" sociocultural effects on learning although they give priority to individual cognition (p. 21).

A general trend in the historical development of constructivism is from individual-objectivist to social-relativist perspectives (Geelan, 1997). This is to say, the common move within constructivism is from viewing knowledge as a creative human endeavor that is "historically and culturally conditioned and not absolute, to the conclusion that knowledge claims are either unfounded or relativist" (Matthews, 1994, p. 143).
According to Matthews (1994), the original core of constructivism is founded on the premise that human knowledge, as well as scientific knowledge, is a theory-laden and subjective construction based on personal experiences and active processes of developing knowledge. Along this line, "constructivists adopt most of the epistemological theses of the postpositivist philosophy of science," especially the theory dependence of observation (p. 140). That is to say, "observations themselves are theoretically dependent or determined; what people look for and notice is influenced by what they want to see or what they regard as relevant to an investigation" (p. 140). In some sense, most constructivists are empiricists—often, instrumentalism is used as a synonym for empiricism—in that they wish to confine the claims of science to what they experience.

As a theory about learning, constructivism shares general principles of learning regardless of its various versions. Borrowing from Fosnot (1996), constructivists construe learning as “an interpretive, recursive, building process by active learners interacting with the physical and social world” (p. 30). Based on this common ground, two major trends can be identified within educational (or psychological) constructivism: one emphasizing the individual as actively constructing schemes and meaning through accommodation in the Piagetian sense, and the other emphasizing social or guided constructions within the zone of proximal development in the Vygotskian sense (Cobb, 1996).

Many Epistemological Perspectives of Constructivism

Even sharing the same terminology, various types of constructivism can mean quite different things depending on a particular epistemological and ontological stance. Throughout all recent movements in education (e.g., epistemology, philosophy and
history of science, cognitive and social psychology, and the sociology of science),
constructivism is accepted as a more appropriate conception of knowledge although there
is no common philosophical agreement across these stances (Gergen, 1995; von
Glaserfeld, 1989; Roth, 1993).

The purpose of this literature review chapter is to present a brief review of the
various versions of constructivism. In doing so, intentionally reducing the domain of
study of constructivism to psychological and pedagogical considerations, my theoretical
and practical perspective in this literature review is taken from science education. That is,
I construct pedagogical meanings of constructivism in the frame of science education.
The three versions of constructivism that follow—individual (or trivial) constructivism
originating in the work of Piaget, radical constructivism of von Glasersfeld, and social
constructivism of Vygotsky—represent for me a range of stances taken by educational
constructivists.

Sometimes the classification of various types of constructivism is made using
terminology in different ways (with different meanings). For reference, from the
educational psychology perspective, two forms of constructivism will be discussed here:
psychological constructivism (also labeled as educational constructivism) and social
constructivism. Psychological constructivists are mainly concerned with how individuals
construct knowledge through cognitive processes. Psychological constructivism can be
further divided into individual (e.g., Piaget and radical) and social (e.g., Vygotsky)
constructivists. Influenced by postmodernists, feminist epistemologists, and sociologists
of knowledge, social constructivists are mainly concerned with "how the public bodies of
knowledge are constructed" (Phillips, 1997b, p. 154). They are further divided into radical (or strong) sociological constructionists (e.g., Harry Collins) and (moderate) social constructionists (e.g., Gergen) (Phillips, 1997b).

Based on the work of Jean Piaget and Lev Vygotsky, constructivism is fundamentally nonpositivist and is said to be in direct opposition to behaviorism (Fosnot, 1996). Von Glasersfeld (1995) contends that the move to constructivism is founded on a radical change of epistemological perspective, which features an adaptive function of knowledge rather than the production of representations of an independent reality. This idea was put forward about 60 years ago by Jean Piaget. From this point of view, if we interpret constructivism as an irrevocable break with the generally accepted epistemological tradition (and theory of learning), it is worth knowing how constructivism is different from other models of learning (e.g., behaviorism) before talking about major philosophical ramifications within constructivism.

Behaviorists' Perspective

Ernest contends that the behaviorist paradigm represents the historical backdrop against which constructivist paradigms developed. It is the "default" paradigm that is deeply embedded in beginning preservice teachers' theories and beliefs about teaching-learning processes. This default paradigm is thought to be formed throughout their own schooling experience whereby preservice teachers were exposed to a traditional mode of teaching during the many years that they played the role of student (O'Loughlin, 1989).
The behaviorist paradigm is characterized by reinforcement, drill, and external motivation provided by a teacher. Moreover, this paradigm explains learning as a system of behavioral responses to external stimuli. Progress by learners is assessed by measuring observable outcomes such as behaviors on predetermined tasks (e.g., “getting the correct answers to problems, performing experiments, writing down certain equations when asked by a teacher, and so on” (Phillips & Soltis, 1998, p. 23). Behaviorist theory often explains behavioral change well, but it offers little explanation for cognitive change by a learner (Fosnot, 1996).

**Ontological Commitments**

The ontology of behaviorism is naive realism in that it maintains the world of things we experience is part of an ultimate reality. In other words, according to this realist perspective, “science and mathematics comprise transcendental truths about an objective universe and their adherents are able to discover and articulate ahistorical and depersonalized characteristics of an objective reality” (Taylor, 1993, p. 283).

**Epistemological Commitments**

Behaviorists advocate empiricism (or objectivism) as an epistemology. According to Hardy and Taylor (1997), “the long-dominant epistemological theory of objectivism assumes that reality has an inherent, observer-independent and, therefore, objective structure,” which can be attained through “rational thought processes” (p. 136). On the other hand, the mind is a blank slate to be written on by experience, and true or objective
knowledge can be attained (Ernest, 1995). Accordingly, science is viewed as a codified, independent body of knowledge to be taught.

**Pedagogical Implications**

The view of pedagogy associated with behaviorism ascribes ready-made knowledge to be transmitted by the teacher, and a passive-receptive view of the learner (Ernest, 1995). That is, pedagogies based on a behaviorist perspective “focus on developing accurate representations of knowledge in learners’ minds,” while identifying knowledge as a process of discovering an objective reality—locating knowledge in sources external to the learner (Taylor, 1993, p. 283). This pedagogy justifies the role of teacher as “an external authority to evaluate the correctness of students’ attempts to construct replicas of the teacher’s knowledge” (p. 285).

Learning is seen as the process of making associations or building bonds. These associations are strengthened through repetition with prompt reinforcement of correct responses and the extinction of incorrect responses. The learner is assumed to be a tabula rasa or blank slate—the recipient of information, rewards, and punishments. Learning is seen as the slow accumulation of knowledge and teaching is seen as the process of transmission of a canonical knowledge, scientific method and concepts. Therefore, content is broken down into small units and sub-skills and carefully sequenced for the learner by an expert. Under this paradigm, educators are exhort...
after a certain lesson. The emphasis here is on observable behaviors rather than mental activities and competencies.

Before getting into more detailed discussion of three versions of constructivism, a descriptive summary of an analytical framework is provided in Table 2.1. Along with exemplary tenets and sample statements describing each paradigm, Table 2.1 provides an advance organizer of how constructivist paradigms differ from each other as well as from the tradition of behaviorist teaching and learning.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Ontological commitments: Realist, Radical, or Idealist</th>
<th>Epistemological commitments: Absolutist, Piagetian, Fallibilist, or Relativist</th>
<th>Conceptions of Science Teaching and Learning (CSTL): Pedagogical implications in light of educational theory: individual focus or social focus</th>
</tr>
</thead>
</table>
| Individual constructivism (Also known as Cognitive; Cognitive-developmental; Piagetian; Personal; Trivial; or Weak constructivism) | [Realist]  
  • Piaget contends, "we only construct those that are in some logical sense 'isomorphic' with nature."  
  • Accept the ontological reality of the external world (Phillips, 1997). | [Piagetian]  
  • The adaptive function of cognition.  
  • The person exists as a real biological entity in a real physical world.  
  • Locate knowledge within the cognizing individual. | [Individual focus alone]  
  • Learning is knowledge-dependent: emphasizes the active engagement of the students and the importance of prior knowledge.  
  [Science learning]  
  • Learning as the accommodation processes.  
  • A process of enculturation into the science community (Driver et al., 1994).  
  • Learning as conceptual change. |
| Radical constructivism | [Radical]  
  • The world is created by and dependent upon human thought (Matthews, 1994).  
  • There is no rationally accessible, extraexperiential reality. | [Fallibilist]  
  • Knowledge, as an adaptive function, is the appropriate ordering of an experiential reality.  
  [Instrumentalist] or pragmatists theory of knowledge. | [Individual focus alone]  
  • Emphasize the adaptive function of cognition in relation to the experiential world.  
  [science learning]  
  • Learning as a subjective sense-making activity for the purpose of enhancing survival, located in learners' minds. |
| Social (contextual) constructivism | [Realist: weak form]  
  • Presume a persistent reality (e.g., Solomon, Tobin, & Vygotsky).  
  [Idealists: strong form]  
  • Knowledge is constructed within a particular community (e.g., Gergen, & Harry Collins). | [Relativism/Fallibilists]  
  • Conventional knowledge as socially accepted, lived and fallible.  
  • Socio-political processes [social negotiation] are the main factors in the scientific knowledge construction. | [Social focus]  
  [Vygotskian tradition]  
  • Learning is coparticipation in culturally organized practices; cognitive apprenticeship; legitimate peripheral participation; or the negotiation of meaning in the construction zone.  
  [Sociolinguistic tradition]  
  • Learning science as an initiation into the culture of doing science; students learn to act in accord with the normative rules. |
| Behaviorists' perspective (Also known as Objectivism; Positivism) | [Naive Realism]  
  • Objective external reality; a human-independent world. | [Absolutism]  
  • Knowledge as a representation of the real world. | [Behaviors learned through reinforcement]  
  • Learner as the recipient of knowledge.  
  Knowledge is to be transferred by means of words. |

Table 2.1: Analytical framework for the comparison of three versions of constructivist paradigm
Individual Constructivism

Ontological Commitments

An ontological realist believes one’s constructs or thoughts to be the reproduction of a given, independently existing external reality (von Glasersfeld, 1987). From this standpoint, an individual’s knowledge is constructed to match the objective world or facts about the world, and “not as a recursive construction based on previous constructions satisfying inner constraints” (Ernest, 1995, p. 470). That is, Piaget admitted, “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, “it is by interacting with a real environment” that each cognizing subject can construct “fundamental physical concepts and logico-mathematical structures (Phillips, 1997b, p. 184). Consequently, “Piaget believed that the knowledge constructed by individuals has the same structural features, and the reason we make the same or similar constructions is because we are dealing with the same reality” (Phillips & Soltis, 1998, p. 51). Furthermore, although knowledge is constructed based on experience, these human constructions can approximate the nature with an inherent order.

Epistemological Commitments

“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). Because they focus on science education rather than on
epistemology, their perspectives tend to take “scientific knowledge as given, and attempt
to find constructivist approaches for teaching” based on a Piagetian framework, which is
mainly concerned with individual cognitive development (p. 21). For Piaget, a person
exists is 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).

This view of conceptual development places the focus of learning by individual
students. Within this view, social groups are also considered important to the learning
process in that personal knowledge is constructed through social interactions and
experiences with the physical environment (Geelan, 1997; Strike & Posner, 1985; Fosnot,
1993; Pines & West, 1986). Later on, Driver and Oldham (1986) advocated that as public
knowledge as well as personal knowledge, science is “a carefully checked construction”
rather than a discovery of a world that exists independent of cognizing experience. Based
on an appreciation of theories as human construction, students’ intuitive meaning
constructions through their imagination are often far from the ‘ways of seeing’ adopted
and found useful by the scientific community. Along this line, Driver and Oldham’s
pedagogy takes on the characteristic of enculturation through which students need to be
introduced to scientists’ ways of interpretation.

**Pedagogical Implications**

Driven by the epistemological perspective presented above, individual
constructivists seek harmony between scientific and children’s conceptions (Driver, et. al.
An individual constructivist pedagogy emphasizes active engagement of students in their own learning processes and the importance of prior knowledge or conceptualizations for new learning. These experiences may facilitate or obstruct further learning. Moreover, they presume that there is a public, symbolic, created world of science that children have to be introduced to and whose concepts they should internalize. That is, “learning science is essentially a process of enculturation into the ideas and models of conventional science” (Driver, 1989, p. 103). Therefore, scientific understanding requires initiation into a scientific tradition and this initiation needs to be provided by science teachers. This recognition of an apprenticeship dimension to science education and the inherently social aspects of scientific discourse are a major departure from literal, traditional individualistic constructivism—“where students create their own meanings and adjudicate their own knowledge claims” (Matthews, 1994, p. 155).

Matthews (1994) contends, “a valuable (scientific) tradition is passed on (transmitted), not invented by each generation” (p. 159).

The essential role of a teacher from this point of view involves providing “appropriate experiential evidence and making the theoretical ideas and conventions of the science community available to pupils” (Driver, 1989, p. 92). Moreover, viewing classrooms as places where students construct and reconstruct meanings as a result of learning experiences, “teachers as diagnosticians” undertake a diagnostic process whereby they become familiar with the features of students’ ideas and current understandings (Driver, 1989).
Teaching science from the individual constructivists' perspective is summarized as following:

- Learning involves the construction of meaning. Meanings are constructed by students from what they see or hear may not be those intended. Construction of meaning is influenced to a large extent by our existing knowledge... The construction of meaning is a continuous and active process.... Learners have the final responsibility for their learning (Matthews, 1994, p. 144).

- The central focus of planning instruction should be in comparing a student’s and the accepted science point of view, thus providing insights to the intellectual, for the learner, of developing the science view ... an instructional strategy which involves exposing students’ initial thinking and using that as a starting point to teaching. Whatever the instructional approach adopted, the teaching should aim to support students in making links between their existing conceptions and the science view (Scott et al., 1994, p. 218).

- Learning science involves not only coming to terms with new conceptual structures but also involves developing a new rationality for knowledge. This rationality values decontextualized rather than situated knowledge; it values explanations which are generalizable to many contexts rather than those which are limited and ad-hoc in nature; it demands internal consistency of theories (Scott et al., 1994, p. 219).
• Teaching science involves ... helping students to construct the particular ‘ways
of seeing’ adopted by the science community. Learning science involves
socialization into a particular way of looking at the world.... Since the science
view is itself socially constructed within the science community, learning
science requires students to be socialized into a ‘new way of seeing’; they need
to be enculturated into the science community (Scott et al., 1994, p. 219).

**Overview of Individual Constructivism**

As the initial departure from Piagetian research that focuses on individual learners,
individual constructivism may be characterized by von Glasersfeld’s (1993) notion of
‘trivial’ constructivism in which individual constructivists locate knowledge within the
cognizing individual while they accept the ontological reality of an external world
(Geelan, 1997). Considering knowledge as individual and adaptive rather than objective,
Piaget’s (1972) “accommodation and assimilation” provide mechanisms for the adaptive
nature of cognition and the individual’s construction of models of the world.

Conceptual change pedagogy can also be located within the individual
constructivist paradigm (Pines & West, 1986; Driver & Oldham, 1986). Attacking the
Piagetian position, the personal constructivist position drew upon analogous theoretical
frameworks from philosophy of science. That is, just as all observation must be theory-
laden, learning is knowledge dependent. That is, a student’s previous conceptions will be
important in making sense out of an experimental situation. Moreover, based on David
Ausubel’s work, they also emphasized the role of preexisting conceptual structures that students relate to new items of knowledge.

According to O’Loughlin (1992), Piaget was mainly concerned with describing what he referred to as “objectivity.” This is interpreted as “the entire purpose of intellectual growth as one of coming to know reality more objectively through developing increasingly decentered, therefore more objective, perceptions of reality” (p. 793).

Piaget’s theory is developmental in orientation (evolving logico-mathematical structures in the mind) and stage-dependent, which refers to the four stages of sequential development through which people presumably progress: sensorimotor, preoperational, concrete operations, and formal operations. Along this line, Piaget suggested, “we begin by developing operations to act on our world, and that eventually, at the stage of formal operations, we acquire logico-mathematical reasoning capacities that allow us to detach ourselves from the object world so that we can reason about it in strictly logical terms” (O’Loughlin, 1992, p. 793).

On the other hand, Piaget’s stage independent theory on the development of human intellect concerns two processes: adaptation--as a process of assimilation and accommodation--of an individual to cope with an ever-changing environment, and organization, the structuring of the adapted world knowledge and experiences (Rieber, 1993; Mayer, 1996). Piaget referred to this organized set of knowledge as schemata (schemas) that is organized in more complex and integrated ways to cope with experiential world. The central feature of Piaget’s model is that throughout interaction with the outer environment the learner is both mentally and physically active in
constructing the logico-mathematical mental structures and basic schemas (Phillips, 1997b).

O'Loughlin (1992) presents Piaget's theory using an evolutionary process of self-regulation analogous to the biological point of view, that is, "that the organism constantly strives toward the reduction of conflict in order to gain equilibrium, which is established through the dialectical interplay of assimilation and accommodation" (p. 794). O'Loughlin also contends, "the end result of this process of intellectual adaptation is an increasing ability to come to view knowledge objectively, a process Piaget refers to as decentering" (p. 794). In Piaget's own words, as a necessary condition of objectivity itself, successive decenterations "make it possible for the subject to take the point of view of other subjects or objects themselves" (p. 710) so that the person successively detaches from his or her own subjective perception—consequently, begins to see the world from several perspectives—and makes it possible for an abstract representation of reality to be constructed (O'Loughlin, 1992).

Assimilation and accommodation involve the process of equilibration upon meeting a state of disequilibrium, or cognitive conflict, that occurs through everyday encounters with the environment. Assimilation, as a process of adaptation to new sense impressions, subsumes new information under an already existing structure or schemata and thus new ideas are understood in terms of existing understanding. Accommodation builds or adapts new structures from old structures when incoming information no longer fits an existing structure. Along this line, learning occurs when an individual resolves a state of
disequilibrium, or cognitive conflict, resulting from a contradiction between the learner’s existing understanding and what the learner experiences (Palincsar, 1998).

Disequilibrium, which leads to learning, occurs when the environment presents a problem that is outside of the individual’s repertoire, a problem that the individual seeks to resolve. Even though the conflict may be induced by some external agent such as a teacher, resolution can only be achieved at the individual child’s initiative (Fosnot, 1989). “Each resolution is an individual construction” in that “old mental structures are refined to be more comprehensive, and new structures are formed as well” (Rieber, 1993, p. 198). Emphasizing the quality of knowledge structures over their quantity, constructivists view learning as the constant reconstruction of ‘what is already known’ rather than the acquisition and accumulation of information in a cognizing subject’s knowledge banks. Through this adaptation process, they either revise existing mental structures to accept new external events or formulate unusual mental structures based on old mental environment when an existing structure is no longer sufficient. As Steffe (1995) puts it, individual constructivists view learning as a process of accommodation whereby the learner “as a self-organizing system” makes modifications in his or her functioning schemes “to neutralize perturbations that arise through interactions with our world” (p. 512). From a cognitive perspective, it is typically described as building up mental representations of knowledge, largely through solitary activity—that is, the learner is seen as a solitary inquirer (Phillips, 1997).

Constructivists recognize that knowledge, rather than being transferred from one individual to another or responding to the environment in a passive way, has to be
constructed by each individual through his or her interaction with the physical and social environment (Driver & Oldham, 1986; Roth, 1993). The dialectic between the world and its representation in a human mind was emphasized by Piaget who held that “intelligence organizes the world by organizing itself.” This means, “the structure of the mind is the source of our understanding of the world” (O’Loughlin, 1992, p. 793). Piaget’s model presents the central problem of epistemology as coming to know reality as it is in order to adapt successfully to it (O’Loughlin, 1993; von Glaserfeld, 1989b). These idiosyncratic constructions can then be negotiated in shared discourse which may, in turn, lead to an internal reconstruction when there is a clash between the individual constructions of learners (Piaget, 1970). From a Piagetian viewpoint, knowledge is always constructed first intrapsychologically before it can be negotiated (Roth, 1993). Meanings that emerge during interactions between individuals are assumed to be compatible from a cognitive perspective (von Glasersfeld, 1987).

**View of Science Teaching and Learning: What Would an Individual Constructivist Teacher Be Like?**

According to individual constructivism, mental representations of certain structures or features of the world outside are stored in the human brain. Therefore, learning is seen as the construction of mental models, and knowledge is something an individual possesses (Duit & Treagust, 1998).

In the past two decades, a rich body of empirical research and theory has grown from documenting children’s ideas and understandings prior to instruction that deviate from the accepted scientific view. Variously described as misconceptions,
preconceptions, intuitive theories, and the like, these findings have fostered the creation of a variety of constructivist theories of learning. What these perspectives share is a conviction that learners approach the task using strategies that, when solving problems, may lead to solutions discrepant from those of formal science. Therefore, teaching science from this perspective is viewed as overcoming misconceptions through instructional strategies such as exploring the ideas that students bring to lessons by means of group discussions or think-aloud reasoning during problem solving, then encouraging students to restructure their knowledge schemes by showing them the limitations or internal contradictions of their notions through a discrepant event, and finally presenting as viable alternatives the more advanced conceptual schemes of the formal science (Driver & Oldham, 1986; Driver, 1989; Driver et al., 1994). The essential role of the teacher in the process is to arrange and assist a potential conflict so that students really recognize the discrepancy and contradiction from their point of view (Cobb, Wood, & Yackel, 1991).

Within this approach, according to Miller (1989), there is a spectrum of interpretations toward the “weight to be given to children’s ideas compared with the accepted scientific view” (p. 4). At one end of the spectrum, children’s ideas as misconceptions “could be simply seen as providing the necessary information for teaching science concepts better” (Miller, 1989, p. 4). In other words, when teaching science, identifying misconceptions acts as a prerequisite to instruction. At the other end of the spectrum, children’s ideas are given “the status of alternative constructions of
meaning about the physical world that stand alongside scientists' ideas and are seen as different, rather than necessarily inferior" (Miller, 1989, p. 4).

Although identification of students' preinstructional alternative framework "is strongly influenced by cognitive psychology, it departs from the Piagetian tradition of identifying generalized cognitive structures," or content-free logical operations (e.g., mental stage theory), and "draws upon Ausubel's theory of preexisting conceptual structures" or the actual content of student conceptions and Kelly's personal construct psychology (Taylor, 1993, p. 269; Driver & Oldham, 1986). The major challenge to the focus of Piaget's research into learning in the 1970s came from Novak and his interpretation of the work of Ausubel. Ausubel emphasized the provision of suitable "advanced organizers" onto which new ideas can be fitted so that a new piece of information or concept can be more likely integrated or subsumed into an existing cognitive structure. Novak questioned whether children develop general cognitive structures or cognitive operations to make sense out of experience, and instead asked whether they acquire a hierarchically-organized framework of specific concepts to allow them to make sense of the experience (Duit & Treagust, 1998).

According to Cobern (1993), conceptual change research is important to constructivists because "learning is viewed as a process of deconstructing misconceptions and reconstructing valid scientific conceptions in their place" (p. 54). In a personal constructivist view, if learning as conceptual change is to take place, a number of conditions need to be met. First, there needs to be dissatisfaction with existing conceptions, and then, the new conception must appear intelligible, plausible and fruitful
in offering new interpretations (Posner et al. 1982). However, the students’ preinstructional alternative frameworks—their conceptual ecology in a sense for perceiving and even determining sense-making process of new phenomena, whether they are physical, social, or imaginative events—is difficult to change by instruction. The overall result of applying the conceptual change model has been complicated by such significant findings as strong persistence of students’ prior knowledge despite science teaching, and students’ inappropriate linking of scientific and prior knowledge. This is far from the meanings intended by the teacher. Pointing out its excessively rationalistic view of science learning adapted by the original conceptual change model, West and Pines criticized the conceptual change model for not considering nonrational components such as “power, simplicity in complexity, aesthetics, and personal integrity” as well as motivational beliefs that are intrinsic to conceptual change in the individual (Coben, 1993, p.54). On the one hand, Duit (1995) maintains that students’ preconceptions have to be taken as conceptions in their own right. They are valuable and viable in explaining everyday situations. Along this line, the traditional conceptual change paradigm of extinguishing students’ everyday ideas and replacing them with scientific ones should be revised by ‘a mode of coexistence’. Moreover, what students should learn in science instruction is what makes the scientific view more valuable and adequate than their everyday conceptions in specific situations, along with “articulation of a relationship between their intuitive views and the science view introduced by the teacher. In their revised and broadened theory of conceptual change, Strike and Posner (1992) emphasized
the need to focus on “the learner’s conceptual ecology and how that ecology structures learning” (p. 159).

On the other hand, Mortimer (1995) proposes the notion of a “conceptual profile” grounded in gradual evolution in learning, not conceptual (ex)change. According to him, the provisionality of knowledge (or the refutability of scientific knowledge following Popper) causes hesitation in the replacement (or eradication) of everyday notions by scientific concepts, which could also be replaced by more advanced concepts. The conceptual profile is constrained by the epistemological and ontological commitments of individuals and conceptual profile change postulates consciousness of one’s own conceptual profile. That is, those who have not only possessed but also changed their profile would be able to reflect upon his or her location on the conceptual spectrum and should be able to judge when or where one or another concept is appropriate. Therefore, conceptual profile change does not presuppose suppressing or lowering alternative conceptions to finally eradicate them. These alternative conceptions have been developed and reinforced as a result of everyday experience. Furthermore, they have been used by students as a comprehensive and powerful way of sharing meaning by enabling social communication over a substantial amount of time and space in an individual life. Along this line, science teaching is supposed to lead students to a reorganization of conceptual structures along the different hierarchical categories of their conceptual profile, while retaining their prior knowledge or common sense. The conceptual profile change also presupposes that students are more aware of their own profile in that they can identify the context and choose the appropriate domain of the profile. Along this line, “instead of
constructing a unique and powerful idea, individuals are portrayed as having different ways of thinking, that is, a conceptual profile, within specific domains” (Driver, et al., 1994, p. 7).

Radical Constructivism

Ontological Commitments

Radical constructivists often take an idealist ontology toward the existential status of scientific and everyday objects, which claims, “the world is created by and dependent upon human thought” (Matthews, 1994, p. 141). In other words, according to idealism defined by sociologists of science, the value of constructed thought is assessed by “the degree of its utility (or effectiveness)”--a pragmatist thesis shared by radical constructivism--not by the degree of accuracy of representation of a given reality (Matthews, 1994).

For von Glasersfeld (1993), even ‘society’ is a conceptual construct, rather than a given. “From a constructivist perspective, knowledge originates in the learner’s activity performed on objects. But objects do not lie around ready made in the world but are mental constructs” (Wheatley, 1991, p.10). On the other hand, what radical constructivism denies is the possibility of any certain knowledge as a representation of the world, not the existence of the physical world; therefore, radical constructivism could be assigned ‘an ontologically neutral position’ (Ernest, 1993).
Epistemological Commitments

Radical constructivists take an instrumentalist approach to scientific knowledge. Sharing roots with skepticism, they maintain “functional fit” in the prediction of subjective experiential reality. That is, our knowledge can only be checked by the extent to which our constructions fit with our experience in a coherent and consistent way rather than by their match with an external reality. From the radical constructivist perspective, knowledge originates in the learner’s activity performed on objects such as scientific objects, which per se are mental constructs (von Glasersfeld, 1991; Wheatley, 1991).

According to Prawat (1997), on the other hand, von Glasersfeld’s implicit assumption in his approach to truth is that the gradual emergence of the coherent (with what one already knows), logical mental structures in individuals’ minds—“the fact that systems of belief become more encompassing and integrative over time—reflects (or captures) a transcendent rationality” that is built into the mind-independent real world (p. 239). With this backdrop, Prawat categorizes radical constructivists’ epistemology as the foundational/rationalist realm.

von Glasersfeld’s ontological/epistemological commitments have been summarized by Matthews (1994, p. 149) as:

1) Knowledge is not about an observer-independent world.

2) Knowledge does not represent such a world; correspondence theories of knowledge are mistaken.

3) Knowledge is created by individuals in a historical and cultural context.
4) Knowledge refers to individual experience rather than to the world. (individualism)

5) Knowledge is constituted by individual conceptual structure. (individualism)

6) Conceptual structures constitute knowledge when individuals regard them as viable in relationship to their experience; constructivism is a form of pragmatism. (individualism)

7) There is no preferred epistemic conceptual structure; constructivism is a relativist doctrine. (relativism)

8) Knowledge is the appropriate ordering of an experiential reality.

9) There is no rationally accessible, extraexperiential reality. (idealism)

**Pedagogical Implications**

Pedagogies based on a radical constructivist perspective focus on "developing the experiential fitness of learners' concepts for making sense of their intersubjective experiences," while identifying knowledge as a subjective, internally located, meaning construction which is constrained by experience (Taylor, 1993, p. 283). In other words, emphasizing the adaptive function of cognition in relation to the experiential world, learning can be interpreted as "a process of reflecting on the adequacy of existing knowledge structures, restructuring (reorganizing) in order to neutralize cognitive perturbations or problematic experiences, and determining the viability of the new knowledge structures" (p. 285). Along this line, the teacher, representing society, must structure and facilitate learning environments with a greater range of experiences so that
students could learn what current society regards as having greatest viability at that particular time (Taylor, 1993; Tobin & Tippins, 1993; Wheatley, 1991, 1993).

On the other hand, according to von Glasersfeld (1989b, 1993), teachers’ verbal explanation of a problem does not guarantee a student’s understanding, unless the student’s conceptual structure is at least compatible with what the teacher had in mind in the given context. Thus teachers should have information about the students’ conceptual networks before teaching—‘an interpersonal fit’ in a sense. Without minimal interpersonal fit of conceptual structures, even the problematic situation may be perceived differently between teacher and students. Ernst von Glasersfeld (1989, 1993) describes the image of radical constructivism as a theory of knowing rather than a theory of knowledge.

Overview of Radical Constructivism

The main theme of von Glasersfeld’s (1989, 1993) radical constructivism, “which he refers to as the ‘radical constructivism principle’, is a relativist view of science” (Geelan, 1997, p. 21). Even though von Glasersfeld mentions social interaction, his perspective maintains, “individuals can only interact socially with their own construction of others” (p. 21). Placing individual cognition in a central position, von Glasersfeld can be located in the ‘individual-relativist’ perspectives (Geelan, 1997), as he maintains “knowledge is something which is personally constructed by individuals in an active way, as they try to give meaning to socially accepted and shared notions” (Boudourides, 1998, p. 4).
From a radical constructivist perspective, knowledge is not transferred directly from the environment or other persons into the learner, but has to be actively constructed within the individual mind. Therefore, knowledge consists of mental constructs, abstracted from one's experience, which have satisfied the constraints or challenges of objective reality which, of course, includes other persons. Since the only world we can know is the world of our experience, knowledge is always "contextual and never separated from the knower" (Wheatley, 1991, p. 10). The metaphysical principle of radical constructivism is that "the function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality" (Wheatley, 1991, p. 10). Moreover, all knowledge is constructed for the purpose of enhancing survival through making experience meaningful and coherent while none of it tells us anything certain about the world itself (Geelan, 1997).

In other words, as Taylor puts it, "although there might be an objectively real world with which we continuously interact throughout our lives, we have no direct access to that world other than through our senses and conceptually laden perspectives" (Taylor, 1993, p. 283). We can know the world only by constructing or reconstructing conceptual structures into more powerful and encompassing schemas whose viability depends on their success in enabling us to deal, physically or cognitively, with the world and in helping us to resolve problems and make predictions that serve our understanding (Taylor, 1993; Confrey, 1995).
It is the concept of viability that makes radical constructivism an instrumentalist (or pragmatist) theory of knowledge in that our ideas are “instruments whose purpose is to lead us fruitfully among our experiences and to resolve problems and blockages of action that confront us” (Phillips, 1997b, p. 180). Moreover, the concept of viability (in a sense, the absence of friction or collision with the environment) prevents radical constructivism from the solipsism of the idealists—the world is as each of us dreams it to be in that our subjective representations are the only reality and nothing exists outside what is in individuals’ minds; furthermore, there are no rational criteria against which to judge constituted representations. That is, radical constructivism recognizes that a knowledge construction process is constrained by the socio-physical environment in which it occurs “by means of language and interpersonal fit” (Hardy & Taylor, 1997, p. 145). Correspondingly, any construct that satisfies the constraints of experience through the course of social interaction is viable, in a sense as an adaptive function.

From this, radical constructivists do identify the social as an indispensable component of the learning process; however, the cognitive learning model of radical constructivism does not provide an adequate explanation of how the socio-cultural and the personal components of learning interact other than “the self-regulating mechanism of determining the ‘consensual fitness’ of one’s position” (Confrey, 1995; Hardy & Taylor, 1997, p. 145).
On the other hand, radical constructivists' denial of both the objective existence of identically shared meaning and the role of language as a transmitter of meaning is based on the premise that each of us assigns meaning to linguistic symbols, and meaning is abstracted from our individual subjective experiences. Although personal experiences are strongly influenced by social interaction (e.g., interaction with other members of community), whereby other cognizing subjects act as a major perturbation source, the function of the social interaction in individual development is limited to that of provoking interpersonal conflict or our awareness of inappropriateness in our concepts. In the same context, the meanings we create are never identical or shared but compatible meanings that have a socially negotiated ‘interpersonal fit’ beyond overcoming perturbation elements of experience (von Glasersfeld, 1989b; 1993; Cobb & Bauersfeld, 1995).

Pedagogies based on a radical constructivist perspective identify knowledge as a subjective sense-making activity for the purpose of enhancing survival, located in learners’ minds and emphasize developing the experiential fitness of learners’ concepts for making sense of their intersubjective experiences. In this viability sense or “principle of economy” in connecting knowledge and items of experience, radical constructivism leads directly to instrumentalism (Matthews, 1994).

View of Science Teaching and Learning: What Would a Radical Constructivist Teacher Be Like?

There is a similarity between Piaget and the radical constructivists in that “they share a common concern with what is happening in the adaptive cognitive apparatus of each individual learner” (Phillips & Soltis, 1998, p. 52). The teacher must be concerned
with what goes on in the student's head so that they can understand and interpret the student's conceptual structure. Even though the teacher introduces conflicts, they are unlikely to lead to a change in the students' thinking if the conflict situation is taken from areas that lie outside the students' fields of experience. Moreover, what really matters is to teach students to see why a particular conception or theory is considered scientifically viable in a given historical and practical context, rather than to present it as an authorized truth (von Glasersfeld, 1995).

Social (Contextual) Constructivism

While sharing terminology, social constructivism entails three different streams. One is (1) sociological constructivism (an extreme version), which will be excluded from my research consideration. The others are, within the realm of the educational constructivism, (2) a moderate (or weak) version and (3) a radical version. These are distinct in the extent to which an external reality plays a role in knowledge construction as well as the extent to which socio-political influences play a decisive role in shaping the form and content of scientific knowledge. That is, depending on the interpretation of the meaning of 'the socially constructed (or determined) character of scientific knowledge'—whether it means that "science is a communal endeavor" or that "science knowledge claims are vindicated by social agreement, not by how the world is" (Matthews, 1997, p. xi)—social constructivism contains within group variance.

The first variety of social constructivism (i.e., sociological constructivism) is derived from the sociology of scientific knowledge. This perspective is concerned
with how the public bodies of knowledge are socially constructed and interpreted in terms of changing socio-political processes, i.e., social structures and institutional powers (Phillips, 1997b; Gergen, 1997). Matthews (1994) contends that in contrast to educational (or psychological) constructivism (e.g., Piaget and Vygotsky), sociological constructivism “ignores the individual psychological mechanisms of belief construction, and focuses upon the extraintividual social circumstances which, it claims, determine the beliefs of individuals” (p. 138). Sociological constructivism, along with philosophical constructivism, provides educational constructivism with epistemological presuppositions such as ‘the social construction of all human knowledge and beliefs’.

Ontological Commitments

According to Geelan (1997), within the social constructivist category, Solomon, Tobin and Vygotsky could be assigned to relatively ‘objectivist’ positions because their “focus is on the social interactions which occur in classrooms; they tend not to problematize scientific knowledge” (p. 21). While they do not accept science as necessarily descriptive of ontological reality, they tend to treat it as a consensual, monolithic social construct into which students are to be acculturated by the social processes (Geelan, 1997; Gergen, 1997). Therefore, the moderate (weak) social constructivist model of the world is that of a socially constructed world that creates, and later on is constrained by, the shared experience of the underlying physical objective reality that is a world out there supporting the appearances to which we have shared
access. In other words, the reality constructed by humans is always “being modified and interacting to fit ontological reality,” to which one’s construction should ultimately be adequate, “although it can never give a true picture of it” (Ernest, 1995, p. 480). In summary, according to Ernest, this weak form of a social constructivist research paradigm can be assigned to a “sophisticated realist ontology” (p. 480) in that they presume a persistent reality to which “one’s constructions should ultimately be adequate” (Gergen, 1997, p. 199).

In contrast, the extremists of sociological constructivism such as Harry Collins maintain, “science is nothing but a form of human cognitive construction comparable to artistic or literary construction, and having no particular claim to truth” (Matthews, 1994, p. 138). In a similar way, for the extreme forms of idealism the reality only comes into existence “in and through discourse,” and even the natural world is constituted in words or “theoretical apparatus” that is humanly constructed (p. 142). Taking sociocultural factors into consideration in the shaping of scientific knowledge, ‘social-relativists’ claim that such knowledge is constructed “within a particular community” by way of “micro-social processes involving interrelationships with other people” (Phillips, 1997b, p. 188). For extreme sociological constructivists (‘radical social constructivist’ in Cobern’s (1995) terminology) like Collins, the natural world has little role in the scientific knowledge construction, while sociocultural (or socio-political) factors play the main role (i.e., even scientific knowledge is constructed entirely out of social negotiation) (Phillips, 1997b; Gergen 1997). Furthermore, they view reality as well as the individual--the cognizing
subject—as constituted in and through social context in which discourse plays a central role in the formation of mind (Ernest, 1993; Matthews, 1994).

These perspectives insist that knowledge be created in societies or discourse communities and emphasize the socially and historically situated nature of knowing throughout the collaborative and social nature of meaning making, which in turn emphasizes fostering collaboration across diverse communities rather than mastery of existing bodies of knowledge (O’Loughlin, 1992, 1993; Gergen, 1997).

Pedagogies based on the radical social constructivist perspective, influenced by the sociologists of science, postulate a “multi-sciences” view, and also extend to multiculturalism in science education in that students are inherently culturally dependent. Consequently, students’ meaning construction in the science classroom is influenced by cultural factors—embedded in students themselves—with which students interpret what the science teacher is trying to teach (Coben, 1995).

**Epistemological Commitments**

Social constructivists ground themselves in a fallibilist epistemology in that they regard conventional knowledge as socially accepted, lived and fallible, whereas they undermine objective knowledge claim, especially scientific knowledge (Ernest, 1993; 1995; Phillips, 1997b). They contend that scientific knowledge is invented in order to make sense of observations which are themselves theory-laden, that is, “what people look for and notice is influenced by what they want to see or what they regard as relevant to an investigation” (cited Matthews, 1994, p. 140). In science education social constructivism
has been influenced by several sources, “from the social theories of language of Vygotsky...
...to the social theories of science of the Edinburgh Strong Programme for the Sociology of Scientific Knowledge” (Nola, 1998, p. 33). Therefore, nevertheless sharing grounds of the epistemological theses of postpositivist philosophy of science, social constructivism leads directly to relativisms of all kinds, from a mere anti-realism to a linguistic idealism, “in which our world is constituted by our language” (Bickhard, 1998, p. 105), and a social idealistic constructivism.

Gergen (1995), assigned as a social-relativist in Geelan’s (1997) scheme, places scientific knowledge more firmly in the social realm. He insists that knowledge be created entirely out of social negotiation in societies or discourse communities, rather than arising within cognizing individuals or within the real, external world. Furthermore, if knowledge is viewed as a form of mental representation whose meaning is mediated by language, then agreed upon meaning is dependent on a particular local sociohistorical context. From his standpoint, even “authority is socially accorded (permitted to do so by a relevant social group)” and, accordingly, “anyone may be an authority” who occupies a given discursive position and maintains it (1995, p. 31). Therefore, from Gergen’s standpoint, the teacher’s role is to enable students to know how “to communicate with efficacy” so that “they are prepared to effectively occupy discursive positions within relationships in ways that will be accorded respect” (p. 32).

Even within the social constructivists, Gergen’s rather a radical position argues that there is only social existence through social-political processes, while the weak (moderate) claim is that there is individual learning, but only in a social context
As I said earlier, I exclude the extreme version social constructivism (sociological constructivism) from my discussions of educational constructivism. These extremists contend, "socio-political processes [social negotiation] are the main factors (or even the only ones) in the production of scientific knowledge"; that is, they even deny the decisive role played by the external natural world in "either shaping or at least constraining the knowledge that inquirers actually construct about it" (Phillips, 1997, p. 154). The more radical sociological constructivists "purport to overturn 'the very idea' of science as a distinctive intellectual enterprise with its special values," which, correspondingly, undermine the pursuit of science itself as well as the value and goals of a science education (Slezak, 1997, p. 185).

**Pedagogical Implications**

Social constructivists emphasize the essential and constitutive nature of language and social interaction in science learning because much instruction and learning takes place in a social context directly through the medium of language as a form of the associated, socially negotiated understandings or the 'public bodies of knowledge' (Phillips, 1997). Thus social constructivists stress the importance of the group as a knowledge-producing and validating mechanism for the development and validation of meanings (Ernest, 1995; Matthews, 1998). That is, "knowledge is actually constituted by the language, as innately theory laden, used to express it" (Wheatley, 1991). Moreover, Grandy (1997) views a group as itself having endowed properties, of course members being part of it, beyond a set of individuals.
Even within this sociological perspective, contrasted with psychological (or individualistic) perspective focused on the individual autonomous learner, two exemplary theories can be located (Cobb & Bauersfeld, 1995). One is the Vygotskian tradition in which learning—the development (or construction) of an individual’s knowledge—is viewed as coparticipation in culturally organized practices whereby scientific meanings are negotiated and institutionalized by members of communities rather than individual mechanisms. Along with such representative constructs as cognitive apprenticeship, legitimate peripheral participation, or the negotiation of meaning in the construction zone, theorists who work in this tradition emphasize social interaction in the activities of the expert, in which language as a culturally developed sign system mediates cultural processes and cognitive processes. The other is the sociolinguistic tradition whereby learning science in school is viewed as an initiation into the culture of doing science characterized as a social or discursive practice whereby, as Solomon put it, students learn to “act in accord with the normative rules” (Solomon, 1989, p.; Driver, 1989).

In terms of the relationship between development and learning, from a Vygotskian perspective, “development occurs as children learn general concepts and principles that can be applied to new tasks and problems, whereas from a Piagetian perspective, learning is constrained by development” (Palincsar, 1998, p. 353).

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

Overview of Social Constructivism

Social constructivism is derived from the work of Vygotsky, ethnomethodology, and the social studies of science. From the sociology of knowledge perspective, taking a learner’s conceptual ecology into consideration, Solomon (1983, 1987) argued that students’ prior knowledge about their surrounding everyday phenomena including nature originates from the common sense attitude which enables them to “interchange perspectives and meanings with others” while formal science is established by logical processes. Moreover, the life-world domains of knowledge are firmly held by children and often show great persistence despite science teaching. Since the primary life-world knowledge structures are reinforced and socially reaffirmed by communication with
others and by language itself throughout continual socialization into "a whole repertoire of non-scientific explanations" or implicit assumptions about how things work, these habitual knowledge structures of the real-world are hardly eradicated by schooling, or "a secondary process of socialization." Documenting the difficulties students have in relating these two different domains of knowledge and coexisting spheres, Solomon (1983) emphasized that students "should be able to think and operate in two different domains of knowledge and be capable of distinguishing," furthermore, crossing over between these two contrasting domains of knowledge (p. 50).

This "interchange" necessitates a social aspect, a dynamic during which meanings are chosen from a repertoire of language tools into which they have been socialized. Considering this, Solomon interpreted the science classroom as a place of social interaction where "a common frame of reference" is created through discourse among students one another and teachers as well. While Solomon continues to believe that ideas are held by individuals, she emphasizes the social effects of the desire for consensus and peer approval in modifying the scientific ideas held (Geelan, 1997). Therefore, contextual constructivism focuses on investigation of students' views within the cultural context, socio-cultural milieu, in which students' views are meaningful.

Taking Solomon's (1987) point about social influences on learning, Cobern (1993) emphasizes, "social interactions do not form all of the context of human cognition; moreover, culture is a central force in the development and organization of student ideas" (Geelan, 1997, p. 19). According to Cobern (1993), cultural context includes two ecologies: "conceptual ecology" as an individual dimension which is composed of
"cognitive artifacts such as anomalies, analogies, metaphors, epistemological beliefs, metaphorical beliefs, knowledge from other areas of inquiry and knowledge of competing conceptions" (Strike & Posner, 1985); and "social and physical milieu" in which individuals are located. These two ecologies are never completely independent. Citing several African American studies of Western style science teaching, Cobern (1993) shows the effects of dramatic cultural differences in a cross-cultural context in which "learners from minority cultural groups within Western countries and scientific culture—the product of Western modernization—move apart" (Geelan, 1997, p. 19).

Focusing on the synthesis of the constructivist interest in the interaction of students’ prior knowledge with new knowledge, Taylor (1993) suggests that the persistence of students’ alternative frameworks was cited as evidence of the central role of social communication in the construction of children’s culturally shared life-world knowing. This perspective, so called ‘Critical constructivism’ as a more extreme social position, suggests that constructivism can most completely fulfill its potential through social reconstruction, and that emancipatory interests must overcome the existing social structures of their school communities if this is to occur. Based on research into interactive aspects of school learning, Taylor (1993) suggests that social interactions of groups are a primary determinant of learning outcomes, perhaps more so than rational considerations of empirical data obtained in practical work. Solomon (1987) claims that, although group work has been nominated by personal constructivists as an important learning activity, there seems to be little appreciation of the need for pedagogy to shape the dynamics of groups.
The implication of learning environments compatible with the above social constructivist perspective is the necessity for collaboration in various social settings (contexts) in which shared knowledge—meaningful for both individual and social as a group through negotiation—is reached within given social contexts such as peer groups, small groups interacting with a teacher, and whole class discussions. As Bauersfeld states, “Learning is characterized by the subjective reconstruction of societal means and models through the negotiation of meaning in social interaction” (Cobb & Bauersfeld, 1995, p. 9). The two main themes characterizing social constructivists' teaching and learning are cognitive apprenticeship and situated cognition.

**View of Science Teaching Learning: Cognitive Apprenticeship and Situated Cognition**

Social constructivist perspectives do not deny that there is something stored in the human brain or in the minds of the cognizing being, but they claim that knowledge has significant social aspects in that it can be distributed among the members of a certain community or shared by this community. Knowledge, then, is something that is between the individual and the social (Duit & Treagust, 1998).

Based on the appeal of the sociohistorical theory offered by Vygotsky, social (or socio-cultural) constructivist teachers regard students as novices in thinking. These apprentices take an active role in their cognitive development by participating with peers and more skilled members of their society to develop skills to handle various culturally defined problems or those encountered in daily life with available tools such as language, behaviors, and other culturally determined patterns of communication (Rogoff, 1990;
Roth, 1993). Moreover, “what is most important to learn” in cooperative social settings are “those psychological tools that human societies have invented to allow individuals to deal effectively with each other and the world” (Phillips & Soltis, 1998, p. 59).

The construction of knowledge is innately a social event, owing to the social nature of language and other sign systems, which reflect objective reality (Matthews, 1994). Working with others is especially important when the research on students’ naive conceptions or alternative frameworks is considered in that “the original, very limited understanding of a concept and its meanings are developed and extended through negotiations with teachers and fellow students. The concepts thus receive more and more texture as they are applied in an ever larger number of settings” (Roth, 1993, p. 147).

Vygotsky created the concept of the “zone of proximal (or potential) development,” in which children develop and learn the skills of a culture through participation in shared problem solving with the assistance of a more knowledgeable adult or in collaboration with more capable peers (Vygotsky 1986; Rogoff, 1990). Stressing the role of social interaction and learning in social settings, Vygotsky was more interested in “the learning potential that a child might have” (i.e., “the level of competence the child can reach with aid as well as the child’s ability to profit from adult assistance”) (Phillips & Soltis, 1998, p. 58). In other words, Vygotsky studied what the child might accomplish through guided interaction contrasted with working independently. According to Newman et al. (1989), this zone becomes the “construction zone,” where individuals construct new knowledge by interacting with others. As the participants in a teaching-learning situation co-construct new conceptual knowledge or skills publicly, they appropriate knowledge and
skills (psychological tools), that is, they reconstruct their personal knowledge. Further cognitive development builds on the appropriation and internalization (i.e., "the process by which external actions are transformed into internal functions") by the novice of the shared cognitive processes to form the individual realm, which, after all, advances their capability of managing problem solving independently (Rogoff, 1990; Boudourides, 1998, p. 5).

In contrast, Piaget (1970) focuses on the development of the capacity to understand and respond to the views of others. He argues that young children are too egocentric to benefit from social interactions. Piaget asserts that, as they get older, students become capable of recognizing disputes and controversies. They can then use these conflicts to spur construction of more sophisticated ideas. Thus, for Piaget, group learning benefits students when controversy is identified and resolved.

Because of the primacy of the sociocultural character over psychology—the primary role of communication and social life in determining the nature of intrapsychological functioning (meaning formation and cognition), Vygotsky argued that the higher cognitive functions or the flow of conceptual development—which make use of cultural mediators to extend human thinking beyond the natural level—move from the social plane to the individual plane by internalization. That is, for Vygotsky, cognitive development is portrayed as the internalization of cognitive activity originally experienced in social contexts and in the interpsychological domain. The learner’s existing knowledge and skills are then extended through appropriation of shared cognitive processes within the
zone of proximal development through speech and communication in collaborative, interactive situations (Hennessy, 1993).

In other words, using discourse as a resource, beyond mere negotiation means, individual partners in the discourse situation "collaboratively construct knowledge interpsychologically" which, in turn, can be internalized by the individual as the new co-constructed structures interact with the child’s "intrapsychological structures to result in individual cognitive change" (Roth, 1993, p. 146). In a similar vein, Gergen (1995) maintains that education occurs primarily through the mutual interchange within the dialogue, thus, they favor a collaborative learning process in which students learn through engaging, incorporating, and critically exploring the views of others. This simultaneous construction of knowledge structure in the inter- and intrapsychological dimensions seems to provide a plausible analyzing framework for situations where individuals interact with more able individuals such as parents, teachers, and peers (Rogoff, 1990; Roth, 1993).

Along this line, by going through a series of processes characteristic of apprenticeship, such as modeling, coaching, scaffolding, fading, articulating and encouraging learners to reflect on their own problem-solving strategies, learning can be enhanced. Beginning with a competent other person and by making explicit an expert’s hidden, tacit mental processes, apprenticeship features a gradual withdrawal of help (fading) and a corresponding increase of learners’ control over their own learning processes in the context of guided social interaction and negotiation with teachers and peers (Collins, et al. 1989). Vygotsky’s focus on social processes led him to examine the
representational systems that are needed to participate in such higher mental functions, thus he emphasized a primary role for language in assisting in the process of internalization (Confrey, 1995).

Vygotsky does not discriminate between cognitive activity and social activity because he views these as entwined (Vygotsky 1987; Wertsch 1995). When an adult, an expert, or a more capable peer facilitates the performance of a student so that achievement is at a higher level than was achieved individually, the process is known as "scaffolding." The role of social context is to scaffold the learner, providing hints and help that make it possible for the learner to progress further than would be possible without this support.

The concept of "cognitive apprenticeship" has emerged to describe the learning through expert-guided experience on cognitive and metacognitive skills (Collins et al. 1989). Cognitive apprenticeship emphasizes authentic practice and situated learning by giving students the critical opportunity to observe, engage in and invent (or discover) expert strategies, both cognitive and metacognitive processes, in situations where the students are located and actively engaged (Hennessy, 1993). The metaphor of apprenticeship also emphasizes the active role a student has to take as she engages in learning the ways of a subculture by being involved in collaboration, shared activity, and problem solving. That is, researchers believe these processes of appropriation and meaning negotiation need to take place by participating in a community of science practice. Typical science practice is comprised of ways of talking and acting, shared
beliefs about what a problem is, how to work on it, and which tools and representations are useful for what conditions of inquiry.

In the apprenticeship model of learning, which honors the situated nature of knowledge, the novice learners get to be experts through the mechanism of enculturation into the world of the expert. In other words, “starting as legitimate but peripheral members of a community of practice, the apprentices became full participants in the specialized life of their chosen field” as they learn a body of knowledge and a set of skills through their involvement in apprenticeships (Phillips & Soltis, 1998, p. 63). Since all cognition is situated in the context of the activity associated with the learning, they need to be exposed to the use of a domain’s conceptual tools—the product of continuing negotiation within the community through authentic activity.

Brown et al. (1989) define authentic activities as the “ordinary practices of the culture” whose meaning and purpose are socially constructed through negotiation among shared cultural members. Often, this learning of new knowledge is tacit and a novice’s learning is facilitated by becoming a member of the culture of the expert (Duit & Treagust, 1998). According to the situated cognitive perspective, learning is a process of guided participation in a sociocultural activity, which involves building bridges between what children know and new information to be learned, and supporting children’s cognitive development (Rogoff, 1990). Moreover, with regard to the dominant conceptual change approach to science learning, the situated cognition view suggests that learning may be better characterized by coexisting alternative models (or parallel constructions) in different contexts (Solomon, 1983; Driver & Oldham, 1986; Driver, et al., 1994). That is,
children's intuitive prior conceptual knowledge of science is understandable, sensible and even fruitful in the everyday context and necessary for communication. Therefore, learning can be interpreted as a process of distinguishing when particular conceptions are appropriate rather than restructuring or exchanging children’s faulty prior conceptions (Solomon, 1983).

According to Collins et al. (1989), a cognitive apprenticeship involves the teacher and a learner or a group of learners in an expert-novice relationship whereby the teacher and learners change implicit, tacit practical knowledge to explicit theoretical and practical knowledge through shared reflection on the details of expert performance in problem-solving situations.

Cognitive Apprenticeship and Collaborative Learning

According to cognitive apprenticeship, learning advances through collaborative social interaction and the social construction of knowledge, whereby learners also acquire some of the culture’s tools such as a shared vocabulary and the means of discussion (Brown, et al., 1989). Collaborative group learning, through social, communicative interaction, assumes synergistic effects that students learn together and co-construct more powerful—over and above their individual abilities—knowing of how to cope with reality than they could construct individually (Brown, et al. 1989; Cobb, et al. 1991).

Provided with appropriate environments and activities that allow for interactive exchanges in the social context of the classroom, the participants of this intellectual community will exceed what they might achieve as individuals, thus amplifying the
learning of each individual. Through challenges and feedback from peers and teachers in class or small group discussion, students are prompted to recognize the need of transformation or reconstruction of their intuitions—unchecked personal views. In collaborative environments, students can make the necessary refinements and extensions in their understanding so that group members can communicate effectively with each other based on shared meanings (Roth, 1993; Wheatley, 1991).

The Conceptual Change Theory

The conceptual change theory is grounded in Stephen Toulmin's general theory of knowledge (or interpretation of alternative conceptions as the way of further conceptual evolution) as a philosophical backdrop.

A significant challenge to teachers is to make the science learned in school appropriately available in the real world of the student. Much of the discussion about enhancing the learning of science seeks a way to make the content of science more plausible, intelligible and fruitful for learners; thus, helping them to make better sense of their world (Hewson & Thorley, 1989).

A revisionary approach to conceptual change theory holds that the aim of scientific instruction is not to replace everyday views but to make students aware that, in certain contexts, science conceptions are much more fruitful than their own conceptions. Ideas of situated cognition have substantially supported this view of the context dependency of conceptions and claim that every cognition and every learning is situated. The situated cognition perspective provides a valuable framework for describing and understanding
research findings which show that change does not come easily and is limited to particular contexts.

**Learning as a Process of Conceptual Change**

Based on the seminal work of Thomas Kuhn (1970), the conceptual change model finds its trajectory from the contemporary views in the history and philosophy of science, driven by the analogous patterns of conceptual change in learning and "paradigm" shift in the history of science. According to Kuhn, the activity of scientists within one accepted paradigm--where paradigm refers to a comprehensive entity including conceptual, theoretical, instrumental, methodological, and even a metaphysical worldview--is called normal science and usually consists of puzzle solving, adding to the accepted stock of knowledge. In the normal science stage, a paradigm guides the whole group’s research activities through the theories it embodies. That is, in a normal science stage, a paradigm’s theoretical aspect defines the problem and the rules, which limit both the nature of acceptable solutions and the steps whereby they are to be obtained, and even guarantees (secures) the existence of a stable solution (predicts an assured solution). Therefore numerous sensible scientists devote their whole life to normal scientific activity through which the theory itself goes through refinement and articulation. This normal science continues until anomalies turn up, which eventually cause a crisis, followed by a revolution producing a new paradigm (Kuhn, 1970). The occurrence of revolutions is a regular feature of scientific change and this revolutionary process is itself part of the regular pattern in the increase of scientific knowledge.
Learning as Restructuring Process within a Prior-Knowledge Framework

In the meantime, based on her extensive research on students’ models and explanations of phenomena in the areas of observational astronomy, mechanics, and thermal physics, Vosniadou (1994) explains the nature of conceptual change in terms of a naïve framework theory of physics. Taking the importance of prior knowledge in learning into consideration, Vosniadou describes learning in terms of weak and radical ‘restructurings’ of prior knowledge, and provides a different view of misconception in the context of conceptual change. The process of acquiring new knowledge from experience of the physical world, according to Vosniadou, involves different kinds of conceptual changes that proceeds “through the gradual modification of one’s mental models of the physical world, achieved either through enrichment or through revision” (Vosniadou, 1994, p. 46). While reminding Piaget’s assimilation and accommodation of existing knowledge structures in the process of knowledge acquisition, Vosniadou differentiate between “the enrichment” and “restructuring (or revision)” of existing knowledge (conceptual) structures (Vosniadou & Brewer, 1987; Vosniadou, 1994; Vosniadou & Brewer, 1994). While enrichment involves the addition of information to existing conceptual structures, restructuring involves “the creation of new, high-order relations between existing concepts” (weak restructuring), or “a fundamental change in schemata, similar to paradigm shifts in the history of science” (radical restructuring) (Vosniadou & Brewer, 1987, p. 62).
Furthermore, Vosniadou differentiates the revision of at the level of "the specific theory that describes the internal structure of a given conceptual domain" from the level of the "framework theory" (Vosniadou, 1994, p. 63). For example, a naïve framework theory of physics (e.g., the up/down gravity on the Earth, force as a property of objects, hotness and coldness as properties of objects, etc.)—which is established early on in infancy, constantly confirmed by everyday experience, and very hard to revise—provides the fundamental ontological and epistemological presuppositions and constrain the way children interpret and acquire new information by providing a radically different explanatory framework (p.63).

Along this line, Vosniadou contends that conceptual change at the level of the framework theory—especially when it requires the revision of the entrenched presuppositions of the framework theory—is considered to be "the most difficult type of revision and the one most likely to cause misconceptions" (p. 46). That is, upon meeting the information to be acquired, which is inconsistent with existing beliefs, entrenched ontological and epistemological presuppositions, or with the relational structure of children’s naïve framework theory, children attempt to assimilate new information into existing framework theory, and in turn create misconceptions, that is, children’s misunderstandings of scientific explanations ("synthetic (mental) models" in Vosniadou’s terminology). As attempts to reconcile the culturally accepted scientific explanation with their initial explanations consistent with everyday experience, without giving up the beliefs and presuppositions of their naïve framework theory that constrain initial models,
children produce synthetic mental models such as “the dual Earth model, the hollow sphere model, the flattened sphere model” (p. 54).

In sum, according to Vosniadou, “the process of conceptual change will be gradual and will give rise to misconceptions” (Vosniadou, 1994, p. 56) in that it “proceeds from initial and synthetic model and eventually to scientific model” through re-interpretation of the presuppositions and beliefs and their replacement with a different explanatory framework, allowing the scientific concept to be acquired (Diakidoy, et al., 1997).

**Conditions of Conceptual Change Learning**

The model of conceptual change presented here includes both the replacement of an existing conception by a new conception (conceptual exchange, or accommodation) because they are mutually irreconcilable, and the incorporation of a new conception within the existing conception (conceptual capture, or assimilation) (Posner, et al., 1982). Before conceptual exchange (accommodation) is likely to occur, the following four common conditions must be fulfilled (Posner, et al., 1982, Hewson, 1980). It must be emphasized that each of these conditions “maps onto multiple components of the conceptual ecology” (Posner, et al., 1982, Thorley & Stofflett, 1996).

**There Must Be Dissatisfaction With Existing Conceptions**

Scientists and students are unlikely to make major changes in their concepts until they believe that less radical changes will not work. Therefore, dissatisfaction can occur when the old conception is unable to be reconciled with a new conception which can’t be ignored.
This can be compared to the crisis stage of Kuhn’s schema which begins when scientists see an anomaly as anomaly. For the first measure to the anomaly, the previous theory—which has resulted in the discovery of anomaly by not accommodating (in other words, conceptual capture cannot occur)—seeks its own elaboration or goes through theory broadening process by accepting exception. Eventually, however, this old theory arrives at a point of saturation and it will hand over its position to a new theory, a new perspective of the world.

In a similar vein, before an accommodation can occur, it is reasonable to suppose that an individual must have collected a store of unsolved puzzles or anomalies and lost faith in the capacity of his current concepts to solve these problems.

On the other hand, dissatisfaction can occur within the old conception itself due to further lack, or violation of some epistemological standards, such as “appearing inelegant or clumsy, or containing ad hoc assumptions, or being unnecessarily complicated” (Hewson, 1981, p. 387).

Most of the presented conceptual change model (CCM) represents the process of conceptual exchange, not conceptual capture. However, considering there is never a perfect paradigm and even a new paradigm is just better than the last one, learning or conceptual change may be better characterized as essentially “an ever-provisional” construction rather than as “constructing a unique and powerful idea” by conceptual exchange process (Driver, et al., 1994, p. 7; Mortimer, 1995). Especially, a preservice teacher’s pedagogical perspective change toward constructivism (conceptual change in his or her pedagogical content knowledge) can be represented by a conceptual capture
process rather than by a radical conceptual exchange process. This conceptual capture process can best be described as a process of gradual adjustment and elaboration in a teacher’s pedagogical content knowledge, which can be compared to the anomaly detection and subsequent adjustment in the old theory stage in Kuhn’s scientific revolution schema (Kuhn, 1970).

**A New Conception Must Be Intelligible**

“A person who is faced with a new conception, will not be able to incorporate it rationally into his or her existing conceptions unless he or she can make sense of it”; moreover, “in order to find a new conception intelligible, the person concerned has to be able to identify or construct a coherent representation of a new conception” which is supposed to have internal consistency (Hewson, 1981, p. 387). Along this line, the CCM often stresses the importance of analogies and metaphors as the ways of representing a new concept. The learner’s ability to make sense of and use the new ideas can be determined by how they represent knowledge and theories using such representation modes as linguistic expressions, criterial attributes, exemplars, images, analogies or metaphors, or even kinesthetic or tactile representations like gesture. After all, “it is possible for the person to say that a new conception was intelligible but that he or she did not believe it” (Hewson, 1981, p. 387). That is, understanding is not the same as believing and it is possible, for example, to understand evolution theory without necessarily accepting it.
A New Conception Must Appear Initially Plausible

“Any new concept adopted must at least appear to have the capacity to solve the problems generated by its predecessors” (Posner, et al., 1982, p. 214, emphasis added). According to Hewson (1981), “the initial plausibility criterion of a new conception depends on its relationship with the existing knowledge of the learner, including his or her past experience,” (p. 388) in that new conception should be consistent and reconcilable with his or her own existing conceptual ecology. On the other hand, from the innate incentive of the new conception, it could be that the new conception fits in with personal standards of knowledge in that it is elegant, economical, and parsimonious (Hewson, 1980, 1981).

This plausibility criterion can be found in the characteristics of the New Normal Science stage of the Kuhnian scientific revolution schema. That is, under a new paradigm, people start to articulate it, focusing on new problems, which are centered on previous anomalies. Under the new paradigm, with the guidance of the new theory, scientists probe new questions and solve new puzzles (Kuhn, 1970).

Initial plausibility can be thought of as “the anticipated degree of fit of a new conception into an existing conceptual ecology.” Along this line, a new conception can become plausible in terms of at least six aspects of judgment.

1) One finds it consistent with one’s current metaphysical beliefs and epistemological commitments, i.e., one’s fundamental assumptions.

2) One finds the conception to be consistent with other theories or knowledge about which one is aware.
3) One finds the conception to be consistent with past experience.

4) One finds or can create images for the conception, which match one’s sense of what the world is or could be like.

5) One finds the new conception capable of solving problems of which one is aware (i.e., resolving anomalies).

6) One finds the conception to be analogous to some other conception with which he or she is already familiar (Posner et al. 1985, p. 220).

As can be seen, each of the CCM conditions, especially for plausibility, maps onto multiple components of the conceptual ecology. This “multidimensional nature” of intelligibility, plausibility, and fruitfulness was also emphasized by Thorley’s (1990, 1991) analysis scheme of the content of science classroom discourse. If a new conception contradicts another explicitly stated conception that an individual believes to be true, regardless of how intelligible one finds the new conception, it may still appear counterintuitive.

A New Conception Must Be Fruitful

“The new conception should suggest the possibility of a fruitful research program” through suggesting new approaches and new experiments (Posner, et al., 1982, p. 214; Hewson, 1981).

Borrowing from the Kuhnian schema, a new paradigm implies a new and more rigid definition of the given field. Throughout a paradigm shift (or scientific revolution), there will be not only a radical change of specific theories and techniques but also a change in the kinds of questions that theories are expected to answer, and consequently there will be
a decisive difference in the modes of solution and the criteria for judging those answers as well as a basic transformation in the worldview. Moreover, it could solve (explain) anomalies experienced by the old theory; therefore, what is anomalous with respect to the old theory is no longer anomalous for the new theory.

Conceptual Ecology

Conceptual Ecology consists of the background of the learner’s current conceptions or learner’s current cognitive resources that govern a conceptual change process through the influence on the selection of a new central concept. Moreover, this conceptual ecology or conceptual context determines students’ ability to learn. What is learned in a given situation therefore depends on the students’ present knowledge structure and beliefs, which influence the meanings they construct (Posner, et al., 1982; Strike, 1983; Strike & Posner, 1985).

The followings are the main resources of a learner’s conceptual ecology, through which a conception is depicted as occupying a “niche” among the following cognitive factors or intellectual environment (Posner et al., 1982; Strike, 1983). Taking conceptual ecology into consideration, based on the key references (Posner et al., 1982; Hewson, 1981; Strike & Posner, 1982; Strike & Posner, 1985; Strike & Posner, 1992, etc.) and previous research for the conceptual change model, I elaborated each component of the conceptual ecology by providing specific examples (in a sense of exemplars) and accommodated the original conceptual ecology components to my research purpose. That is, to examine how the conceptual ecology structures the development of preservice
teachers' constructivist ideas, I expound upon each component of the conceptual ecology in terms of the practical pedagogical perspective and the framework which I employed for the analysis of the different versions of the constructivist paradigm (ontological commitments, epistemological commitments, and CSTL). The adapted six components within conceptual ecology are: ontological beliefs (metaphysical beliefs and concepts), epistemological commitments, conceptions of science teaching and learning as characteristics of theory, conflicts or anomalies, past experience, and other knowledge (background knowledge).

**Ontological Beliefs: Metaphysical Beliefs and Concepts**

a. Metaphysical beliefs about science. Beliefs concerning the extent of orderliness, symmetry, or nonrandomness of the universe are often important in scientific work and can result in epistemological views which, in turn, can select or reject particular kinds of explanations. Beliefs about the relations between science and commonplace experience are also important here.

b. Metaphysical concepts of science. Particular scientific conceptions often have a metaphysical quality in that they are beliefs about the ultimate nature of the universe and are immune from direct empirical refutation. A belief in absolute space or time is an example (Posner et al. 1982, p. 215).

Metaphysical beliefs are each individual’s fundamental assumptions about the world. Examples of metaphysical beliefs include Newtonian commitment to a mechanistic view of the world such as commitment to absolute space and time (Posner et al., 1982), believing concepts like heat, light, force, and electric current as a material
substance (Chinn & Brewer, 1993), and reference to the ontological status of objects, that is, deeply-held belief that tables cannot exert forces (Thorley, 1990).

Upon looking into preservice teachers’ metaphysical beliefs, I will focus on their ontological beliefs— their beliefs about “the fundamental categories and properties of the world” in terms of my analytical framework for the different versions of constructivism (Chinn & Brewer, 1993, p. 17). Each individual’s deeply-held ontological assumptions and commitments, which are very hard to change (Chinn & Brewer, 1993), could not only lead preservice teachers to reject constructivism but also make it difficult for them even to comprehend each constructivist theory itself if his or her ontological beliefs are in conflict with those of a specific version of constructivism.

As can be seen from the theoretical comparison between various versions of constructivism, each paradigm (individual, radical, and social) is epistemologically as well as ontologically different from others since the conceptual features change as one moves through the profile of constructivism. Considering the difficulties in changing the ontological or epistemological beliefs (generally implicit or unconscious), which each version of constructivism is assigned to, this feature has special importance. In the conceptual profile notion Mortimer (1995) contends, “the teaching process and its steps depend on the specific epistemological and ontological features of each profile zone of the concept to be taught” in that these features could be obstacles to the development of a new zone of the profile (p. 274). That is, the faulty or discrepant ontological or epistemological beliefs not only lead preservice teachers to reject other versions of constructivism but also make it difficult for them even to comprehend other constructivist
paradigms (Chinn & Brewer, 1993). Therefore, by identifying, acknowledging, and making explicit each preservice teacher's ontological and epistemological obstacles identified in the previous zones of his or her constructivist profile, I can help preservice teachers overcome the obstacles as well as help them understand each version of constructivism in terms of epistemological and ontological features.

**Epistemological Commitments**

a. Explanatory ideals (such as generalizability, internal consistency). Most fields have some subject matter specific views concerning what counts as a successful explanation in the field.

b. General views about the character of knowledge. Some standards for successful knowledge such as elegance, economy, parsimony, and not being excessively ad hoc seem subject matter neutral (Posner et al. 1982, p. 215).

Epistemological commitments are each individual's fundamental assumptions about what theory of theories is, what theory of knowledge is, and what the relation of disciplinary knowledge to everyday knowledge is (Posner et al., 1982). These epistemological commitments determine "what they find initially plausible" and, thus, shape their conceptual changes (Posner et al., 1982, p. 218).

In sum, the original meaning of epistemological commitments can be interpreted as the quality of the theory (or rational criteria for making choices among theories) in terms of its explanatory power as well as its accuracy, internal consistency, and consistency with other knowledge (Posner et al., 1982; Strike & Posner, 1985; Chinn & Brewer, 1993). However, in this research I interpret and examine preservice teachers'
epistemological commitments in light of their views about what scientific knowledge or
the scientific enterprise is as a way of knowing, and what their view of the relation of
their own epistemological commitments to each version of constructivist epistemology. It
certainly seems probable that making each teacher’s own epistemological commitments
explicit would promote a rational perspective change by comparing the different versions
of constructivist epistemological commitments. Furthermore, by helping each preservice
teacher to make explicit his or her epistemological commitments I can track and locate
his or her perspective changes by reflecting upon each version of constructivist
epistemology.

Conceptions of Science Teaching and Learning: Pedagogical Implications

Through this component, I want to investigate how preservice teachers represent
their pedagogical perspectives (or minimal understanding of each version of
constructivism) even though they may not possess sophisticated technical language with
which they can describe their epistemological, ontological, and pedagogical perspectives.
For this component of the conceptual ecology, I collapsed originally two components
(Analogies and metaphors; and Exemplars and images) into one (metaphors) with which I
probed each teacher’s conceptions of science teaching and learning. That is, the
metaphors of preservice teachers “can offer insights into teachers’ construction of their
a language device that presents an exemplar in the language of a different culture
precisely for the purpose of bridging the two cultures” (p. 293). Accordingly, any of these
four representation forms could serve as a bridge by providing sufficient common ground
between the preservice teachers’ own ordinary, well known objects (or language) from their everyday life and a very different way of seeing (a new concept, that is, constructivists’ ways of seeing) (Cobern, 1995, p. 293).

As Ogborn (1997) puts it, “ways of thinking about things generally rest on some fundamental metaphorical basis” (p. 121). For example, the many versions of constructivism which are currently recommended as an alternative to the epistemological theory of objectivism have been grounded in the key metaphor of making (or constructing) knowledge (Ogborn, 1997). Contrary to objectivists’ metaphor of finding as the ways of knowing, this constructivists’ constructing metaphor entails its own views of learning as the active construction of one’s own knowledge.

Conflicts or Anomalies

“The character of the specific failures of a given idea is an important part of the ecology which selects its successor” (Posner et al., 1982, p. 214).

As one major source of dissatisfaction, anomalies exist when a person is unable to assimilate an experience or a new conception that is presumed to be assimilable (Posner et al., 1982; Strike & Posner, 1985).

If preservice teachers are to accommodate a constructivist epistemology as a new alternative to their prior pedagogy (i.e., traditional pedagogy), they need to see what problems (or lack of explanations and emotional needs) the constructivist pedagogy solves (Strike & Posner, 1982, 1985). The sources of anomalies could be the lack of explanatory power of the previous pedagogy, unacceptable implications of the previous pedagogy in terms of ontological or epistemological aspects, and/or inconsistency with
knowledge in other areas including the social sources of pedagogical perspective revision demands. After all, all these anomaly sources are grounded in the inability to cope with internal and external demands.

**Past Experience or Personal History**

"Conceptions which appear to contradict one's past experience are unlikely to be accepted" (Strike & Posner, 1985, p. 217).

At the beginning of their teacher education program, preservice teachers will be guided by the images of their past experiences to which they themselves were exposed (enculturated) as a student (Kagan, 1992; Pajares, 1992). According to Kagan (1992), two crucial elements in determining past experiences are what it takes to be an effective teacher based on "exemplary models of teachers," and how students ought to behave based on a preservice teacher's "image of self as learner" (p. 154). That is, as a default paradigm preservice teachers have adopted a traditional pedagogy based on their own schooling experiences. These prior experiences, in turn, will exert a potent force, either a positive or a negative way, in determining "what could be learned from course work" of their preservice program (Kagan, 1992, p. 141), not to mention their responses to the constructivist epistemology (O'Loughlin, 1989; Pajares, 1992). Accordingly, preservice teachers are constrained by their prior experience whereby they make sense of constructivist epistemology as well as sift and screen it, from their first impression of constructivism to the subsequent perspective changes toward constructivism.
Other Knowledge

a. Knowledge in other fields. New ideas must be compatible with other things people believe to be true.

b. Competing conceptions. One condition for the selection of a new conception is that it should appear to have more promise than its competitors. (Strike & Posner, 1985, p. 217)

Each preservice teacher’s accessible background knowledge, which he or she “assumes to be valid,” (Chinn & Brewer, 1993, p. 18) is also a potent factor in determining how the individual responds to constructivist pedagogy. On the one hand, one’s own background knowledge could be at least one type of barrier in that each preservice teacher is unable to make sense of constructivism within the context of his or her background knowledge. Before that, “if an individual possesses too little relevant background knowledge, he or she will not even be able to understand that the anomalous data are anomalous” (Chinn & Brewer, 1993, p. 20). On the other hand, each individual’s awareness of concurrent social issues and movements (e.g., emphasis on the multicultural education) or knowledge of other fields (e.g., theories of sociology of scientific knowledge) are also the main sources of background knowledge that fosters or hampers his or her pedagogical perspective changes.
Constructivism and Teacher Education Programs

A constructivist approach is advocated by some as the appropriate core component of the method courses of teacher education programs, which employ the constructivist aspects of teacher education and generate applications of constructivism to the practice of teacher education. That is, a team of educational psychologists recently advocates the tenets of a "contemporary psychological perspective (i.e., constructivism)" as a guide to assist in the preparation of prospective teachers (Scheurman, 1995). In this section, based on researches on "how beginning teachers learn to teach," I summarized emerging themes in terms of future research implications, which, in turn, will provide a backdrop for my own research. Based on Wideen et al.'s (1998) extensive review, I primarily focused on researches that were concerned with "prior beliefs of beginning teachers and program interventions occurring during teacher education," which examined the perceptions and developing beliefs of beginning teachers related to preservice teacher education (p. 135).

Prior Beliefs of Preservice Teachers

Through longitudinal studies, researches examined the importance of the beliefs held by beginning teachers prior to entering programs of preservice teacher education in that these well-established prior beliefs about teaching are hard to change and act as filters through which teacher education program experiences are interpreted (Hollingsworth, 1989; Pajares, 1992; Richardson, 1996; Wideen et al., 1998). The origin of beliefs or experience that influences the development of beliefs are "personal experience (e.g., parenting, life decision, family influences, etc.), experience with schooling and instruction (e.g., years of pedagogical modeling from teachers, the
apprenticeship of experience based on their own experiences as students, etc.), and experience with formal knowledge (e.g., experiences with formal pedagogical knowledge)” (p. 105).

Using interviews, elicitation of metaphors, narrative semiotic analysis, concept maps, journals, personal biographies, and portfolios to examine conceptual changes in teachers’ beliefs in preservice teacher education, a number of researchers found that the student teachers’ perspectives are difficult to change (Kagan, 1992; Richardson, 1996) whereas “[in-service staff development] programs that approach learning to teach in a constructivist manner are successful in engaging and changing their beliefs and practices” (Richardson, 1996, p. 113).

The Impact of Teacher Education Program: Preservice Interventions

Richardson (1996) contends, “except for the student-teaching element, preservice teacher education seems a weak intervention” in that “it is sandwiched between two powerful forces”: one is the previous life history of being a student that sets images of teaching, and the other is the classroom experience as a [student] teacher that provides practical knowledge through the socialization process of the school (p. 113). However, the academic elements of preservice teacher education in terms of an introduction to the new and alternative conceptions and beliefs, which have beginning teachers examine their beliefs, have an impact on teachers although there could be “a lag time” to make an impact on practice or “perhaps not recognized by them” (p. 113). In the following section, studies on the impact of teacher education program interventions during university coursework are examined.
According to Richardson (1997), to date, research on constructivist teacher education takes on two quite different forms: "One form attempts to teach preservice teachers how to teach in a particular constructivist manner," whereby the teacher educator directly instructs preservice teachers in a constructivist theory (e.g., Piagetian) whereas another form involves the investigation of preservice teachers' tacit, prior beliefs of teaching and presentation of alternatives to those held by them, through modeling of a constructivist classroom by a teacher educator (p. 10).

One of the influences of the constructivist psychological perspective on the preparation of teachers is found in the 'developmental teacher education (DTE) program' at Berkeley. The DTE program, a two-year graduate program in elementary teacher education, has adopted a "developmental-constructivist" model for pre-service teacher education over a decade, whereby it attempts to teach students how to teach in a Piagetian constructivist manner. Thus, throughout the DTE program there is a heavy emphasis on the study of Piagetian cognitive development theory. Teacher educators try to promote "teachers' developmental understandings,"—development in a teacher's own way of thinking about children, learning, and teaching: the nature of their students' knowledge development and the relevance of the same principles to the teachers' own development (i.e., development of pedagogical conceptions). For instance, a developmental curriculum builds on the child's initial understandings by providing meaningful instructional activities that recognize levels of child development as conceptual hurdles (Kroll & Black, 1993). Researchers associated with the DTE program have proposed a model of the development of teacher's thinking in the pedagogical domain (Ammon & Hutcheson,
1989; Ammon et al., 1985; Hutcheson, & Ammon, 1986, 1987). According to this model, pre-service teachers in the DTE program change their perspectives from behaviorist pedagogical conceptions (transmission view of teaching and learning) to constructivist conceptions (helping students develop reflective ways of thinking). In other words, there has been a gradual change in teachers' pedagogical conceptions, from vague, global and relatively undifferentiated to more specific, differentiated and integrated views of teaching (Ammon & Hutcheson, 1989; Kagan, 1992). Considering the importance of developing constructivist psychological perspective in this study, “it seems that any teacher education program could not function adequately without knowledge of their students’ personal epistemologies,” defined as “beliefs about learning, dispositions toward thinking, and assumptions about knowledge itself” (Scheurman, 1995, p. 2).

Teacher educators need to consider and articulate their students’ “evolutionary ways of thinking” about pedagogy to promote conceptual change in preservice teachers by incorporating this tenet into their curriculum design and instruction so that this sequence of conceptual advances can serve as the goals for a developmentally based curriculum. Like children’s preconceptions, preservice teachers’ epistemological orientations as well as concepts entering a teacher preparation program affect what and how they learn (Pajares, 1992; Scheurman, 1995).

Along this line, “if the objective of teacher education is to equip teachers with a contemporary psychological perspective of teaching and learning (known collectively as constructivism),” then teacher educators need to anticipate “the developmental variations” in preservice teachers’ personal epistemologies (Scheurman, 1995, p. 17). On
the other hand, for pre-service teachers it is important “to anticipate the developmental variations they are likely to encounter as teachers” (Scheurman, 1995, p. 17).

In sum, based on emerging themes from the previous research, suggestions as to how this research might inform preservice teacher education can be summarized as following:

- [Considering the fact that] the big advances in understanding about student learning [with a constructivist orientation] have not been matched by equivalent advances in understanding about teaching....Research in science teacher education needs to move in this direction as well, that is, researching how to teach teachers to teach in a constructivist manner (Anderson & Mitchener, 1993, p. 37).

- The constructivist theories of learning suggest that students bring beliefs to a teacher education program that strongly influence what and how they learn (Richardson, 1996, p. 105). [Therefore], the goal of teacher education is to help teachers transform tacit or unexamined beliefs about teaching, learning, and the curriculum into objectively reasonable or evidentiary beliefs.

- [Preservice students should have the opportunity] to explore their own beliefs, as well as alternative beliefs and practices (Richardson, 1996, p. 113).

- Preservice students should have the opportunity to engage extensively in the active exploration of classroom contexts, that is, in written and videocases, discussions with practicing teachers, and field work. This process may promote
the first stages in the acquisition of practical knowledge (Richardson, 1996, p. 113).

- Research on teacher educators' (within a faculty of teacher education) beliefs and practices will be particularly helpful in the improvement of teacher education practice (Richardson, 1996, p. 115), [along with the research that] examines the influence of teaching by academic subject-matter professors on the entering pedagogical beliefs of preservice teachers (Mayer-Smith, et al., 1997; Wideen et al., 1998, p. 170).

- Future research should pay more attention to the programs in which specific interventions occur.... Published accounts should include a more comprehensive description of the total program structure [considering] a course must be regarded as a component that varies the research rather than a constant (Wideen et al., 1998, p. 149).

- Faculty recognizes that if students are to acquire a non-traditional orientation, curriculum messages must be reinforced and supported in all facets of the program (Graber, 1996, p. 456).

- The solution proposed by most researchers [who studied the beginning teachers since they are the central problem in teacher education] is to have preservice teachers reflect more on their practice, to employ teaching approaches more consistent with constructivism, or to recruit a different population of prospective
teachers [so that they can teach an increasingly heterogeneous population of students] (Wideen et al., 1998, p. 168).

- Programs to develop teachers with a constructivist view [need] to provide prospective science teachers with a model for constructivist learning situations and help them develop practical knowledge—the type experienced expert teachers possess (Anderson & Mitchener, 1993, p. 31).

In the meantime, research or evaluation on multicultural teacher preparation programs, which feature incorporating many of the changes recommended by the teacher preparation reform frameworks, has examined beginning teachers' assumption and beliefs towards multiculturalism, developing views of teaching in multicultural classrooms, perceptions within model multicultural programs, and experiences in dealing with multicultural contexts. Considering a fundamental problem, that "an increasingly homogeneous population of teachers are instructing an increasingly heterogeneous population of students" (Gomez, 1994, p. 320), there are increasing needs to recruit a more multicultural population of beginning teachers so that they can communicate with students whose cultural backgrounds are different from their own.

On the other hand, although new theories and methods that differ from existing teachers' classrooms "appear to be washed out in the real world of the classroom" during the practicum, preservice teachers can learn those alternatives when they are "coached by informed supervisors" (Hollingsworth, 1989, p. 162). In other words, for preservice teachers to translate constructivist philosophies of learning that could supplant traditional
ideas through pedagogical practices, "directed supervision or coaching with preservice teachers and communicating program expectations to cooperating teachers appeared to be necessary" (p. 181). Hollingsworth (1989) contended that cooperating teachers' encouragement to experiment with important ideas presented in method courses helped changes in preservice teachers' knowledge and beliefs about teaching and learning.

Along this line, considering that student teaching is a critical (or even the most valuable) component of teacher education programs and that cooperating teachers have great influence on student teachers' professional development (Hollingsworth, 1988; Guyton, 1989; Sudzina et al., 1997; Borko & Mayfield, 1995), cooperating teachers are expected to become directly involved in teaching student teachers by providing positive support of experimental behavior (Grimmett & Ratzlaff, 1986). To help classroom teachers make the transition to teacher educators, teacher education institutions provide preparation and support for their new roles through ongoing training programs (Hollingsworth, 1989; Borko & Mayfield, 1995).

To prepare experienced classroom teachers participating in teacher education programs for the cooperating role, a substantial inservice component needs to be implemented so that the classroom teachers can be informed about the content and philosophy of teacher education programs as well as about university sponsored practices (Hollingsworth, 1988; Guyton, 1989; Borko & Mayfield, 1995). Based on this information, cooperating teachers "could give substantive feedback to their student teachers" (p. 29) by integrating theoretical and research-based ideas from their university courses into their teaching practices followed in the classroom. In her experimental
program, Hollingsworth (1988) conducted inservice seminars around classroom teacher needs within the preservice program in an attempt to connect schools and universities. By incorporating inservice work within the preservice teacher education program, teacher educators in her program could improve the quality of supervision as they increased cooperating teacher knowledge of the teacher education program and new instructional strategies (approaches) through inservice seminars. It further contributed to bridging the gap between "the university-sponsored theoretical pedagogy and the real world of the classroom." This is accomplished through the inservice training program that nurtured the theories and practices introduced in preservice education and promoted "the transfer of research findings to classroom settings" (p. 34).

In sum, cooperating teachers need to be prepared to mentor student teachers through inservice training provided by the university teacher education programs. This inservice seminar should provide training in both the principles of practice and the principles of effective supervision and mentoring practices (Sudzina et al., 1997; Wolfe, 1992; Bey, 1992) Based on this, cooperating teachers are expected to help preservice teachers in making the transition between theory and practice by not only being a role model, but also promoting an atmosphere in which risk taking is regarded as safe. Moreover, several studies suggest that this preparation through inservice training also results in various positive effects on cooperating teachers' side, including "enhancement of the cooperating teachers' active listening, use of different teaching models [in their own teaching], autonomy and self-direction, improved communication between cooperating teachers and student teachers, and more specific feedback to student teachers" (Borko & Mayfield,
1995, p. 516; Guyton, 1989). Several research corroborates that by providing adequate preparation and support for cooperating teachers’ roles, teacher education programs can “maximize the likelihood that student teaching will be teacher education” by enabling student teachers to “move beyond the status quo and explore new ways of teaching” (Borko & Mayfield, 1995, p. 517).
Overview of the Chapter

This study is primarily a descriptive study. Its main purpose is to describe the status of preservice teachers' pedagogical perspectives in terms of versions of the constructivist paradigm as they are reified throughout their preservice teacher education program. The basic analytical framework of this study, as shown in the previous chapters, is to use categories derived from the conceptual ecology components to interpret preservice teachers' pedagogical perspectives. The selected components of conceptual ecology as an analytical framework are the result of a dialectic interplay between the epistemological theory of constructivism itself and each preservice teacher's conceptual ecology. That is, each conceptual ecology component went through redefinition or meaning elaboration processes in consideration of the theoretical characteristics of constructivism so that each preservice teacher's personalized constructivism paradigm could be located in his or her conceptual ecology.

This section provides (1) an overview of the MSAT preservice teacher education program (fifth-year master's program) along with a timeline of the study and a description of the subjects, (2) a description of selection and collection of data sources, and (3) the procedures for data analyses for each of the research questions presented in
a previous chapter. Based on the conceptual analysis of three different versions of the constructivist paradigm and redefinition of the descriptions of conceptual ecology components, the analysis is to categorize segments of interview transcripts in terms of the conceptual ecology components to trace any perspective changes.

Overview of the MSAT M. ED. Program

The program assumes five quarters of full-time registration, beginning in the summer quarter and continuing until the following summer. The integrated Master of Education (M.Ed.) program in the Mathematics, Science, and Technology Education (MSAT) department aims to provide a comprehensive master’s program in mathematics, science, and technology education leading to grades 7 through 12 teacher certification. In science education, corresponding teacher certifications are biology, earth science, chemistry, physics, all sciences (grade 7 & 8), and general science (grades 9-12). In terms of classroom experience, the MSAT M.Ed. program features a gradual increase of classroom experiences through fieldwork where preservice teachers can engage extensively in the active exploration of classroom contexts from the second quarter. From the second quarter on, preservice teachers typically receive over 270 hours of field experiences through their university coursework prior to their 10-week student teaching experience--practicum experience--in the fourth quarter.

Conceptual Analysis of the Constructivist Paradigm

The conceptual ecology components emerged from the dialectic synthesis described in the previous chapters. The adopted six components of conceptual ecology are: ontological beliefs, epistemological commitments, conceptions of science teaching and learning (pedagogical beliefs), and explainers that include conflicts or anomalies, past
experiences, and other background knowledge. The meaning of each conceptual ecology component was clarified in Chapter 2. It is important to re-emphasize here that the adopted conceptual ecology components are to illuminate each preservice teacher’s adopted constructivist ideas rather than to establish a range of cognitive factors of each cognizing subject. That is, in this research each conceptual ecology component has its meaning in the context of science teaching and learning: metaphors of science teaching and learning, past schooling experiences in science learning, past educational pipelines that one has gone through, conflicts between one’s prior beliefs (e.g., traditional pedagogy) and constructivist epistemology, and other background knowledge as a potent factor in determining how an individual responds to constructivist epistemology. Even epistemological and ontological commitments within each preservice teacher’s conceptual ecology have meaning in light of whether they are compatible or incompatible with the specific epistemological and ontological features of each version of the constructivist paradigm to be presented in the M.Ed. methods courses.

Collection of Data Sources

It is important to note that any segment of preservice teachers’ interview transcripts (i.e., their conceptions of science teaching and learning, with their ontological and epistemological commitments as a backdrop) could be related to one or more of the components of the conceptual ecology. In addition, considering the characteristics of a conceptual ecology which is often held unconsciously by a cognizing subject, the use of quantitative methods to identify some components of the conceptual ecology may be counterproductive in that they may not capture some of its relevant qualities. According to Kagan (1990), any short-answer test of teacher belief, such as an instrument consisting
of prefabricated statements, has certain inherent limitation in that “standardized statements may mask or misrepresent a particular teacher’s highly personalized perceptions and definitions” (p. 426). Moreover, each individual’s conceptual ecology is idiosyncratic in that the personal context—cognitive as well as social—in which one resides is never the same as that of anyone else. Thus, this study needed in-depth interview methods whereby each preservice teacher could reveal and confront his or her own conceptual ecology, and furthermore one could experience constructive or reconstructive change in one’s cognition (refer to Lather’s catalytic validity). On the one hand, interview itself could provide preservice teachers with an opportunity to begin thinking about their implicit beliefs and to think reflectively about their own views of teaching and learning, or during the interview process they could come up with and elaborate pedagogical language with which they could describe their pedagogical perspectives. On the other hand, considering various components of conceptual ecology and the inherent complex, multifaceted aspects of teaching and learning, which are the main concerns of constructivism, the use of multiple approaches seems to be superior, to provide triangulation (Kagan, 1990).

I followed one cohort through the M.Ed. program’s theoretical coursework (i.e., from the summer quarter to the end of the winter quarter) tracing their perspective changes toward constructivist epistemology. Data that were periodically collected over the three-quarters include: interviews (e.g., interview about instances, general open-ended questions, and forced-choice questions) and the Constructivist Learning Environment Survey (CLES) questionnaire. All of the science M. Eds who had been accepted into their university teacher certification program in 1999, completed questionnaires and a subset
of the 34 science M. Eds were interviewed periodically throughout the three quarters. Out of 34 science M. Eds, 16 students—nine female teachers and seven male teachers—in the secondary science methods class agreed to participate in this study.

Interviews were conducted at each of four points in the M.Ed. program: during the first week of the first summer quarter of the university coursework, at the end of the first summer of coursework, at the end of the fall quarter, and at the end of the winter quarter—that is, right before student teaching experiences, practicum, or internship in the following spring quarter. The significance of this timeframe in preservice teachers’ perspective change is that (a) entry level schemas based on prior experiences as students in classrooms can be revealed by the first interview; (b) theoretical schemas that have incorporated constructivist language reflected on their coursework can be revealed by the second interview whereby purported change in their perspectives may simply reflect mastery of content as they progress through method courses; (c) revised schemas that emerged throughout intra- and interpsychological variables and desirability can be revealed by the third interview as well as by the fourth interview where subjects were also asked to compare their own pre- and post-interview responses and to draw inferences regarding changes through a member check process. By revealing and confronting the evidences of their perspective changes, the underlying implicit, unstated intra- and interpsychological factors could be revealed in the third and the fourth interviews.

My study ends with beginning of student teaching whereby preservice teachers experience different challenges and variables other than their prior beliefs and theoretical perspectives provided by university coursework. Other potential social and pedagogical variables after their classroom placement are embedded in two dimensions. One is from
interpsychological dimension in terms of the school/classroom context; for example, “the nature of pupils, parental attitudes, availability of materials, communication between school and university personnel, attitudes of teachers in a school,” and principal’s beliefs in terms of the degree of autonomy afforded to teachers as well as each preservice teacher’s personal relationship with his or her cooperating teacher (Kagan, 1992, p. 150). The other is from the intrapsychological dimension in terms of the need to construct or reconstruct “the image of self as teacher” upon acquiring knowledge of pupils, and “cognitive dissonance” caused by dialectic interplay between theory and practice, which in turn makes preservice teachers “question the appropriateness of personal images and beliefs” (p. 150).

**Personal Background Characteristics**

In spite of the same pedagogical interventions, some preservice teachers may be more open-minded toward constructivist epistemology than others. Information about each preservice teacher’s personal backgrounds—each candidate’s biography, in a sense, including his or her prior experiences in classrooms as students, which is to determine what could be learned from course work—can help the researcher to understand, in part, a preservice teacher’s peculiar responses to new constructivist epistemology. The background information included his or her subject area to teach, personal schooling history along with science courses previously taken—science content background, what kind of educational pipeline they went through, how they were employed before they began the M. Ed. program, etc.
General Open-Ended Questions on Constructivist Epistemology

For each interview, to avoid imposing the technical language of constructivism or philosophical terminology without understanding, general open-ended questions were asked so that preservice teachers could describe their ontological, epistemological and pedagogical beliefs with their own language. The first interview results became the basis for preparing the subsequent interview questions. That is, for the subsequent interviews, I revised interview protocols by incorporating a list of words or sample statements based on the interviewees' initial responses regarding epistemological, ontological, and pedagogical commitments most frequently mentioned in the first interview. A list of the questions asked in the first interview can be found in Appendix B.

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

Forced-Choice Questions on Constructivist Epistemology

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

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

Provided with forced-choice items, each interviewee was asked for a clarification of the meaning of each item in the context of the discourse, and modification or combination of given statements to better describe their own positions. The interview protocols were designed to allow each interviewee to better describe or find appropriate words and expressions for her own unique position by assimilating one of the given items as her own or modifying pre-given exemplary statements to better fit her beliefs.
Interview about Instances on Science Teaching and Learning

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

It was noted earlier that the focus of the research is on probing preservice teachers’ pedagogical perspectives on science teaching and learning in which their ontological and epistemological commitments and other conceptual ecology components are situated. Therefore, in the first interview, without confronting the technical language of constructivism or philosophical terminology, I tried to elicit preservice teachers’ general conceptions of science teaching and learning using an interview-about-instances task similar to the one developed by Hewson & Hewson (1989). The original interview consists of 10 descriptions of activities or tasks intended to represent both instances and non-instances of science teaching and learning inside and outside of the classroom contexts, whereby respondents are to consider the components of an appropriate conception of teaching science as they respond to particular events. The 10 events are to provide teachers with an environment in which a variety of views could be expressed “by encouraging them to link the events to larger conceptual issues” (Hewson & Kerby, 1993, p. 7). Except minute modification of science content of two or three interview events, I used the original format and protocol intact. Taking the highly chemistry-oriented science content in the original interview task into consideration, I rephrased a couple of event
descriptions with better known concepts so that even non-chemistry major preservice teachers could understand each specific situation. Each preservice teacher was shown in sequence a written description of each event and asked, "whether, in his or her view, there was any science teaching happening there, and invited to give reasons for his or her answer" (p. 7). The interview-about-instances task was used in the first and the third interview. In the first interview, 10 descriptions of activities or tasks were used, in which each preservice teacher was asked to consider the components of an appropriate conception of teaching science as they responded to particular events. In the third interview, a short version of interview-about-instances task was reused with five descriptions of events that represented both instances and non-instances of science teaching and learning. The interview transcripts were examined with a view to identifying examples of conceptual ecology components, which were embedded in their conceptions of science teaching and learning.

**Constructivist Learning Environment Survey (CLES) Questionnaire**

The CLES, as a departure from traditional practices in learning environment research, was designed to measure the extent to which teachers perceive their science teaching environments are at once compatible with a constructivist epistemology and social-constructivist referents for learning, that is, viewing students as co-constructors of knowledge (Taylor et al., 1997; Fraser et al., 1998). The new version of the CLES, focused on critical discourse within a classroom learning environment, is to measure students’ and teachers’ perceptions of the frequency of occurrence of five key dimensions: personal relevance, uncertainty, critical voice, shared control, and student negotiation.
As one of data sources, the CLES provides a baseline of the M.Ed. cohort as a whole, not to mention triangulation of data to infer a preservice teacher's pedagogical perspective. That is, by comparing the features entailed in the CLES questionnaire data between the whole M.Ed. cohort and interview volunteers, it is possible to infer whether the interviewees were a typical representative of the whole cohort or not. Even though the aim of this research is not to generalize to all preservice teachers in constructivist-oriented teacher education programs, the CLES data will help the researcher to identify how specific the interviewees are. It also, in part, provides verification by enabling the researcher to find association between preservice teachers' self-stated pedagogical perspectives in the interviews and their reified future classroom atmosphere, which is represented by the implicit CLES question items.

**Characteristics of the MSAT M.Ed. Teacher Education Program**

This study aims to track the development of preservice teachers' beliefs about constructivist epistemology that occurred through the university coursework in a constructivist-oriented preservice teacher education program. To provide details of the context in which these preservice teachers worked in their preservice program and background for interpreting the interview data, a faculty email interview was conducted during the spring quarter. The faculty email interview was designed to reveal major issues guiding the present program and the preservice science teacher educators. In addition, syllabi from methods courses and informal conversations with faculty members who taught M.Ed. methods courses were also collected and used to document intentions of the M.Ed. faculty and characteristics of the MSAT M.Ed. program. However, I did not gather systematic data about the program or about the 'intended' curricula, or about
M.Ed. preservice teachers’ learning because these areas were outside of the intent of my study.

Methods of Data Analysis and Interpretation

Qualitative Analysis of Interview Data

Preservice teachers’ developing notions of constructivism were determined, mainly, using interview data. The interview protocols were designed to enable interviewees to consider each component of the conceptual ecology (e.g., epistemological, ontological, and pedagogical beliefs (CSTL) that are consistent with constructivist views of teaching and learning), while providing alternative options whereby a variety of views can be expressed by assimilating as one’s own or modifying pre-given statements to better describe one’s unique position. Based on the four times’ longitudinal interview data, the analysis entails identifying each component of preservice teachers’ conceptual ecology; categorizing them into three subsuming categories—ontological, epistemological, and pedagogical beliefs on constructivism; and tracing any perspective change by identifying each teacher’s constructivist profile.

The analytical scheme for this study has two different fields of view. On the one hand, I will concentrate on an individual preservice teacher as he or she will construct or restructure existing and new beliefs over a three-quarter length of time by constructing each preservice teacher’s constructivist profile. On the other hand, I will look across the individual case analyses for the longitudinal change of the group as a whole. The procedures employed in the data analysis had two aspects. The first involved descriptions of the characteristics of each conceptual ecology component using prototypical examples drawn from the data sources. The second aspect assessed each preservice teacher’s
ontological, epistemological and pedagogical beliefs changes based on the construction of ontological, epistemological and conceptions of science teaching and learning (CSTL) profiles.

**Description of Each Conceptual Ecology Component**

Focused on each component of conceptual ecology (i.e., ontological beliefs, epistemological beliefs, conceptions of science teaching and learning, past experiences, conflicts, and other knowledge), I asked the following questions: What kind of statements as evidences could be located within each component?; What kind of conceptual ecology component did they have?; Were there any common components across individuals?; and Did any statements change within each conceptual ecology component over the given time span?

Taking conceptual ecology components prescribed in the theoretical framework in Chapter 2, the analysis involved searching the transcripts for segments which exemplify each of the conceptual ecology components. The ultimate task of this analysis could be regarded as identifying and characterizing exemplary statements of constructivist ideas, which are adopted by preservice teachers, expressed in their own words, and reflected in conceptual ecology components. For the individual level analysis, I first classified interview transcripts according to the analytical framework (see Table 1.2), along with the frequency of each exemplary statement.

**Constructivist Profile Changes**

Borrowing Mortimer’s (1995) concept of conceptual profile, each preservice teacher’s constructivist profile—a profile of his or her perspective on constructivism rather than an epistemological or conceptual profile—change can be traced over the time
span of preservice teacher education program, if there is any. Upon looking at the individual’s constructivist profile in terms of conceptual ecology, I need to consider the complexity and difficulties in changing some of the conceptual ecology components. Moreover, a preservice teacher’s internalization process of the constructivist paradigm can be hardly assumed as a total, stark exchange with their traditional teaching and learning paradigm. In other words, even though preservice teachers become aware of the limitations of their own alternative paradigm, compared with constructivist paradigm, they remain attached to the previous paradigm for a variety of reasons, such as emotional attachment or low status (intelligibility, plausibility, and fruitfulness) of an alternative (i.e., constructivist) theoretical framework per se.

If there is any change, that process will more likely be conceptual capture rather than conceptual exchange, by which I mean that over most of the time span, different versions of a theory coexist in each cognizing individual’s conceptual ecology. Considering the cognizing beings’ nature of pursuing a better theory, even the concurrent blending movement within various versions of constructivism can be interpreted in a similar vein. Drawing from this position, not only a collective or societal level, made of a number of individuals, but also each individual’s internal cognition, there is a coexistence of different versions of perspective and each individual continues to differentiate and select a compatible version depending on a given specific context. Accordingly, even in an individual’s cognition level, we could find a blending movement. An additional feature of the constructivist profile is that each component of the profile can be divided into intra-, and interpsychological aspects.
Within this framework, the subsequently emerging challenge is then how can I quantify the height of each component in an individual’s constructivist profile? One possibility of analyzing responses is to tally the frequency of characteristic statements obtained for each version: traditional paradigm, individual, radical, and social constructivist paradigm. In the end, it is necessary for the purposes of this study, to accept that the quantification of the height of a constructivist profile as well as assignment of segments of interview transcripts to each version of constructivist paradigm calls for high inference on the interpreter’s side.

Analysis of Data

In this section, how the final analytical framework was developed for using the conceptual ecology components to interpret interview transcripts is discussed. This framework was used for the following data analysis procedures: coding, summary data displays in the format of constructivist profiles and tables, and identification of themes.

Structure of Analysis Scheme

In the first phase of the analysis, four main categories—Ontological Beliefs, Epistemological Beliefs, Conceptions of science teaching and learning (CSTL), and Explainers—were developed to characterize each preservice teacher’s beliefs about the role of reality in scientific knowledge construction and their conceptions of science teaching and learning.

These categories were derived from the analytical framework of this study that consists of redefined components of conceptual ecology. As I stated in Chapter 2, selected components of conceptual ecology were the result of dialectic interplay between the epistemological theory of constructivism itself and each preservice teacher’s
conceptual ecology. That is, I redefined and elaborated each conceptual ecology component in consideration of the theoretical characteristics of constructivism so that each preservice teacher's personalized constructivist ideas could be located in his or her conceptual ecology (refer to Chapter 2 for the refined definition of selected components of conceptual ecology). In addition, it is important at this point to reemphasize that there are epistemological and ontological differences between different versions of educational constructivism (i.e., individual, radical, and social constructivism). These different ontological and epistemological positions that emerged from the synthesis and conceptual analysis of different versions of educational constructivism were used as forced-choice items in the interviews, and formed coding categories in assigning segments of the interview transcripts related to each interviewee's ontological and epistemological beliefs. The four main categories are described below.

**Ontological Beliefs**

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

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

For each subcategory, a detailed definition along with three to four exemplary quotes taken from the interview transcripts is provided in Appendix C. The definitions of each category are derived from related literatures where theorists articulated their positions, whereas exemplary quotes are taken from the interview transcripts that show ontological position statements made by preservice teachers in their own words.

**Epistemological Beliefs**

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

**Conceptions of Science Teaching and Learning (CSTL)**

This category includes any statements in which preservice teachers were commenting on inferred practical pedagogical outcomes and principles based on their differing ontological and epistemological standpoints, as well as the means to facilitate
learning according to an epistemology. The purpose of this category is to examine implications of the differing ontological and epistemological understanding of knowledge taken by different versions of constructivism in terms of pedagogical activity. This category is further divided into two subcategories: "teaching and learning" and "preferences". The teaching and learning subcategory includes: the role of the teacher, the role of the learner, how to teach, how students learn, and rationale. The preferences subcategory includes traditional, Piaget’s individual constructivists, von Glasersfeld’s radical constructivists, and Vygotsky’s social constructivists. In fact, these two subcategories—"preference" and "teaching and learning"—are intertwined and embedded in each other.

Subcategories of teaching and learning.

It was noted in an earlier section that each teacher’s conceptions of science teaching and learning were elicited through (1) open-ended questions about pedagogical beliefs, (2) an interview-about-instances task, and (3) forced-choice questions on pedagogical preferences. Each preservice teacher’s CSTL could include statements of ideals which include behaviors, values, dispositions, the role of herself as a teacher, the expected role of students in her science class, how to teach, how she thinks students learn, rationales of her way of teaching, as well as rationales of expected learning outcomes. Accordingly, statements related to the subcategories of “teaching and learning” were embedded in the exemplary statements and descriptions of each preference subcategory. The participants also made statements related to these “teaching and learning” subcategories as they commented about each forced-choice item. For each subcategory, a detailed definition is provided in Appendix C.
Subcategories of preferences.

The forced-choice items about pedagogical preferences were used throughout the interviews. Each preservice teacher’s set of ideals about science teaching and learning in his or her ideal classroom are further categorized into four subcategories of a conceptions of science teaching and learning (CSTL) profile: Traditional, Piaget’s individual constructivist’s views, von Glasersfeld’s radical constructivist’s views of science teaching and learning, and Social Constructivist’s such as interactionalist and socioculturalist views of science teaching and learning. Readers may want to refer to the pedagogical implications of each different version of educational constructivism in Chapter 2 to see how each statement is placed and coded under each category. Whole sections of the second part of Chapter 2 were allotted to extract and summarize ‘teaching science from the individual, radical or social constructivists’ perspective that is informed by their views of knowledge and learning. These summaries and position-statements were taken from relevant literatures written by well-known theorists such as Piaget, von Glasersfeld, Cobb, Bausersfeld, Vygotsky, Driver, Solomon, Gergen, etc. (refer to Chapter 2 for specific information about the exemplary coding statements used in the data analysis). Driven by their ontological and epistemological perspective, individual, radical, or social constructivists have different sets of ideals in terms of their views of science teaching and learning—views that guide their instruction. Each set of ideals include statements related to how they think people learn, what is involved in learning and teaching science, what the central focus of planning instruction is, what an individual (radical or social) constructivist teacher would be like, and, sometimes, what instructional approaches they adopt, which has to do with their view of how people, specifically
students, learn. A detailed definition of each subcategory along with three to four exemplary quotes taken from the interview transcripts is provided in Appendix C.

**Explainers**

This category includes any statements in which preservice teachers were commenting on any opportunities to change their perspectives. These opportunities were sought in terms of 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 is learned from coursework of their preservice program, field experiences, observations of other teachers such as the program faculty and their mentor teachers, discourses with their peers), other background knowledge, and conflict that includes each teacher's expression of complaints based on previous schooling experience or perceived educational context. Additional categories of coding were made for constructivism, constructivism/viability, and member check. For a list of coding categories within a sample-coded transcript, please refer to Appendix D.

**General Comments on the Development of Analytical Scheme**

This analysis scheme, in the form of a system of analytical categories—which also affected the design of guided interview protocols—was modified after the analysis of the first interview transcripts. That is, throughout further coding of the interview transcripts, new categories emerged and were added to the list of nodes. For example, since the second interview where preservice teachers were introduced to constructivist epistemology, or so called constructivism, in the M.Ed. coursework, the analysis scheme incorporated new categories related to constructivism, such as 'constructivism' and 'viability of constructivism'. In addition, the Explainers node also expanded to include
the influence of the M.Ed. program. In the last interview analysis, a Member Check node was added to capture preservice teachers’ responses to their constructivist profiles.

To identify characteristics of three main components of a preservice teacher’s conceptual ecology—ontological beliefs, epistemological beliefs, and conceptions of science teaching and learning, the analysis proceeded through the following steps:

**Step One**

As I read the first interview transcripts I coded segments of the interview transcripts in terms of the first four analysis categories. Each statement, which illustrates components of a preservice teacher’s conceptual ecology, was then placed within its appropriate category. If an interview segment applied to more than one category it was placed in both. It is important to note that assignment of a transcript segment to each category required further interpretation and high inference on my part.

**Step Two**

Each teacher’s constructivist profile was constructed using the coding table function from in the NUD*IST program that presents the number of text-units coded at any set of sibling nodes in each document as a table. Each teacher’s constructivist profile consists of three sub-profiles: an ontological beliefs profile, an epistemological beliefs profile, and a 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. For example, for an ontological profile, each subcategory of ontological preferences (i.e., realist, radical, and
idealistic) constituted a different component of the profile, and the percentage of text units for each component was used to present the height of each category in a profile, which "corresponds to the extension in which this 'way of seeing' is present in the individual's thought" (Mortimer, 1997, p. 271). To describe changes in each teacher's ontological beliefs throughout the theoretical coursework in the M.Ed. program, one ontological profile was constructed over time.

Step Three

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. Both an ontological profile and an epistemological profile were examined to locate any change or lack of change in the content of each preservice teacher's ontological and epistemological beliefs over time. For the 16 interviewees, 5 teachers changed their ontological and epistemological beliefs over time. These five teachers were subjected to further in-depth analysis for Research Question 2. Among eleven other teachers, who remained unchanged over time, there was one outlier who had consistently maintained an Idealist and Relativist epistemological position from the beginning of the study and was subjected to another case analysis. Ten other teachers who consistently maintained the scientific realist beliefs were presented as a composite case.

An exemplary Application of the Analysis Scheme to a Sample Interview Transcript

In Chapter 4, the analysis categories that emerged and illustrated in this chapter were used in interpreting a sample case of Rob1 that appears on a superficial level to be

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1 All names are pseudonyms.
rich in his belief system changes. The remaining analyses and interpretation of the complete data source of the other 15 teachers are described as five cases and one composite case in Chapter 5.

The ultimate task of this investigation could be regarded as identifying and tracing the development of each preservice teacher’s belief changes towards constructivist epistemology using the constructivist profile notion. The identification of the existence of constructivist profiles in their belief changes and the description of components of profiles drawn from the data sources will provide valuable research tools in answering further questions of further research in teachers’ belief changes.
CHAPTER 4
APPLICATION OF THE ANALYSIS SCHEME TO ROB'S CASE

Introduction

In this chapter, the analysis of the interview data is illustrated with results of a sample analysis. The chapter contains two main sections. In the first section, the analysis scheme for guiding the analysis of interview transcripts, developed in Chapter 3, applied as a first trial to a sample case. The transcript sample to which the analytical scheme is applied is Rob's case, which features significant belief changes during the interviews in addition to rich descriptions of his ontological and epistemological positions. A complete transcript of Rob's fourth interview, showing the coding categories in the format produced by the NUD*IST program can be found in Appendix D. In this sample transcript, the categories are identified by the coding labels employed in analyzing the transcripts with the NUD*IST computer program. Examples of interview transcripts are provided to capture the context and support reasons why a segment was classified into one of the categories of the scheme. These examples drawn from the data sources would also suggest prototypical examples of each of the analysis categories. Using the percentage of text units for each ontological, epistemological, and pedagogical subcategory throughout the interviews, each corresponding profile was constructed at 121
the end of each ontological, epistemological, and conceptions of science teaching and learning (CSTL) summary section. Accordingly, each participant has three—ontological beliefs, epistemological beliefs, and CSTL—profiles, which in turn constitute a constructivist profile, i.e., a profile of each preservice teacher’s perspective on constructivism. In the second section, the ideas and a descriptive summary which emerged from the initial analysis are provided as a basis for the remaining analyses in Chapter 5.

Rob’s Case

Each participant’s case story is divided into five subsections. Each case study begins with a brief sketch of each teacher’s past experiences and personal history prior to the college courses in teacher education. Subsequent sections elaborate Rob’s ontological beliefs profile, epistemological beliefs profile, and his CSTL profile. In general, the analysis categories or components of each profile are illustrated with appropriate examples from the transcripts. In the final section, “Explainers” for each participant’s beliefs changes—or lack of changes—and constructivist profile changes are discussed.

Past Experiences

Rob is a Mexican American male in his middle thirties, requesting a certification in high school biology. Through his previous career experiences as a Spanish/English interpreter at children’s hospital, a regional Field Recruiter for a Department of Migrant Education, and a part-time biology instructor for undergraduate college students, he has felt a great need for “clear understanding and communication of information,” and believed in students’ “resilience and enthusiasm, as well as their level of understanding—characteristics which can be found in most younger people if one is willing to take the
time” (Rob, personal communication: Statement of Intent in his M.Ed. application, June, 1999). He came to the M.Ed. program to share his “enthusiasm for the natural world with seventh through twelfth grade students.” He has always been fascinated with biological sciences that “offer a unique opportunity to engage the interest of students of all ages... and the applications and relevance to one’s everyday life are readily apparent.” He wanted to be a teacher who can “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 Beliefs

What follows is my analysis of Rob’s ontological profile changes throughout the M.Ed. program, with particular examples of representations of his ontological beliefs according to my interpretations from interview transcripts (see Appendix C for the definition of each category). All quotes are taken directly from interview transcripts.

Rob’s Initial Ontological Commitment to a Realist Position

Exemplary quotes that show Rob’s commitment to Realist ontological position are represented in Table 4.1, which were extracted from a transcript of Rob’s interviews. As noted earlier, these are Rob’s responses to the forced-choice interview questions. The focus of this segment was on different ontological preferences presented during the interviews in which Rob was asked to discuss or comment on the given options A, B, C, or D describing different ontological standpoints one by one and then finally choose one as his own position (see Appendix B for the interview protocol).
Q: Of the statements, which would most align with the way you think about reality (outside world)? Does this view fully describe your position? If not, you may describe your own position by (1) combining the positions, (2) making any necessary modifications, or (3) creating your own version.

Rob: Okay, I definitely wouldn’t agree with, I think I don’t agree with B [idealistic position]. I think it [nature] does exist independently, I think it can exist independently.... I think, I generally I would agree more with this [realist] position. (Rob 1, 120-123)

I would tend to go more with A... I think there are other ways of perceiving things that are necessarily rationalized. There are different senses that you can process, which doesn’t necessarily always be filtered through the mind. It’s kind of combination of the two, but I would lean more with A. (Rob 2, 133-139)

I think knowledge is there [in nature]; it’s not necessarily invented. There are possible concepts that we can grasp or understand regardless of whether we do appreciate them or not, those concepts are there for our grasping. (Rob 2, 199-203)

I think nature itself can be consulted or observed to come up with conclusions. So there is no book, but nature itself is something that we can consult. (Rob 2, 210-213)

Table 4.1: Exemplary Quotes: Rob’s Realist Ontological Position

Annotated comments. 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 in the realist ontology subcategory (see Figure 4.1). Rob’s comments provided evidence that he aligned his ontological position with that of a realist until the end of the second interview. As can be seen from above quotes, Rob concurred with the provided realist preference word-by-word and claimed that “[nature] does exist independently.... regardless of whether we do appreciate it or not. Those concepts are there for the grasping” (Rob 1 & 2). According to Rob, “there is a real world of material and other objects which exists apart from his or anyone else’s theorizing about it” (Matthews, 1994, p. 125). Rob maintained this realist ontological position as the largest component through the end of summer quarter. His realist ontological beliefs seemed to be firmly grounded in his science background experiences as can be seen in Table 4.2.
In addition to the forced-choice questions, to reveal an interviewee’s implicit ontological beliefs about “the existential status of scientific and everyday objects” (Matthews, 1994, p. 141), each interviewee was asked to elaborate his or her own views on the differences between the real objects of science and the theoretical objects of science. The discussion focused on how to account for the existence of scientific objects or real objects. Rob’s responses to these questions are represented in Table 4.2.

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

Rob: I guess using the examples of tectonic plates and planet’s movement... right in here of structures [pointing at the desk], I mean, molecules are moving whether we see them or not in the desk. (Rob 1, 139-144)

I would say that genes, tectonic plates exist.... for genes I have seen like, I have done experiments in labs where you actually do separation of chromosome.... so those I would say exist because I think I have seen them. Tectonic plates I have not seen but I am actually taking a geology course now in which a very good teacher, he explains things very clearly. And I did not believe tectonic plates before, but now it seems even more clear to me how they are related to the world around us. And then electrons are, again the thing that I have not seen but I believe there is such a thing as an electron that represents ex-charge on an object and the effect that has.... So I would say they do exist. (Rob 3, 117-130)

Table 4.2: Exemplary Quotes: Rob’s Realist Ontological Position on Scientific Objects

Annotated comments. These examples indicate that the existence of theoretical objects and reality is determined based on his experience with scientific background knowledge. That is, if a concept was within his knowledge and understanding, it did have a concrete existence. If a concept was outside of his knowledge reservoir, it was just a conceptual thing, which was “made up to explain why this is happening.” Accordingly, in Rob’s case, the plausibility—in a sense that Rob “believes the conception to be potentially true, to be consistent with his or her worldview” (Hewson & Hewson, 1984)—of a
theoretical element determines its physical reality. For example, he knew that "genes, molecules, and tectonic plates exist" since he experienced or saw them directly or indirectly. To him, black holes "are more of those things that people … conceptualized to explain other phenomena" (Rob 3). In the meantime, as he did with the tectonic plates, if "a very good teacher explains very clearly," there is a high possibility for Rob to "believe in" theoretical objects or to understand "how they are related to the world around us" (Rob 3). Rob's comments quoted here are representative of his statements placed in the realist category.

Figure 4.1: Rob’s ontological beliefs profile

As can be seen in Figure 4.1, in the first and the second interview, a realist ontological position represented the largest component in Rob’s ontological belief profile with 100% of the total text units coded within Realist category in the first interview and 65% in the second interview. That is, of all the text units coded under the Ontological
belief category—so called a parent category—all were located within the realist ontology subcategory—so called a children category—in the first interview. The percentage of text units for each subcategory was later used to present the height of each component in Rob’s ontological belief profile. Until the end of the second interview, Rob hardly made any statement showing his commitment to the Radical or Idealist ontological beliefs. However, from the second interview, Rob showed a profile that included different ontological views of varying degrees. Regardless of theoretically incompatible tenets of the three different ontological positions—Realist, Radical, and Idealist, his comments distributed across different positions depending on the context and phrasing of interview questions.

Rob’s Ontological Commitment to a Radical Position

Exemplary quotes that show Rob’s commitment to Radical ontological position are represented in Table 4.3. These responses are taken from transcripts of Rob’s interviews where he was asked to reflect on his ontological beliefs by commenting on ontologically distinct options A, B, C, or D presented during the interview.
Q: Of the statements, which would most align with the way you think about reality (outside world)? Does this view fully describe your position? If not, you may describe your own position by (1) combining the positions, (2) making any necessary modifications, or (3) creating your own version.

Rob: We’re only... it [the external world] does constrain in a sense that I can only understand things as far as I can perceive them, or speculate about them. If I don’t see something and it doesn’t occur to me, then it’s not going to occur to me to come up and to ask a question. (Rob 2, 185-188)

I would say, you have your world of images and you never really have access to the reality and everything is a construct... because everything is, whatever interpretation we give to it, we do agree on things, but we all have different filters, and that’s going to affect the way that we assimilate information. (Rob 3, 177-183)

How do we know that there is a reality or, you know, the reality is a subjective thing. My reality is different from your reality. I don’t think there is one objective reality. (Rob 4, 144-147)

I think there is a reality. There is a physical reality that we all perceive in different ways. We all see stars and we all see the sun and we all see the moon but the way we interpret our daily laws and everything that we all perceive in different ways. We don’t really think in-depth about those things. (Rob 4, 172-175)

Table 4.3: Exemplary Quotes: Rob’s Radical Ontological Position

Annotated comments. With the same forced-choice prompting question as with previous interviews, Rob provided different interpretation regarding the external world of nature. From the second interview, when Rob talked about humans’ perception of the world that is independent of humans (i.e., realist’s portion of his ontological beliefs), he also made statements which corresponded to von Glasersfeld’s ontological assumption: 35% of the total text units in the second interview, 12% in the third interview, and 22% in the fourth interview. Some typical statements placed in the Radical category for Rob included: “[since] we all have different filters and that’s going to affect the way that we assimilate information.... you have your world of images and you never really have access to the reality... everything is a construct” (Rob 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 3). While Rob accepted the idea that there is a reality that includes “stars, the sun and the moon,” he contended, “there is
no way to directly access reality because of each individual's different "filters" (Rob 3),
which was well aligned with a Radical ontological position.

Rob's Ontological Commitment to an Idealist Position

Exemplary quotes showing Rob's commitment to Idealist ontological position are
represented in Table 4.4. These responses are taken from the transcripts of Rob's
interviews where he was asked to choose one of the given ontologically distinct options
A, B, C, or D presented during each interview.

Q: Of the statements, which would most align with the way you think about reality (outside world)?

Rob: And then C, I think, is very important as far as [groups of individuals carve the world up through a
process of social interaction] because if you look at cultural groups, like native Americans and their
conception of time is completely different from, say, European conception of time, or even
Mexican.... So all of these are interactions between individuals. (Rob 3, 184-193)
So the social group that you grew up in and developed in are going to affect how you assimilate
information. (Rob 3, 205-206)
We are co-participants in a socially shared activity and I also think that we are determined more or
less by our social interactions, by environments that we grow up in... the negotiation, all of this
forms our world; our language sculptures our world, our relatives, our family, friends, and all those
things have an influence on who we are and how we come to see the world. (Rob 4, 148-154)
You can negotiate your reality with somebody else's reality and hopefully reach a compromise or at
least an understanding of someone else's reality and why their reality is X and your reality is Y.
You don't necessarily, I think, have to say that mine is better than yours or yours is better than
mine. We just have different realities and as long as we are trying to understand those of other
people, I think, things are okay. (Rob 4, 164-171)
Reality that each individual constructs, evolution could be one, for example, religious beliefs that
are not accepting of evolution or a creationist theory. Those are different realities. My reality is, I
see things and I think well those things came from other things. And if you speak with someone
who is a creationist, that's not the case. Their reality is that everything is here the way it was created
and there has been no change, right?
That would be their perception and their use. That's cultural differences as well. People see things
with different uses, or different focuses and, I think, that's the way it should be. (Rob 4, 180-189)

Table 4.4: Exemplary Quotes: Rob's Idealist Ontological Position

Annotated comments. These examples provide evidence of Rob's ability to
articulate his idealist ontological beliefs, according to which different social groups
construe the world in different ways" (Phillips, 1997b, p. 188). In the third interview,
asked to choose one among the ontologically distinct options that most align with the way
he thinks about reality, Rob chose an option representing an Idealist position with 53% of
the text units coded within this category. He strongly emphasized, “the language, cultural
beliefs, and social group that you grew up in and developed in are going to affect” how
one perceives the world and “the way that we assimilate information.” Rob’s idealist
position was maintained and further elaborated in the fourth interview as he articulated
how “cultural differences” as well as “our social interactions, and environments that we
grow up in” determine “how we come to see the world” (Rob 4). Rob’s comments quoted
here are representative of his statements placed in each category.

**Summary of Rob's Ontology Profile Changes**

As was discussed earlier, Rob maintained and demonstrated preference for a realist
ontological position as the largest component through the second interview. In the second
interview, Rob demonstrated radical ontological beliefs as he acknowledged that our
perceptions and experiences constitute our reality (Matthews, 1994). However, in the
third interview, I can find apparently contradictory ontological beliefs (i.e., Realist and
Idealist) co-existing to different extents (Mortimer, 1997) in Rob’s ontological profile:
34% Realist, 12% Radical, and 53% Idealist.

Finally, in the fourth interview, none of his statements were located in the realist
position he initially supported. For the fourth interview, Rob’s ontological belief profile
was 22% Radical and 78% Idealist. As he read through an exemplary realist option
presented during the interview, he questioned back, “how do we know that there is a
reality.” Furthermore, he positioned himself in the radical position: “the reality is a
subjective thing. My reality is different from your reality. I don't think there is one
objective reality.” Most of his comments and arguments against given ontological options were aligned with the idealist position.

It is not a new idea that “people can have different ways of seeing and representing their world,” (Mortimer 1997, p. 269) which is also exemplified in Rob’s conceptualization of his reality. Up to the third interview, when I asked him to describe his perception of reality with common, non-philosophical language, Rob displayed a realist ontological standpoint. For example, when we talk about the existence of electrons, tectonic plates, and black holes, whereby I attempted to determine his ontological stand by looking for the use of the categories that characterize each distinct category in his explanation of some phenomena, his ontological beliefs seemed to be grounded in a realist position. However, when he was asked to align his ontological beliefs with one of the given options—that is, exemplary statements of Realist, Radical, and Idealist identified in the theoretical analysis of the literature, which use more sophisticated language—he revealed the coexistence of the different ontological assumptions and beliefs. Rob’s perception of reality moved from one category to another depending on contexts and contents of his reality. On the other hand, as time went on, his profile diversified into more distinct components: beginning with solely the Realist component and then showing Radical as well as Idealist component by the time of third interview.

As Mortimer (1997) contends, reasons for the changes in Rob’s ontological profile can be found in “the different experiences” he had and in his “distinct background” (p. 273), which will be discussed after reviewing his epistemological profile in the following
section. Whether he achieved a consciousness of his own profile and was able to decide where each zone is applicable in an appropriate context will also be discussed.

Rob’s Epistemological Beliefs

What follows are Rob’s epistemological profile changes during the interviews, with particular examples of representations of his epistemological beliefs according to my interpretations from interview transcripts. Text units were coded within subcategories of absolutist, Piagetian, Fallibilism, and relativist for epistemology. My focus when analyzing the interviews was to determine the foundations for Rob’s views on scientific knowledge and truth. Rob was asked to discuss his ideas and to comment on forced-choice options describing different epistemological standpoints.

Rob’s Epistemological Commitment to an Absolutist Position

Exemplary statements coded under the Absolutist epistemological category in Rob’s interview transcripts are represented in Table 4.5. The focus of each segment was on the foundations of scientific knowledge and truth in which Rob was asked to discuss or comment on given options describing different epistemological standpoints one by one and then finally choose one as his own position. In addition to the forced-choice question, a variety of open-ended questions were also used to elicit each interviewee’s views about the origins, validation procedures of scientific knowledge, what science is, how scientific knowledge has been produced, whether scientific theories change, and what scientists are trying to do (refer to the interview protocol in Appendix B for specific probing questions).
Q: Of the statements, which would most align with the way you think about scientific knowledge? Does this view fully describe your position? If not, you may describe your own position by (1) combining the positions, (2) making any necessary modifications, or (3) creating your own version.

Rob: I think knowledge is there; it’s not necessarily invented. It’s just, there are possible concepts that we can grasp or understand regardless of whether we do appreciate them or not, those concepts are there for the grasping. (Rob 2, 199-203)

Table 4.5: Exemplary Quotes: Rob’s Absolutist Epistemological Position

Annotated comments. One significant feature in Rob’s epistemological profile is that the Absolutist sector showed up for the first time in the second interview (see Figure 4.2). Asked to comment about whether knowledge is invented or discovered, Rob advocated an Absolutist assertion: “I think knowledge is there, it’s not necessarily invented… there are possible concepts that we can grasp or understand regardless of whether we do appreciate them or not, those concepts are there for the grasping.” This absolutist epistemological belief seemed to reflect Rob’s realist ontological beliefs revealed in the second interview where he insisted, “[nature] does exist independently… regardless of whether we do appreciate it or not” (Rob 2).

Figure 4.2: Rob’s epistemological beliefs profile
However, as can be seen in Figure 4.2, in the third and the fourth interview, this absolutist position disappeared as he put more emphases on "our subjectivity" in perception or interpretation of "objectivity of a physical reality," "representation of the external world by our senses," and a scientific truth validated only "within a community and within a specific culture." Moreover, by the time of the fourth interview, Rob said that "sometimes people have come up with ideas that go beyond what has currently been observed [as] results of inferences and speculations, [which] nobody can prove that this is so physically." This quote indicates that he moved away from 'truthfulness depending on the correspondence between absolute existence of nature and scientific knowledge' to 'truthfulness and fruitfulness of scientific knowledge depending on human beings' capability of "going beyond what we can see," which is valid and truthful only within a culture, society and community that one belongs to.

Rob's Epistemological Commitment to a Piagetian position

Exemplary statements coded under the Piagetian epistemological category in Rob's interview transcripts are represented in Table 4.6. The focus of each segment was on the foundations of scientific knowledge and truth in which Rob was asked to discuss or comment on epistemologically distinct options presented during the interviews.
Q: Of the statements, which would most align with the way you think about scientific knowledge? Does this view fully describe your position? If not, you may describe your own position by (1) combining the positions, (2) making any necessary modifications, or (3) creating your own version.

Rob: The ultimate goal of doing science... I don't think there are any absolute in that sense... there's a puzzle, by definition, you have, or many puzzles maybe and you're trying to collect pieces that make of these different puzzles. I guess you could call that maybe theories would be a completed puzzle. But maybe there are other pieces that could fit in the same place, one that you've already had so that's why it wouldn't be absolute truth. (Rob 1, 207-218)

It [the external world] does constrain in a sense that I can only understand things as far as I can perceive them, or speculate about them. If I don't see something and it doesn't occur to me, then it's not going to occur to me to come up and to ask a question. (Rob 2, 177-189)

Scientific truth appears necessary and inviolable because they are being presented as truth, which there is no absolute truth. (Rob 3, 79-80)

You know black holes are more of those things that people ... conceptualized to explain other phenomena.... So it would be something that people didn't say [hum, there are black holes so I must discover them], I don't think that's the way it worked. I think people saw things that were happening like movements of stars and paths outside of their orbits, and said, there must be reason to explain why this is happening. And the best reason is a black hole or the best way to explain is through a black hole. (Rob 3, 98-113)

Well, the thing is if you are going towards an ultimate truth, then that means that there is no possibility of revision at some point. You will reach a point where there is no revision, correct? I don't believe that's the case. I don't think we will ever reach a point of ultimate truth. Maybe that's a goal that you might strive towards, but I don't think it is an attainable goal... because that means things are always perfectly logical and rational and explainable, and I don't see the universe is working in that way. (Rob 3, 263-272)

It's meaningless to speak about the absolute reality of scientific objects.... I don't think there is ultimate scientific truth. I think there is a point where you integrate more and more things and you expand your base of knowledge but I don't know that there is an ultimate scientific truth... (Rob 4, 210-219)

I don't think that we merely copy in a relatively passive fashion because I think that sometimes people have come up with ideas that go beyond what has currently been observed. I mean all the time if you think about atoms and things like that, a lot of these things are not seen. They are the results of inferences and speculations and it's the best explanation that we have of something but nobody can prove that this is so physically.... I do think that the nature does play a role and shaping what we know about it because we base ourselves on phenomena that we observe to create laws and explanations. (Rob 4, 227-240)

We see things and then we try to devise tests to see whether our interpretations or explanations hold true for certain things that we observe.... All of these [scientific theories] are inferences. We don't know if those things are true or not. We are trying to come up with, say, a dictionary of explanations for things and we have to change things in that dictionary. We have to cross things out or we have to add parentheses and put something more in there or maybe we have to put a little drawing of something new that has come about. So it's kind of like a book that we are constantly editing. We are changing things in the book all the time based on things that are happening. Some things have made more constant over longer period of time. Other things are more susceptible to change. There is no absolute, ultimate scientific truth; no I don't think so. There is no final answer. (Rob 4, 252-278)

Table 4.6: Exemplary Quotes: Rob's Piagetian Epistemological Position

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Annotated comments. Rob's comments provided evidence that he aligned his epistemological position with that of a Piagetian position throughout the interviews. The Piagetian category in Rob's epistemological profile was maintained as the largest component throughout the interviews: 79% in the first interview, 76% in the second interview, 51% in the third interview, and 70% in the fourth interview. As is the case for other interviewees, Rob's epistemology was to some extent related to his ontology (Prawat, 1997). During the first and the second interviews, the Piagetian position was represented as the largest, which was compatible with the Realist ontological beliefs represented in Rob's ontological profile during the first two interviews. Some typical statements placed in the Piagetian category for Rob included: although "nature itself can be consulted or observed to come up with conclusions" (Rob 2), nature does not uniquely determine what we can believe about it. In other words, "nature does constrain in a sense that I can only understand things as far as I can perceive them, or speculate about them. If I don't see something and it doesn't occur to me, then it's not going to occur to me to come up and ask a question or something" (Rob 2). According to Rob, scientists "are trying to collect pieces that make of these different puzzles" (Rob 2) or "try to come up with an explanation to try to fit all those observations in [and] whichever one best accommodates those things would be what scientific knowledge you invented" (Rob 3). The point of Rob's Piagetian epistemological stand is that "there is no absolute truth" (Rob 3) in that "there are other pieces that could fit in the same place [of a puzzle], one that you've already had, so that's why it wouldn't be absolute truth" (Rob 1). Rob seemed to deny not only that "there is any way to secure complete and absolute truth", but also "the notion of approximate truth" (Matthews, 1994, p. 38). Rob consistently
emphasized that "people conceptualized [black holes and other scientific objects] to explain things that you observe" and that "you should keep the open mind to other explanations as well because there is no absolute [truth] right there" (Rob 3):

Well, the thing is if you are going towards an ultimate truth, then that means that there is no possibility of revision at some point. You will reach a point where there is no revision, correct? I don't believe that's the case. I don't think we will ever reach a point of ultimate truth. Maybe that's a goal that you might strive towards, but I don't think it is an attainable goal. I don't think, because that means things are always perfectly logical and rational and explainable, and I don't see the universe is working in that way. (Rob 3)

I just think 'absolute' is a very narrow word, which I don't think has much to do with science.... I don't think there is ultimate scientific truth. I think there is a point where you integrate more and more things and you expand your base of knowledge but I don't know that there is an ultimate scientific... what would an ultimate scientific truth be, would that be to be a god or something, but I don't think there is an ultimate scientific truth. (Rob 4)

In the fourth interview, Rob’s Piagetian epistemological position got elaborated as he contended, on the one hand, “the nature does play a role in shaping what we know about it because we base ourselves on phenomena that we observe to create laws and explanations.” On the other hand, “I don't think it acts as a constraint, though, necessarily because people speculate and infer beyond what we can see, and have come up with ideas that go beyond what has currently been observed” (Rob 4). In sum, according to Rob’s Piagetian epistemological beliefs, “all of scientific theories are our inferences” that we “conceptualized our interpretations or explanations so as to hold true for certain things that we observe” (Rob 4). His Piagetian epistemological beliefs can be summarized as follows:

I don't know if you can get to a true picture of reality. We don't know if those things are true or not. We are trying to come up with, say, a dictionary of explanations for things and we have to change things in that dictionary.... So it's kind of like a book that we are constantly editing. We are changing things in the book all the time based on things that are happening. Some things have made more constant over a longer
period of time. Other things are more susceptible to change. There is no absolute, ultimate scientific truth; no I don't think so. There is no final answer. (Rob 4)

Rob's Epistemological Commitment to a Fallibilist Position

Exemplary statements coded under the Fallibilist epistemological category in Rob's interview transcripts are represented in Table 4.7. The focus of each segment was on the foundations of scientific knowledge and truth in which Rob was asked to discuss or comment on given options describing different epistemological standpoints one by one and then finally choose one as his own position.

Q: Of the statements, which would most align with the way you think about scientific knowledge? Does this view fully describe your position? If not, you may describe your own position by (1) combining the positions, (2) making any necessary modifications, or (3) creating your own version.

Rob: I think more than anything else we're kind of constrained in our perceptions.... we have certain constraints or limits in our perception. (Rob 1, 171-173)
I think scientific theories change because a theory might cover a certain topic up to a point. (Rob 3, 27-28)
In a sense we are limited by our senses. Our senses are represented to us the external world. (Rob 3, 233-234)
I agree that scientific truth is fallible and controvertible. (Rob 3, 219-220)
Well, the thing is if you are going towards an ultimate truth, then that means that there is no possibility of revision at some point. You will reach a point where there is no revision, correct? I don't believe that's the case. I don't think we will ever reach a point of ultimate truth. Maybe that's a goal that you might strive towards, but I don't think it is an attainable goal. (Rob 3, 263-272)
We are subjective beings and we tend to interpret things subjectively. Our personality plays a lot even if you are scientist and you will always, there always be passions and things involved so objectivity is tough one to achieve. (Rob 4, 139-142)
I think science should always be open to revision. (Rob 4, 220-221)
You would want them to understand why a certain interpretation is the most accepted, why is it the one that have the most evidence in favor, is that the one they have not been able to disprove.... but you definitely don't want to say what is sense and what is nonsense because you never know if things 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. Things should be subject to further questioning and possible modification. (Rob 4, 374-382.)

Table 4.7: Exemplary Quotes: Rob's Fallibilist Epistemological Position

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Annotated comments. Rob’s comments provided evidence that he was aware of “the vulnerability of scientific theories to new evidence or interpretation” (Harding & Hare, 2000, p. 231). Rob consistently maintained this Fallibilist epistemological belief to different extents once it showed up in the first interview: 21% in the first interview, 9% in the second interview, 30% in the third interview, and 23% in the fourth interview. Aligned with his realist ontological beliefs, Rob contended, “more than anything else we’re kind of constrained in our perceptions” (Rob 1) that represent “to us the external world” (Rob 3). According to Rob, “the world is always interpreted through mind” (Rob 2) and we as “subjective beings tend to interpret things subjectively… so objectivity is tough one” to achieve in science (Rob 4). Accordingly, Rob acknowledged, “scientific truth is fallible and controvertible” (Rob 3) and “science should always be open to revision” (Rob 4). Rob’s commitment to fallibilist epistemological beliefs entailed on the one hand, “open-mindedness,” but on the other hand, refusal of “a thesis of increasing verisimilitude” (Ernest, 1998, p. 58). Furthermore, Rob went on to say that, although we “might strive towards” an ultimate truth, “I don’t think it is an attainable goal because that means you will reach a point where there is no revision… and things are always perfectly logical and rational and explainable, and I don’t see the universe is working in that way” (Rob 3). This fallibilist perspective led Rob to emphasize leaving “students with an open minded to accept that things should be subject to further questioning and possible modification” in his teaching (Rob 4). When talking about what he wanted to do in his future classroom, Rob insisted, “you definitely don’t want to say what is sense and what is nonsense [about the students’ ideas or solutions] because you never know if
things will change, what we are discussing now, you want to always leave them with an open mind to accept that there is nothing that is absolute or set in stone” (Rob 4).

Rob’s Epistemological Commitment to a Relativist Position

Rob’s epistemological commitment to a Relativist epistemological position was represented using Rob’s own words in Table 4.8. These exemplary quotes are extracts from transcripts of Rob’s interviews. The focus of each segment was on the foundations of scientific knowledge and truth in which Rob was asked to discuss or comment on given options describing different epistemological standpoints, one by one, and then finally choose one as his own position.

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Table 4.8: Exemplary Quotes: Rob’s Relativist Epistemological Position

Annotated comments. These quotes illustrate Rob’s relativist epistemological standpoint concerning the nature and status of scientific knowledge--that is, issues of
justifying and evaluating scientific knowledge. From the third interview, where Rob revealed an idealist as well as a radical ontological belief for the first time, Rob expressed a relativist epistemological perspective when he talked about how to judge the truth or validity of theories. Rob showed his awareness of a Relativist position with 18% of the total text units coded within this category in the third interview and 7% in the fourth interview. Some typical statements placed in the Relativist category for Rob included: “the reality that each individual constructs” as well as “the acceptance of every knowledge claim depends on the culture and society” to which each individual belongs (Rob 4). For example, according to Rob, a reality constructed by “someone who is a creationist with religious beliefs that are not accepting of evolution” would be different from Rob’s own reality that is constructed based on the theory of evolution (Rob 4). Rob went on to say, “those are different realities” and “that’s cultural differences as well [based on which] people see things with different uses or different focuses” (Rob 4). Once surfaced and articulated, this relativist epistemology showed up again in the fourth interview, as Rob acknowledged “the acceptance of every knowledge claim” within a particular community, such as a Western community or an Amazon native community (Rob 4).

Rob’s awareness of culturally laden or culture specific criteria of justifying and evaluating scientific knowledge thus fit with his ontological beliefs where he commented that his reality “has meaning in his culture” just as “the witch doctor in the Amazon is accepted within his community even though it might not be accepted within the larger scientific community” (Rob 3). Furthermore, Rob emphasized, “the scientific community
decides the acceptance of every knowledge claim; [however], the non-scientific community doesn't necessarily always agree with the scientific community” (Rob 4).

In sum, according to Rob, depending on different cultures and societies where people have grown up, people “construct different realities,” have different “perceptions” of an external world, as well as “see things with different uses or different focuses,” which “is accepted within his community” (Rob 4). For example, Rob went on to say, “I prefer to think of this [as pointing at a desk in front of him] as a desk for me in my culture [and] most people who come from a Western culture who have seen a desk before will say it is a desk; [however], if you show it to somebody who has never seen a desk, then maybe they will give a completely different interpretation” (Rob 4).

Summary of Rob’s Epistemology Profile Changes

Throughout the interviews, Rob consistently maintained the Piagetian as well as the fallibilist perspectives as the backbone of his epistemological beliefs. Features of Rob’s Piagetian position include: (1) “the nature does play a role in shaping what we know about it because we base ourselves on phenomena that we observe [in nature] to create laws and explanations”; (2) However, nature does not “act as a constraint because people speculate and infer beyond what we can see” in nature; and (3) “I don’t think there is ultimate scientific truth [although] there is a point where you integrate more and more things and you expand your base of knowledge but I don’t know that there is an ultimate scientific truth” (Rob 4). Rob rejected the possibility of obtaining “an ultimate scientific truth” although human beings are striving for it in our attempt to “come up with a dictionary of explanations for things that are happening” (Rob 4). According to Rob, because “these [scientific theories and explanations] are all our inferences, we don’t
really know what happens and we don’t know if we can get to a true picture of reality and there is no final answer” (Rob 4).

In the meantime, as is the case for other interviewees, Rob’s epistemology was to some extent related to his ontology (Prawat, 1997). For example, Rob, on the one hand, had Absolutist epistemological component (15%) in accordance with his Realist ontological beliefs in the second interview. Accordingly, Rob contended that as “[nature] does exist independently” (Rob 1), “knowledge and those concepts are there regardless of whether we do appreciate them or not” (Rob 2). On the other hand, in accordance with his articulation of an Idealist ontological perspective, however, Rob revealed a Relativist epistemology from the third interview. Accordingly, in the third interview, I can find apparently contradictory epistemological positions—Piagetian and Relativist—coexisting (Mortimer, 1997) in Rob’s epistemological profile to different extents: 51% Piagetian, 30% Fallibilist, and 18% Relativist. From his Relativist epistemology, Rob acknowledged that different sociocultural communities—such as a Western community or an Amazon native community—construct different realities and the acceptance of every knowledge claim “depends on the culture and society” within a particular community (Rob 4). In the fourth interview, Rob still maintained this Relativist epistemological position to a lesser extent than in the third interview. Accordingly, Rob’s epistemological profile in the fourth interview featured, again, coexistence of three different epistemological positions: 70% Piagetian, 23% Fallibilist, and 7% Relativist.

In conclusion, Rob consistently maintained a Piagetian along with a Fallibilist position as the strong backdrop of his epistemological beliefs. In the meantime, Rob also showed his awareness of a Relativist epistemology. One important issue with Rob’s
ontological and epistemological profiles is that of how he could transfer his ontological and epistemological beliefs to his views of science teaching and learning. That is, further consequences of his position shift in ontological and epistemological beliefs as a science teacher will be discussed in the explainer section after reviewing his CSTL profile change in the following section.

Rob's Conceptions of Science Teaching and Learning (CSTL)

What follows are Rob's CSTL profile changes throughout the interviews, with particular examples of representations of his pedagogical beliefs according to my interpretations from interview transcripts. As noted earlier, any statement regarding CSTL was searched and coded under one of the four subcategories of CSTL: Traditional, Piaget's Individual, von Glaserfeld's Radical, and Vygotsky's Social.

Rob's Pedagogical Commitment to a Traditional Position

Rob's exemplary statements revealing his commitment to a Traditional pedagogical position are represented in Table 4.9. These exemplary quotes are extracts from transcripts of Rob's interviews. The focus of each segment was on inferred pedagogical activities and learning theories that follow from differing epistemological as well as ontological standpoints. Rob was asked to discuss or comment on given options describing different pedagogical standpoints and implications for educational practices one by one and then finally choose one as his own position.
Q: Of the statements, which would most align with the way you think about pedagogy? Does this view fully describe your position? If not, you may describe your own position by (1) combining the positions, (2) making any necessary modifications, or (3) creating your own version.

Rob: The sharing of knowledge or the experiences, you [the teacher] can only do your best and try to convey, try to create an interest. (Rob 1, 323-324)

Table 4.9: Exemplary Quotes: Rob’s Traditional CSTL Position

Annotated comments. In Rob’s CSTL profile during the first interview, the Traditional views appeared with 10% of the total text units coded within this category, which reflected his beliefs about the nature of teaching based on his experiences as a student (see Figure 4.3). This traditional category was revealed when Rob argued that the role of the teacher was to “do the best to convey information” and the expected role of students was to figure out “what sort of response the teacher is looking for” (Rob 1). This perspective was from his own experiences as a student, observing teaching models where “the only real teaching, or for the most part the type of teaching I have been exposed to, was rote memorization. Teachers would come in, and dictate, you would take notes, when the exam came, you would write exactly what the teacher taught you. So that was the only type of learning that I had experienced in the formal setting.” With the salience of real world, life-long learning experiences, these beliefs affected his self-image as a teacher that he initially brought to the M.Ed. program. However this traditional component completely disappeared after the first interview. A CSTL profile was constructed using categories of traditional, Piaget’s Individual, von Glasersfeld’s Radical, and Vygotsky’s Social pedagogy.
Figure 4.3: Rob’s CSTL profile

Rob’s Pedagogical Commitment to Piaget’s Individual Constructivist Position

Rob’s exemplary statements showing his commitment to a Piaget’s Individual constructivism are represented in Table 4.10. These exemplary quotes are extracts from transcripts of Rob’s interviews. The focus of each segment was on “inferred practical pedagogical outcomes and principles” (Ernest, 1995, p. 467) in which Rob was asked to discuss about given options describing different pedagogical standpoints one by one and then finally choose one as his own position.
Rob: [I define science teaching as] allowing students to answer these questions themselves in a more or less directed manner, by referring them to sources or providing them a certain key pieces of information that might allow them to build on what they know or want to know. (Rob 2, 8-11) Well, students probably would not construct the same knowledge... there are certain things that you would want them to come to the same ultimate conclusions, I guess, and to eliminate misconceptions that they might have... but you don’t necessarily... like they might come up with different definition of what the natural selection is, but as long as certain requirements are met within that definition, then it would be a valid definition. (Rob 2, 88-96) And if I can help, direct them in a certain direction to get over certain hurdles and that will be my role [as teacher].... There are certain concepts that they’re not going to be able to arrive at by themselves; you have to help them understand those. (Rob 2, 348-350) You should accept various interpretations or solutions if they are acceptable interpretations or solutions. If it is a completely mistaken interpretation or solution based on what we understand it would be correct, then you would be doing them a disservice by accepting their interpretation without challenging it and forcing them to explain themselves. (Rob 2, 355-361) I do think that there are certain principles that have already been a consensus reached in the general scientific populations and you would want to encourage your students somehow directed so that they reach that same consensus. If they reach a completely different consensus, then you have problems because there are certain accepted consensuses.... Whenever possible, I would want students to participate actively in scientific activities so that they can discover things on their own instead of me telling them what happens and why. I do think teachers should 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. (Rob 4, 319-334)

Table 4.10: Exemplary Quotes: Rob’s Individual CSTL Position

**Annotated comments.** These quotes illustrate that Rob’s views of science teaching and learning were well aligned with those of Piagetian individual constructivists and their pedagogical implications of what individual constructivist teachers might be like in an ideal situation, which is not yet challenged, neither confronted, by the reality of the real classroom. The Piagetian category in Rob’s CSTL profile was maintained as the largest component by the end of the second interview and gradually decreased in the third and the fourth interview: 90% in the first interview, 85% in the second interview, 15% in the third interview, and 32% in the fourth interview.

The point of Rob’s Piagetian individual constructivist pedagogical beliefs was that “there are certain concepts that students are not going to be able to arrive at by
themselves; you have to help them understand those... there are certain things that you would want them to come to the same ultimate conclusions” (Rob 2). Rob went on to say, “I do think that there are certain principles that has already been a consensus reached in the general scientific populations and you would want to encourage your students somehow directed so that they reach that same consensus” (Rob 4). Accordingly, as a teacher, Rob wanted to “accept various interpretations or solutions if they are acceptable interpretations or solutions,” “eliminate misconceptions that they might have if it is a completely mistaken interpretation or solution based on what we understand it would be correct,” and “force them to explain themselves [so that] hopefully in the act of explaining themselves they will notice that there’s something perhaps intrinsically wrong with their interpretation or solution to some problem” (Rob 2). These aspects of Rob’s CSTL thus fit well with a position that views teaching science involving socializing “students into a particular way of looking at the world; students need to be enculturated into the science community” (Driver et al., 1994, p. 219). Rob’s pedagogical perspective, aligned with that recommended by individual constructivism, can be summarized as follows: “I do think teachers should 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” (Rob 4). This Piaget’s individual constructivist component in Rob’s CSTL profile was gradually replaced by a radical or a social constructivist’s pedagogical implications after the second interview.

Rob’s Pedagogical Commitment to von Glasersfeld’s Radical Constructivist Position

Rob’s exemplary statements showing his commitment to a von Glasersfeld’s Radical constructivism are represented in Table 4.11. These exemplary quotes are
Extracts from transcripts of Rob's interviews. The focus of each segment was on inferred pedagogical implications in which Rob was asked to discuss or comment on given options describing different pedagogical standpoints one by one and then finally choose one as his own position.

Rob: I like the idea that [knowledge is subjective sense making activity], so you're trying to make sense of what you see, or what you hear, what you smell, or what somebody tells you. (Rob 2, 325-327)
I think learning is a process of self-organization. In that sense I do think it is subjective. (Rob 3, 496-497)
I do think you construct schemes to try to understand things.... I guess it's important that you [the teacher] tell students what the society thinks is the best explanation. It's up to them to decide whether or not it's the best explanation for them, but that it is what your contemporary western society or whatever society you are in thinks as the best explanation. (Rob 3, 511-520)
Students can learn what the current society regards as having the greatest viability of the time.... My opinion of what the society considers valid is that it might be very different from what a very conservative traditional old person thinks as valid in the society, or what a very young person thinks as valid. So that would also be something that changes from individual to individual. (Rob 3, 562-568)
Hopefully you will give them a wide selection of things from which they choose those which they personally find enjoyable or productive or useful depending on what they want to pursue. (Rob 3, 579-582)
I think for the most part at least in the Western world, we do build plans in our head and then we try to relate things in our head to the outside world based on those plans that we make. Therefore the teacher should definitely know what is going on in the student's head and try to understand how the student understands. I do agree that learning environment should try to include a range of experiences so that the student knows what is the most accepted theory but also knows what are other alternative possible theories to something or alternative explanations.... because everybody brings their own experiences which we can't really share. Everybody's own experiences create that person. (Rob 4, 339-351)

Table 4.11: Exemplary Quotes: Rob’s Radical CSTL Position

Annotated comments. From the second interview, Rob's comments provided evidence that he, to some extent, aligned his pedagogical position with that of von Glasersfeld's radical constructivist's recommendations (9% of the total text units in the second interview, 34% in the third interview, and 29% in the fourth interview). Rob consistently maintained, "learning is a process of self-organization... in that sense I do
think it is subjective” (Rob 3). In this “subjective sense making activity,” Rob contended, “I do think you construct schemes to try to understand things” (Rob 3), and “we do build plans in our head and then we try to relate things in our head to the outside world based on those plans that we make” (Rob 4). Accordingly, “the teacher should definitely know what is going on in the student’s head and try to understand what the student understands” (Rob 4). In addition, Rob went on to say, “hopefully you will give them a wide selection of things from which they choose those which they personally find enjoyable or productive or useful depending on what they want to pursue” (Rob 3).

The major point of Rob’s Radical pedagogical position was that it is important for a teacher to provide “a wide a range of experience as possible” so that “the student [not only] knows what is the most accepted theory but also knows what other alternative possible theories to something are” (Rob 4). Although the teacher can “tell students what the society thinks is the best explanation, it is up to them to decide whether or not it is the best explanation for them” (Rob 3). With this strong emphasis on individualistic philosophy of learning, Rob contended, “everybody brings their own experiences which we can't really share, and everybody's own experiences create that person” (Rob 4).

Rob’s Pedagogical Commitment to Vygotsky’s Social Constructivist Position

Rob’s exemplary statements showing his commitment to a Vygotsky’s Social constructivism are represented in Table 4.12. These exemplary quotes are extracts from transcripts of Rob’s interviews. The focus of each segment was on implications for educational practices in light of differing epistemological standpoints in which Rob was asked to discuss or comment on given options describing different pedagogical standpoints one by one and then finally choose one as his own position.
Q: Of the statements, which would most align with the way you think about pedagogy? Does this view fully describe your position? If not, you may describe your own position by (1) combining the positions, (2) making any necessary modifications, or (3) creating your own version.

Rob: I like the thing of teaching as modeling.... I just like the idea modeling scientific methods because that way you can explain to them more or less how scientists go about working.... you make things available to them .... and if you follow [scientific] processes it might help you. (Rob 3, 521-531)

I like this idea of reaching consensus, that societal skills that you are teaching in societies about interacting with people, reaching consensus.... I like the idea of learning by observing whether it is science or anything else. So I like this, the teacher being a facilitator and supporter. I like the idea of scaffolding or apprenticeship. (Rob 3, 544-557)

Hopefully, [I want to teach science through] on-going dialogue as opposed to conflict or an argument, which is non-constructive. Just tell them that they can believe whatever they want to believe... as long as they are open to other people's explanations and they come up with justifications and rationale for their point of view. (Rob 3, 624-629)

I mean if you want to teach them how to do scientific inquiry or investigation, you would have to teach them how to do scientific method because that is the accepted model for how to do things. If you want to get a paper published in science you are going to have to do an experiment in a pretty inflexible way so it depends what you want for students to do ultimately. It would be good for them to understand the [scientific] process.... you do have to know how to do that. (Rob 4, 352-358)

So I am kind of there to link students and the scientific community. In a way you would help them interpret things from a scientific community back and forth until they have enough of conceptual framework to do their own interpretations and go off on their own. (Rob 4, 366-370)

You would want them to understand why a certain interpretation is the most accepted, why it is the one that has the most evidence in favor, and why that is the one they have not been able to disprove.... but you definitely don't want to say what is sense and what is nonsense because you never know if things 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. Things should be subject to further questioning and possible modification. (Rob 4, 374-382)

In B, I like the idea about a consensus, reaching a consensus. I would also agree with the idea of encouraging students to explain themselves, justify their positions, and the fact that you are not giving them to practice routines or standard interpretations. I like that you are leaving them open and I like the teachers facilitate and support as students construct their own ideas. (Rob 4, 400-405)

Table 4.12: Exemplary Quotes: Rob’s Social CSTL Position

| Annotated comments. Rob’s comments provided evidence that he aligned his pedagogical position with that advocated by Vogotsky’s social constructivism. This social category emerged from the second interview in Rob’s CSTL profile, and was maintained as the largest component in the third and fourth interview—6% in the second interview, 51% in the third interview, and 39% in the fourth interview—replacing Piaget’s individual constructivist category |

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The major point of Rob's Vygotskyan social constructivist standpoint is that, students "can always benefit from learning from other people" in their knowledge construction. That is, according to Rob, the teacher is "kind of there to link students and the scientific community. In a way you would help them interpret things from a scientific community back and forth until they have enough of conceptual framework to do their own interpretations and go off on their own" (Rob 4). In this "scaffolding or apprenticeship" processes, students are encouraged to "explain why they believe something so and justifying their interpretations" and "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" (Rob 3). Rob wanted to teach his students how to "interact with people, how to reach consensus," and "how to do scientific inquiry or investigation" by having students observe and practice "routines or the accepted model for how to do things" (Rob 4). In addition, through an "on-going dialogue," Rob maintained, "the teacher would want the students to understand why a certain interpretation is the most accepted, why it is the one that has the most evidence in favor, and why that is the one they have not been able to disprove," but still "you want to always leave them with an open mind to accept that there is nothing that is absolute or set in stone" (Rob 4).

Summary of Rob's CSTL Profile Changes

In the first interview, Rob's CSTL profile was 90% Piagetian and 10% Traditional, where he viewed his science class as a way of introducing "a certain core body of knowledge and certain standards" to his students so that the students can compare their own conclusion and constructed meaning with "certain standards" (Rob 1). During the
first interview Rob amplified his earlier description of a good science teacher, which he said in his Statement of Intent. According to Rob, a good teacher shows “enough connections between what students have learned in science classroom and what they would see when they’re walking outside of the classroom” so that students can “see the relevance to the subjects or applicability.” Rob also felt that it is important to create associations between science classes and students’ everyday lives that will make students think and stimulate students’ interest.”

Rob’s second CSTL profile right after the first summer quarter in his M.Ed. program was 85% Piaget’s Individual, 9% von Glasersfeld’s Radical, and 6% Vygotsky’s Social. Having been introduced to different theoretical works of educational philosophy including constructivism, Rob moved away from the traditional pedagogical perspective and replaced it with new conceptions of science teaching and learning as he strongly aligned his position with that of conceptual change teaching and learning.

Along this line, his role as teacher is to “see what’s already there, what of the stuff that’s there might not be what you consider correct or is not considered to be correct, and 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 2). Rob wanted to “more or less direct students in a certain direction or put them on shortcuts that would avoid like a lot of dead ends” because not only “students are tested on specific sets of knowledge when they want to pass to the next grade” but also, otherwise “you as a teacher would be doing them a disservice” (Rob 2). Moreover, 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 2). Along this line, “the teacher must structure and facilitate learning environments with as wide a range of experience as possible” to reach as many students as he can. Therefore, he “wouldn’t necessarily completely exclude the lecture method because there are some people who were doing better with that method” (Rob 2). In the mean time, Rob also acknowledged possible “various interpretations or solutions” of students and was willing to accept those based on the same validating criteria that are used to validate the teacher-suggested alternative interpretation.

Rob’s ways of teaching still 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 so that they can find some interest in it, or some application which might help to make it more appealing to them and then get them to ask questions” (Rob 2). Ultimate goals of Rob’s science teaching were to have students “understand at least how thinking goes in other areas, what is considered acceptable and not acceptable, how to present information, and how to express themselves, which is what they are going to be doing eventually when they are not in school anymore” (Rob 2).

In his third interview, Rob’s CSTL profile was 15% Individual, 34% Radical, and 51% Social. Although Rob still viewed, “learning is subjective and a process of self organization,” by the end of the autumn quarter, he amplified his earlier description of rationale of science teaching and learning, and included more details on the importance of reaching a consensus in terms of desired learning goals, negotiated between the teacher and the students. 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 to decide
whether or not it's the best explanation for them” (Rob 3). Moreover, for Rob as well as for his students, established scientific theories are no more than “a structure or a framework which makes it easier for you to relate to the world around you” (Rob 3). Accordingly, Rob’s focus of his 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” (Rob 3). To reach his goals, Rob’s way of teaching features “on-going dialogue as opposed to conflict or an argument.” He described himself as a teacher being “a facilitator and supporter” who is “teaching in societies about interacting with people, reaching consensus, and encouraging students to explain why they believe something and to justify their interpretations” (Rob 3). When asked to describe himself as a teacher during the fourth interview, Rob illustrated his roles were “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 3).

In the fourth interview, Rob’s CSTL profile was 32% Individual, 29% Radical, and 39% Social. Rob’s fourth CSTL profile featured a little bit recovery of Individual component and stabilized Social component after having gone through the winter quarter field experience, while maintaining almost the same level of commitment to von Glasersfeld’s Radical category with the third interview. Although Rob still believed, “teachers facilitate and support as students construct their own ideas,” he firmly realized
that as a teacher his role is to “link students and the scientific community [the public standard]... In a way, you would help them interpret things from a scientific community back and forth until students have enough of conceptual framework to do their own interpretations and go off on their own.” After all, Rob 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 4). So the teacher was “kind of there”:

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. (Rob 4)

On the other hand, Rob’s conceptions of science teaching fit well with his beliefs about the nature of scientific knowledge, according to which he contended, “you never know if things 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. Things should be subject to further questioning and possible modification” (Rob 4). Accordingly, as a teacher, Rob throughout the interviews continued to believe, “the learning environment should try to include a range of experiences so that the student knows what is the most accepted theory but also knows what are other alternative possible theories to something or alternative explanations” (Rob 4). Rob also acknowledged, “learning is a process of self-organization and then knowledge is in most cases our attempt to explain what we observe” where “everybody brings their own experiences which we can't really share” (Rob 4). According to Rob, “everybody's own experiences create that person [by] building plans in their head and then they try to relate things in their head to the outside
world based on those plans that they make” (Rob 4). Grounded in his radical or highly individualistic ontological beliefs and his awareness of the fallible, tentative nature of knowledge, one of Rob’s rationales of science teaching was to have students “understand why a certain interpretation is the most accepted and why it is the one that has the most evidence in favor.” 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 it.” Rob wanted his students to leave his science class with the criteria of how to judge validity of information, “how to do scientific inquiry or investigation to discover things on their own, and how to explain themselves and justify their positions” rather than with specific science content (Rob 4). Therefore, 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 4).

After his winter quarter field experience, Rob said he had been frustrated by students’ indifference in learning science, and continued to insist “the ultimate goal of the teacher” is to “spark an interest in your students”: “Your ultimate goal is to try, make students interest in science and help them to understand information that is available in science” (Rob 4). Since Rob thought communication and social interactions are the foundation for coming to know, he valued “the cooperative learning and students-mentoring, where students “present that [their own research on certain subjects] in a coherent and well-prepared way for their fellow students” and learn about “how to communicate experiences or knowledge that they have” (Rob 4).
General Characteristics of the Explainer Section

Beginning with the second interview, at the end of each interview, I asked each interviewee to explain what was the most influential in helping him to form his beliefs about teaching and learning, what were the significant changes in himself as a preservice teacher after one (or two or three) quarter in the M.Ed. program, and what he had learned most throughout M.Ed. coursework. In this explainer section, I compiled and examined each participant’s responses to these questions searching for ‘Explainers’ for his beliefs changes or lack of changes. Other parts of each participant’s transcripts were also subjected to the rigorous search for examples that fit the explainer categories.

In this section, in particular, the focuses are on: (1) whether each preservice teacher was conscious of his ontological and epistemological profile and was able to decide where each zone is applicable in an appropriate context, (2) whether each preservice teacher was aware of any changes in his profiles or his level of awareness of different components of his profiles, (3) the extent to which each preservice teacher was conscious of the relationship between his ontological/epistemological beliefs and CSTL, and (4) how changes in the ontological and epistemological beliefs helped each preservice teacher to understand the concepts (i.e., constructivist epistemology) better and to change his views of science teaching and learning. 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, which in turn results in different views of science teaching and learning. To that end, attention will be turned first on explainers for each preservice teacher’s beliefs changes, that is, the ‘whys’ of any of beliefs changes.
Explainers for Rob’s Constructivist Profile Change

When asked to provide the most influential factors in helping form beliefs about teaching and learning, Rob offered (1) M.Ed. coursework—especially field experiences, (2) interactions with other fellow preservice teachers who showed him “there are many different ways of learning” through group work in the program, and (3) his family and other living situation where he “had a chance to hear and talk to them about how they teach and what their opinions are” (Rob 4). What he has learned most throughout the M.Ed. coursework is that “there are many different ways of learning and therefore there should be many different ways of teaching,” which is quite different from “the type of teaching he has been exposed to (e.g., rote memorization)” (Rob 4).

A member check confirmed that Rob was not quite conscious of his ontological and epistemological profile changes throughout the M.Ed. program. However, after reflecting upon his profiles, he explained that his ontological beliefs “shift towards the social sector,” through the influence of “interactions with peers and interactions in the classroom.” Rob contended, “passing through radical would not necessarily be the way to get from realist zone to social [idealist] zone.” Aligned with his strong commitment to Fallibilist epistemology, he assured that his “profile is dynamic” and “is probably going to continue to change constantly since it has obviously changed in that period” (Rob 4).

He also acknowledged, “there is concordance between ontological and epistemological beliefs, and that’s reflected over pedagogical beliefs as well.” However, he didn’t provide specific instances of those interactions and concordances.

On the other hand, when I questioned his awareness of different versions of constructivism during the second interview—right after the summer quarter, he could not
tell the difference between various versions or "weak, radical, and social" in his own
words. However, he clearly remembered that "social constructivism was that everything
is kind of bringing in, I guess, Vygotsky perspective that would be, the things are
determined by the social context and you are going to learn based on the society which
you’re developing in" (Rob 2). He expressed his version of constructivism as "learning
has to be, or should be in an active process, optimally. And I would definitely think that
you can’t separate your environment from your learning experience."

The ones I remember are weak constructivism, radical, and social. The weak, I
believe, the only principle that they say, learning has to be, like a proper
experience, it has to be something that happens to you, it’s not a passive; learning
is not a passive experience. So that would be a 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, recall quite right now what
the second principle was.

As far as I could tell, Rob’s ontological and epistemological beliefs are consistent
with how he viewed how people learn and how to teach. Throughout the interviews, Rob
moved away from Realist ontology towards Idealist ontology as he insisted a socially
negotiated, culturally bounded representation of reality. In the meantime, Rob to some
extent also showed a Radical ontological standpoint in the third and fourth interview as
he acknowledged, “our senses, as filters, represented to us the external world.”

Aligned with these ontological beliefs, Rob’s epistemological beliefs were firmly
grounded in “no ultimate truth,” hard-to-obtain objectivity due to “human beings’
subjectivity,” “no immediate access to world” because of constraints by our perception,
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” since “there is no final answer”
(Rob 4). In other words, 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 1). Rob also revealed a strong fallibilist perspective, according to which he refuted the possibility of any absolute truth, yet viewing science as human beings’ ongoing struggling for finding puzzle pieces in nature.

This epistemological position is reflected on his conceptions of science teaching and learning. Since Rob believed the tentativeness of scientific knowledge which is “subject to further questioning and possible modification” and culturally shaped and accepted knowledge, he wanted to be a “link between students and the scientific community” (Rob 4). Accordingly, he would present “what the society thinks is the best explanation, certain principles that have already been a consensus reached in the general scientific populations.” However, “it is up to the students to decide whether or not it’s the best explanation for them,” which again reveals his radical zone of epistemological beliefs that can be summarized as “everybody's own experiences create that person… students should know what is the most accepted theory but also knows what are other alternative possible theories to something or alternative explanations” which fit with each student’s own experience. He continually advocated that the teacher needs 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 4).
Conclusions from the Initial Analysis

Three major conclusions follow from the initial application of the analysis scheme to Rob’s transcripts. First, the constructivist profile notion showed promise as a tool to trace teachers’ beliefs changes. For Rob’s case, he revealed changes in ontological, epistemological, and CSTL profiles as he newly incorporated various constructivist ideas without abandoning his previous beliefs. Accordingly, the constructivist profile notion, rather than conceptual exchange notion, demonstrated its potential power to illustrate coexistence of (in)compatible ideas in a teacher’s belief system. Second, upon looking at each teacher’s constructivist profile changes, I need to consider the difficulties in changing an individual’s unconsciously held, deeply rooted ontological and epistemological beliefs (Chinn & Brewer, 1993; Mortimer, 1995). In particular, it is important to note that the participants in this study were not followed into their student teaching experiences and their beliefs changes were documented during the portion of university coursework of the MSAT M.Ed. program. In other words, when we interpret each teacher’s ontological and epistemological profile changes, we need to consider a possibility that the three-quarters of university coursework could be a relatively short intervention for an individual to change his or her ontological or epistemological beliefs.

Finally, as can be seen in Rob’s case, it is possible to change—or at least challenge—preservice teachers’ ontological and epistemological beliefs as well as pedagogical beliefs through the constructivist-oriented MSAT M.Ed. teacher education program that explicitly advocated constructivist epistemology. Therefore, the description of the characteristics of the MSAT M.Ed. program that enabled the participants to change their
constructivist profiles needs to be examined along with a more extensive examination of constructivist profile changes with more cases. That task is addressed in Chapter 5.
CHAPTER 5

ANALYSIS AND RESULTS OF CASE STUDIES

Overview of the Chapter

This chapter is designed to respond to the research questions stated in Chapter 1. These questions are:

1. What are the developing notions of constructivism in terms of ontological, epistemological or pedagogical commitments during the period of this study? That is, what are the epistemological and ontological characteristics for each student's developing view of learning with the influence of constructivist epistemology taught in the core MSAT M.Ed. courses?

2. What experiences contributed to the development of ontological and epistemological views that are consistent with constructivist views of teaching and learning? That is, why do some preservice teachers capture and subsume constructivist ideas, while others ignore this position on learning in favor of retaining their previous views of learning?

3. How did changes in the ontological and epistemological beliefs help preservice teachers to understand the concepts--constructivist epistemology--better and, in turn, to change their views of science teaching and learning? That is, what is the relationship between science teachers' beliefs of teaching and learning and their
philosophical beliefs about reality and knowledge (i.e., ontological and epistemological beliefs)?

This chapter describes the analysis of interview data into a categorization scheme for ontological and epistemological beliefs and conceptions of science teaching and learning. The ultimate goal of this analysis is a complete analysis of preservice teachers’ understanding of constructivist learning, encompassing explanations given for their belief change or lack of change. 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.

Information obtained from this analysis is summarized for each interviewee in graphs. That is, ontological profile and epistemological profiles were prepared to represent the data obtained for each individual case. These two profiles were examined to locate any change (or lack of change) in the content of each student’s ontological and epistemological beliefs over time. For the 16 interviewees, five changed their ontological and epistemological beliefs throughout the M.Ed. coursework. Eleven other interviewees remained unchanged over time. The five cases, which showed ontological and epistemological beliefs changes, were subjected to further, in-depth analysis to answer Research Question 2. Rob’s case was presented in Chapter 4. This analysis is summarized in Table 5.1.
An overview of the MSAT M.Ed. program

Faculty email interview: Section I

CLES data: Section II

Change: 5 teachers
Lack of Change: 11 teachers

Past Experience or Personal History
Ontological/Epistemological Beliefs Changes over time
Conceptions of Science Teaching and Learning
Explainers

Section III: Case studies of the five teachers
Section IV: a composite profile of the 10 interviewees (Section IV) & one outlier (Section V)

Table 5.1: Analysis Scheme

Based on the analysis of all data sources, the chapter is divided into six major sections. In the first section, the results of faculty email interview data are discussed to provide the context for this study. The faculty email data, informal conversations with faculty members of the program, and course syllabuses document the intentions of the M.Ed. faculty and stated intentions of the MSAT M.Ed. program. In the second section the result of CLES questionnaire is presented.

The third section presents Ellen's case. Overall, there are a total of seven case stories that include five preservice teachers who showed significant ontological and
epistemological beliefs changes (i.e., Rob, Ellen, Ginny, Len, and Lynda), one outlier Ben’s case, and a composite Young’s case. Of these seven case stories, Rob’s case was already presented in Chapter 4 to show how interview transcripts were analyzed. Of the remaining six case stories, Ellen’s case is presented in the third section of this chapter. Three other teachers’ case stories (i.e., Ginny’s, Len’s, and Lynda’s) are presented in Appendix E in the same format as the other cases presented in Chapter 5. Ellen’s case was chosen because she provided rich descriptions of her ontological and epistemological beliefs, and she acknowledged the influences of the MSAT M.Ed. program. The fourth section illustrates a composite case of the ten teachers who did not show any significant change in their ontological and epistemological beliefs. In the last case study, an outlier, Ben’s case, is presented. As with Rob’s case, the analyses of the other six cases showing some change—Ellen’s, Ginny’s, Len’s, Lynda’s, Ben’s, and Young’s—are divided into five subsections. These subsections provide a brief sketch of a preservice teacher’s past experiences, descriptions of his or her Ontological Beliefs profile, Epistemological Beliefs profile, and CSTL profile, and Explainers for any change (or lack of change) in these three profiles.

In the final section of Chapter 5, results of case analyses are summarized, with particular attention given to explanations for the change or lack of change; how changes in the ontological and epistemological beliefs helped preservice teachers to understand the concepts better and to change their views of science teaching and learning; and how each teacher’s level of awareness of different components of his or her constructivist profile helped their beliefs change. Conceptual transitions are illustrated using extensive
verbatim quotes from my interviews with the M.Ed. preservice teachers throughout the teacher education program.

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

Before providing details about the group of science preservice teachers who enrolled in the MSAT preservice teacher education courses in 1999 - 2000, I will describe details of the context in which these preservice teachers worked in their preservice program. This context is necessary for an understanding of each case and for making interpretations. As background for interpreting the data, the intentions of the M.Ed. faculty are discussed. I did not gather systematic data about the program or about the enacted curricula, or about M.Ed. preservice teachers’ learning because these areas were outside the intent of my study.

1999, was the 4th year of the MSAT M.Ed. preservice program for secondary school science teachers. Based on response of faculty to an email interview, the major issues guiding the present program are summarized as follows. In each case, support for an issue is described briefly, using verbatim quotes from faculty email interviews--one professor volunteered for a face to face interview, which was audiotape recorded and transcribed, informal conversations with faculty members, and course descriptions distributed as syllabi.

Assertion 1: Faculty in the MSAT M.Ed. program advocated and taught a constructivist perspective of learning, or so called constructivism, for preservice teachers.

Ten out of twelve faculty in this program expressed an opinion about a basic “theme” of the program, which was to ‘assume a constructivist approach’ (personal communication: faculty email response). A subset of the methods instructors
acknowledged that they ‘provided some groundings in constructivism, which is not fully
based on readings because many of the preservice teachers are getting the readings on
constructivism in other courses, for instances the 721 course (Learning and Cognition in
School Mathematics, Science and Technology) that they take at the same time’ (T1 &
T10, from faculty email response):

Students receive a philosophical grounding in constructivism in their other courses
in our M.Ed. program. (T2)
They are exposed to the theory of constructivism in classes with T1, T6, T10, and
T11 (here T11 refers to a M.Ed. methods course instructor who did not reply to the
faculty email interview). (T3)
I think they get a good grounding in constructivism in our program. (T4)
In my course, students are introduced to the theory of constructivism through
readings and by cooperative learning group activities that model and provide
experience with constructivist principles. (T5)
Since my class is introductory and mostly about integrated curriculum, they are
only introduced to constructivism, often in an informal way via readings about
related topics. More time is spent in
modeling constructivist teaching and participating in activities. (T6)

As the quotes above illustrate, some instructors contended, “since my students are
exposed to constructivism in their other classes, I model various constructivist strategies
in my class” (T2). In the meantime, other instructors maintained, “we did not explicitly
address the philosophy of constructivism; however, we assumed an underlying
philosophy of individual constructivism and did talk about how students, especially in
middle grades, construct various concepts, so you could say that a constructivist
perspective was an assumption of the course” (T7):

I taught field experiences seminar courses this year and I did not have an
opportunity to address constructivism directly. However, it was introduced when
situations arose where interns were devising lessons and planning learning
activities. In my course, the constructivism ideas were discussed in light of intern
experiences in the classrooms where they did their practice teaching. (T8)

My students [preservice teachers] experienced constructivist learning first hand
through activities. In addition, they had readings and discussions, observations in
A major theme expressed by the instructors of the methods courses was the fact that they “go at it [constructivism] from a very practical point of view other than providing just a very brief definition, and we do some activities that are blatantly constructivist in nature” (T1). That is, most of instructors “felt free to use modeling as my main approach because I knew that the theory of constructivism was being covered in other coursework. And then again, I repeatedly ask the students what do you see going on here and they were most likely to be the ones who labeled it constructivist” (T1).

I really don’t approach constructivism with a specific philosophical intent. I do ask them [preservice teachers] to evaluate what they are learning. (T3)

Students had hands-on activities, read articles, and had many class discussions regarding their own learning in a constructivist manner as well as observing their students’ learning [in their field experiences]. (T9)

We [co-taught course] assumed an underlying philosophy of individual constructivism and, perhaps, social constructivism (though quite honestly I can’t recall a time we appealed directly to social constructivism unless you consider that term in the very broadest sense to include sharing and discussion of various solution approaches, etc.). (T7)

I do use constructivist teaching strategies, especially social constructivism to teach students [preservice teachers] concepts relative to diversity. (T2)

This directly leads to the next assertion which needs a little further elaboration.

Assertion 2: Faculty of this program modeled teaching/learning approaches advocated in the program through a variety of techniques such as ‘cooperative learning, group activities, inquiry and/or problem-solving activities, and hands-on activities’.

As mentioned, most of the instructors contended that they teach about constructivism using approaches informed by constructivism where they placed their preservice teachers in the position of being learners of science content and ‘continued to model what I believe to be constructivist practice’ (T1, T2, T4 & T10). The assertions
made by the instructors of methods courses are epitomized in the following quote from a faculty member (T1), who taught the Science Methods course during the summer quarter and Practicum in Science for Teachers during winter quarter:

I view constructivism as a description of how people learn and the way I understand it is that you can structure teaching situations to enable students [preservice teachers] to put things together themselves in their own way... for instance, one of the first hands-on activities we do in my course is this candle activity... and then I ask them to explain what they think has happened to tell what’s going on there. And they do in a group but usually members of the group don’t have the same ideas about what’s going on.... Then I think it’s very important to put up those alternate theories for the whole class, list them and then I ask them to discuss what they see in those alternate theories and them to propose what they could do to distinguish between those to determine which one is the most likely to be true. (T1)

In other words, teacher educators in the MSAT program “take an approach that assumes constructivism as a way of understanding how people are going to construct essentially new knowledge for yourself. And we do so in a group because I want them to have to Negotiate that through talk” (T1). One feature that emerged from faculty email interviews was that instructors of the methods courses brought various “tools of constructivism to bear on issues and problems that the students pose” instead of “lecturing or reading about constructivism” (T7). Through ‘a variety of teaching approaches that modeled and provided experiences with constructivist principles’ the instructors wanted preservice teachers ‘to experience and engage in these experiences, to discuss the approach, to think about their learning from both a student and a teacher perspective, [and then ultimately] to use some of these ideas and activities in their own teaching’ (T5, T7 & T9). Some of them contended that preservice teachers “have to be engaged with the content [constructivist epistemology] for any learning to take place” (T10):

Regardless of the method of being engaged with material/content (lecture, small/cooperative groups, reading, whatever), the only way it is learned is by individual construction. (T10)
On the other hand, a subset of the instructors expressed that although many of our preservice teachers learned the theory of constructivism well, 'some were resistant because not only did it not fit with their past school experiences, but also many of their students were not accustomed to having to think' (T3, T8 & T9). In addition, one instructor contended, "I do not entirely believe the theory of constructivism. Parts of it are useful but students learn in so many ways, so to say that one theory fits all is to deny the diversity of learning styles our students have" (T3). Another instructor, who taught a clinical seminar course designed to provide interns with opportunities to teach mini lessons and share their experiences in the field indicated, "I don't think our interns understand constructivism well at all. Mostly because many experienced teachers don't understand it" (T8). He went on to say, "it took me several years as a teacher before I knew how to elicit ideas from students early in lessons, and then to try to allow them to work with their ideas to construct meaning. Even so, it is an activity that is on-going and one is never "finished" constructing and revising their concept or understanding of an idea” (T8). Overall, as one of the instructors of the final seminar of the M.Ed. program puts it, “in the program THEY LEARNED IT [the theory of constructivism] very well. My assessment is, they felt they had been indoctrinated” (T10, emphasis is original).

Assertion 3: In terms of classroom experience, the MSAT M.Ed. program features a gradual increase of classroom experience where preservice teachers can engage extensively in the active exploration of classroom contexts through written and videocases as well as fieldwork.

The program begins with ten weeks of subject-specific and general methods and theory courses in the first quarter. That is, a theoretical introduction to teaching and
learning through review of videocases and written works. From the second quarter on, preservice teachers typically received over 270 hours of field experiences through their university coursework prior to their 10-week student teaching experience--practicum experience--in the fourth quarter. The first field experience occurs during the second quarter. During this experience, preservice teachers are supposed to teach at least five full-class lessons. They are also in the schools observing for 3 and half hours per day, which sums up to total 126 hours of field experience during this quarter (i.e., 3.5 hours per day * 4 days per week * 9 weeks). The focus of this experience is on becoming aware of the public school environment and becoming familiar with fundamental teaching skills. The second field experience occurs in the third quarter along with the methods courses. During this field experience, preservice teachers are supposed to teach the equivalent of one class period, four days per week, for ten weeks. Therefore, this field experience equals approximately 150 hours in the schools (i.e., 3.5 hours per day * 5 days per week * 10 weeks). The focus of this experience is on observing and practicing some of the methods that have been illustrated in the university methods classes. The 10-week student teaching experience is done under the supervision of a cooperating teacher and a university supervisor. Student teaching equates to 350 hours of clock time in a school.

Summary of the Program

Overall the majority of the MSAT M.Ed. faculty explicitly stated that one of the goals and objectives of their methods courses was to “promote constructivism as a way of understanding how students learn concepts and as a teaching strategy for improving and stimulating students’ conceptual changes” (A methods course syllabus, July, 1999).
In addition, the instructors of the methods courses modeled what they believed to be constructivism, where they interpreted constructivism as a perspective on how people learn. By allowing the preservice teachers to participate in activities that are blatantly constructivist in nature as learners of science content, the methods instructors wanted them to gradually move away from viewing teaching from a student’s viewpoint to knowing teaching from a teacher’s perspective, where they thought, “this idea of constructivism is the strongest way to help our preservice teachers understand that they need to meet the needs of every learner by maintaining engagement on the part of the students” (personal communication with T1, May, 2000). Moreover, having experienced constructivist learning firsthand themselves in individual or group settings, the MSAT preservice teachers were expected to implement constructivist-based approaches in their classroom practices.

CLES Results

The results of preservice teachers’ perceptions of their own future classroom environment are presented in Table 5.2 and 5.3. All of the science preservice teachers who had been accepted into their university teacher certification program in 1999 completed CLES questionnaires. The CLES, as a departure from traditional practices in learning environment research, was designed to measure the extent to which teachers perceive their science teaching environments are at once compatible with a constructivist epistemology and social-constructivist referents for learning. In this view, students are acknowledged as co-constructors of knowledge in critical discourse within a classroom learning environment (Taylor et al., 1997; Fraser et al., 1998).

The Cronbach alpha reliability coefficient was estimated to provide a measure of
internal consistency of each of the three times of CLES measurement ranged from 0.84 –
0.89 (see Table 5.2). A General Linear Model (GLM) for repeated measure was
performed on the CLES score data, grouped by treatment groups (i.e., interviewees and
non-interviewees) and the time of measurement (i.e., CLES 1, 2, & 3). There was no
significant interactions between ‘treatment groups’ and ‘the time of measurement’. There
were no significant differences between the two treatment groups on the first, second and
third test (see Table 5.3). While there was no significant difference between the groups,
there was a significant increase for both of the groups from the first CLES score to the
second CLES score ($p<0.05$ in a within group contrast between CLES 1 & CLES 2) as
well as from the first CLES score to the third CLES score ($p<0.05$ in a within group
contrast between CLES 1 & CLES 3, see Table 5.3). That is, in tests of within-group
contrasts using the first CLES data as a baseline, there was a significant change from
traditional views of teaching and learning to constructivist approaches in their projections
about classroom learning. However, there were no significant differences for both of the
groups from the second CLES result to the third result.

Overall, it appears that preservice teachers’ self evaluations of their ideal classroom
learning environments indicated a change toward constructivist teaching approaches and
the development of constructivist classroom climates, at least in their projections of an
ideal classroom learning environment. It is important to note that both of the groups
showed significantly different orientations toward their classroom environments on the
second and the third CLES measurements compared to the first CLES measurement. That
is, after one quarter of university based coursework and having been introduced to
constructivism through methods courses, preservice teachers revealed a change in their
perceptions of their ideal classroom teaching and learning environment from traditional to constructivist approaches. After the second CLES measurement, further CLES scores were not significantly different from each other. On the other hand, no significant differences between the two groups—interviewees and non-interviewees—indicated that the interview process itself did not contribute to any significant change in the participants’ perceptions of their classroom environments towards more constructivist approaches compared with non-interviewees. However, interpreting the fact that there were significant increases on the second and the third CLES measurements compared to the first CLES measurement must be done cautiously. While changes in CLES scores are encouraging, these changes were reported through preservice teachers’ self-evaluations of their ideal classroom learning environment, not changes revealed and reported by real classroom practices and observations where these teachers might have taught their own classes.

<table>
<thead>
<tr>
<th>Time of measurement</th>
<th>Cronbach alpha reliability</th>
<th>Mean and (Standard deviation) Interviewees (n = 16)</th>
<th>Mean and (Standard deviation) Non-interviewees (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st CLES</td>
<td>0.84</td>
<td>97.4 (7.8)</td>
<td>97.1 (9.6)</td>
</tr>
<tr>
<td>2nd CLES</td>
<td>0.88</td>
<td>103.8 (9.1)</td>
<td>99.9 (9.6)</td>
</tr>
<tr>
<td>3rd CLES</td>
<td>0.89</td>
<td>103.3 (10.7)</td>
<td>99.7 (8.7)</td>
</tr>
</tbody>
</table>

Table 5.2: Descriptive information for the CLES
### Tests of Between-Subjects Effects

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degree of Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>F Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>321268</td>
<td>1</td>
<td>321268</td>
<td>5676.971</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>56.003</td>
<td>1</td>
<td>56.003</td>
<td>0.990</td>
<td>0.328</td>
</tr>
<tr>
<td>Error</td>
<td>1697.743</td>
<td>30</td>
<td>56.591</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Tests of Within-Subjects Effects

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degree of Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>F Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLES</td>
<td>419.021</td>
<td>2</td>
<td>209.510</td>
<td>4.689</td>
<td>0.013*</td>
</tr>
<tr>
<td>CLES x GR</td>
<td>62.271</td>
<td>2</td>
<td>31.135</td>
<td>0.697</td>
<td>0.502</td>
</tr>
<tr>
<td>Error (CLES)</td>
<td>2680.708</td>
<td>60</td>
<td>44.678</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Tests of Within-Subjects Contrasts

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degree of Freedom</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLES 1&amp;2</td>
<td>675.281</td>
<td>1</td>
<td>675.281</td>
<td>5.899</td>
<td>0.021*</td>
</tr>
<tr>
<td>CLES 1&amp;2 * GR</td>
<td>101.531</td>
<td>1</td>
<td>101.531</td>
<td>0.887</td>
<td>0.354</td>
</tr>
<tr>
<td>Error</td>
<td>3434.188</td>
<td>30</td>
<td>114.473</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLES 1&amp;3</td>
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<td>578.000</td>
<td>5.128</td>
<td>0.031*</td>
</tr>
<tr>
<td>CLES 1&amp;3 * GR</td>
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<td>1</td>
<td>84.500</td>
<td>0.750</td>
<td>0.393</td>
</tr>
<tr>
<td>Error</td>
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<td>30</td>
<td>112.717</td>
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<td></td>
</tr>
<tr>
<td>CLES 2&amp;3</td>
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<td>3.781</td>
<td>0.092</td>
<td>0.763</td>
</tr>
<tr>
<td>CLES 2&amp;3 * GR</td>
<td>0.781</td>
<td>1</td>
<td>0.781</td>
<td>0.019</td>
<td>0.891</td>
</tr>
<tr>
<td>Error</td>
<td>1226.438</td>
<td>30</td>
<td>40.881</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p<0.05

Table 5.3: CLES Analysis Results of GLM

General Comments on Case Stories

In what follows, each participant’s case is divided into five subsections: personal history; ontological profile; epistemological profiles; conceptions of science teaching and learning (CSTL) profile; and explainers for changes in a participant’s profile. Each case study begins with a brief sketch of a preservice teacher’s past experiences and personal history prior to the teacher education program with the exception of the composite case, “Young”. In the second and the third subsections, each participant’s ontological and
epistemological beliefs changes are discussed with appropriate examples from interview transcripts. The fourth subsection describes each preservice teacher's conceptions of science teaching and learning with the influence of views of constructivist learning, where each student's views on the role of the teacher, how to teach, the role of the learner, how students learn, and rationales of teaching are also discussed. Each of these subsections on changes in ontological beliefs, epistemological beliefs, and CSTL ends with a presentation of Ontology, Epistemology, or CSTL Profile along with a brief summary that highlights any significant changes over time. In the final section, “Explainers” for each participant's beliefs changes or lack of changes and constructivist profile changes are discussed in terms of experiences that contributed to transitional changes or lack of changes of profiles.

Ellen's Case

Ellen’s 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 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 students are just provided information in this way because it placed her in a “learning situation where she couldn’t learn” (Ellen 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 surroundings. Through her “powerful and rewarding” experience with a group of urban Gatos kids in the Peace Corp, 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 1).

Ellen’s Ontological Beliefs

Based on the analysis of text units coded for 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 (see Figure 5.1). In the first interview, Ellen began with accepting the existence of an external world that constrains “what we can believe about it” (Phillips, 1997, p. 160). Some typical statements placed in the Realist category for Ellen included: “there is a human independent world” and “people have discovered that the 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 it [the real world] and make sense of it ... [our understanding] might not be right.” Statements like these are consistent with the ontological perspective described as Realist in previous chapters.
Figure 5.1: Ellen’s ontological beliefs profile

In the meantime, asked to align her own ontological beliefs with one of the forced-choice items during the first interview, Ellen chose an option representing a Radical ontological position (or “a perspectivist” in Ellen’s terminology). Still, in her first ontological profile, Realist and Radical ontological beliefs coexisted. However, this Realist category could not be located after the first interview. Furthermore, Ellen expressed an “anti-realist” (Searle, 1998, p. 18) 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 1)

Ellen contended that our knowledge of reality is never unmediated and each individual constructs his or her own 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—a radical view. When asked about her use of terminology and statements about the role of reality, she acknowledged having been “a philosophy major” in her undergraduate.

After the second interview, Ellen aligned her ontological belief with that of von Glasersfeld’s radical constructivism—100% of text units were coded in the Radical category. After the first quarter 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 recalled his way of describing reality:

We have read a bunch of different articles on constructivism. The one that I most liked the reasoning and argument was 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 an influence of social community. But I don't think he was a social constructivist purely, I think he also talked about the individual being able to be different from what is necessarily just a social construct. I agree with him. (Ellen 2)

When she talked about the role of reality, she replicated von Glasersfeld’s argument word for word, including the idea that “there is a reality that exists independently, but nobody has access to it,” as well as that “our theory is the most viable explanation and it fits for our knowledge of our world right now” (Ellen 2). Along the line of her “perspectivism” standpoint, she continued to insist, “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 [or we receive from different technologies] is the best scientific theory” (Ellen 3).
Following the third interview, Ellen's ontological beliefs profile was 53% Radical and 47% Idealist. Once articulated, Ellen's Radical perspective remained the largest component in her ontological profile throughout all interviews. In the third interview, Ellen revealed her Idealist ontological belief as she endorsed an Idealist assumption, "reality is constituted by our perceptions and other sorts of representations" (Searle, 1998, p. 16). In supporting her 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 3).

After the fourth interview, Ellen's ontological profile was 57% Radical and 43% Idealist. Ellen's idealist ontological beliefs became more sophisticated as she articulated how different cultural or language groups could construct multiple interpretations of the world. Regardless of these multiple interpretations, Ellen contended, different cultures could communicate with one another "based on a common language, like, for example, math that requires more consistent thought processes."

Summary of Ellen's Ontology Profile Changes

By the end of the fourth interview, Ellen's profile showed a coexistence of Radical and Idealist ontological beliefs. 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 "constituted by our perceptions and other sorts of representations" and multiple interpretations or constructions of reality depending on different cultural groups (Searle, 1998, p. 16). During the member check, Ellen indicated, "there has been an evolution" in terms of her ontological beliefs, which
has been caused by “readings in class.” Whether she achieved a consciousness of her own profile and was able to decide where each component is applicable will be discussed after reviewing her epistemological profile in the following section.

Ellen’s Epistemological Beliefs

Ellen’s epistemological profiles showed less variation than her profiles for ontological beliefs. After the first interview, Ellen’s epistemological beliefs profile was 51% Piagetian, 32% Fallibilism, and 17% Relativism (see Figure 5.2). Throughout the interviews, it was rare to place Ellen’s comments in the Absolutist category for her epistemological profile. Furthermore, as is the case for other interviewees, Ellen’s epistemology is to some extent related to her ontology (Prawat, 1997). Aligned with the Realist ontological beliefs represented in her first interview, Ellen had the Piagetian position as the largest component of her epistemological profile after the first interview, according to which “there is a world that someway constrains our creativity or our theories or knowledge” (Ellen 1). For example, she went on to say that, “on the earth things drop 9.8 meters per second squared, and that is what happened, and that is not something that people made up.” However, the process of grasping the external world was “tainted by human interactions”; therefore, she argued, “our analysis of the real world is not necessarily describing what’s actually out there.”
Figure 5.2: Ellen’s epistemological beliefs profile

As can be seen in Figure 5.2, this Piagetian epistemological component—scientific realism in Ernest terminology—in Ellen’s profile showed a gradual decrease, but was maintained throughout all interviews: 30% in the second interview, 15% in the third interview, 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 that world is passive thinking in that we are constructing that knowledge” (Ellen 2). Ellen assumed “an inaccessible world” in which humans are striving to reach a viable explanation or interpretation. 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, 1997, 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 3 & 4).
Ellen also exhibited Fallibilist epistemological beliefs in the first interview as she strongly acknowledged “the vulnerability of scientific theories to new evidence or interpretation” (Harding & Hare, 2000, p. 231). Aligned with her Realist ontological beliefs in the first interview, she viewed that we, sometimes, “totally misinterpret what the scheme of reality is or theoretical objects [of science] that exist”; therefore, “all theories are in principle revisable as proven in Newton’s physics or probably even in the Big Bang theory.”

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 2). On the other hand, she emphasized 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 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 component in Ellen’s epistemological profile was maintained throughout the interviews as she advocated “the vulnerability of scientific theories to new evidence or interpretation,” no unmediated, direct access to a reality, and “the viability of concepts that is measured by their non-contradictory fit into the largest possible conceptual network” (von Glasersfeld, 1995, p. 68). The Fallibilist category was the
largest component in her third (56% of the text units) and fourth interviews (46% of the text units):

I agree with that, all scientific theories are fallible and liable to refutation. I am thinking of my science, just 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 4)

Another feature of Ellen’s epistemological profile is that she had a Relativist epistemology from the first interview, which was well aligned with her initial Radical interpretation of reality. That is, she denied any direct or unmediated access to an external reality. Since the second interview, with her strong alignment with von Glasersfeld’s radical constructivism and his ontological, epistemological assumption, the Relativist component in Ellen’s epistemological profile surfaced as the largest component followed by the Fallibilist component (59% in the second interview, 29% in the third interview, and 37% in the fourth interview). Ellen contended that society not only creates reality, but also “creates scientific theory” by validating and accepting “people’s knowledge of reality” (Ellen 1 & 2). When asked to align her own epistemological beliefs with one of the forced-choice items, she consistently chose Relativist options throughout the interviews.

The assumption implicit in Ellen’s approach to scientific truthfulness is that each individual’s constructed scientific knowledge should “corresponds with the accepted version of the world and how the scientific community has agreed to explain something” (Ellen 4). In other words, although “there is no real reality” that validates one individual’s construction over that of another, individuals should construct their own knowledge “responding to how the scientific community has agreed to explain something or
corresponding with the accepted version of the world” (Ellen 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 4).

During the member check, Ellen continued to be fascinated by von Glasersfeld and his emphasis on an individual’s reality (as well as knowledge) construction.

**Summary of Ellen’s Epistemology Profile Changes**

In sum, the number of text units placed within the Piagetian category gradually decreased in Ellen’s epistemological profile and was replaced by Fallibilism and Relativist components. This change in Ellen’s epistemological profile fit with her ontological belief shift from Realist to Radical or to Idealist. That is, as she displaced an independent existence of an external world with no direct access to reality (von Glasersfeld, 1995) and, furthermore, multiple realities constructed by people “in a different epistemic community” (Phillips, 1997, p. 189), her epistemological beliefs shifted from Piagetian to Relativist, according to which knowledge is constructed and validated “within a particular community” (p. 188).

One important issue regarding 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 the consequences of her shift in ontological and epistemological beliefs as a science teacher. This issue will be discussed in the explainer section after reviewing her CSTL profile change in the following section.
Ellen’s CSTL

After the first interview, Ellen’s CSTL profile was 50% Traditional and 50% Individual. The traditional component of Ellen’s profile initially reflected her beliefs about the nature of teaching based on her experiences as a student, where she “was a good student who did what she was supposed to” (Ellen 1). When asked to describe characteristics of a good learner, she offered, “A good learner is somebody who can be attentive and disciplined.” This was intimately related to how she did during her own schooling. In addition, 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, 1992, 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 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 1). However, it was rare to locate a 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 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.”
In her initial CSTL profile, Ellen aligned her role as a teacher and the way she thinks about science teaching and learning with those recommended by individual constructivism, where teachers “compare the students’ and the accepted science point of view, thus provide insights to the intellectual demands, for the learner, of developing the science view” (Driver et al., 1994, p. 218). As Ellen put it:

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 is, or whatever we’re probably trying to learn. (Ellen 1)

Ellen viewed that teaching science involved socializing “students into a particular way of looking at the world; students need to be enculturated into the science community” (Driver et al., 1994, p. 219). This Piagetian component in Ellen’s CSTL profile remained the largest or second largest component throughout all interviews (33% in the second interview, 46% in the third interview, and 46% in the fourth interview).
According to Ellen, one of the main rationales of science teaching is to have “students understand sort of a best approximation of accepted scientific ideas of that time” and “it is the teacher’s responsibility to expose students to the accepted scientific interpretation” (Ellen 2). She went on to say, “the method of doing that can be constructivist and doesn’t necessarily have to be through traditional teaching”; for example, “going through some sort of conceptual change, and that misconceptions need to be restructured in order to for children to really understand what's going on” (Ellen 2). Although she was initially unsure of “whether she can be that kind of teacher or not,” she seemed to be fascinated by Sister Gertrude Hennessey’s (1991-1992) science classroom, where “she [Sister Gertrude] was able to introduce the interpretation of the scientific community without necessarily imposing that perspective on her students as an authority” (Ellen 2).

Following the second interview, Ellen’s CSTL profile was 33% Individual, 35% Radical, and 32% Social. In the meantime, Ellen’s CSTL profile was 46% Individual and 54% Radical in the third interview where her social component disappeared. In the second interview, although Ellen was fascinated by notions of social constructivism whereby students “develop certain common perspectives with regard to objects and events in the world” through communicating with themselves (Prawat, 1996, p. 220), Ellen always reverted to the teacher’s role as enculturating students into the theoretical ideas and conventions of the science community. According to Ellen, “practically, students’ being the constructivists or kids creating their own knowledge is not necessarily practical in the schools” (Ellen 3). Whenever asked to choose one of the given preferences that would most align with the way she thought about science teaching and
learning, she chose ways of teaching informed by 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 [individual constructivist’s ways of teaching]. I like B [social constructivist], but it seems like it might take too much time and it’s sort of, unable to do as a teacher with 15 learning objectives that you are required to go over throughout a year. (Ellen 4)

Ellen also recognized, “students own interpretation of the given ideas in their own heads, or their own ideas constructed for themselves may not be consistent with what the teacher meant, intended for them to learn” (Ellen 4). Thus, she emphasized, “teaching must involve a process of regular feedback and checking to identify the reasoning students are using” by having students justify and explain their interpretation (Driver et al., 1994, p. 219). In sum, Ellen seemed to perceive her role as a teacher to “teach an agreed-upon, accepted scientific knowledge” (Ellen 3). The reason she wanted to deliberately encourage “the scientifically acceptable viewpoint” was, she thought, “it was to students’ benefit to know what that established beliefs and knowledge that a scientific community has agreed upon” (Ellen 4). In particular, “of all communities,” Ellen wanted to “work with underprivileged kids, and acknowledge that there is a system and that there is, in terms of politics, a scientific community that has agreed upon something is helpful in empowering kids” (Ellen 4). As a teacher, Ellen wanted to link the culture of science and the culture of the learner, especially of underprivileged kids, and she thought, “having that type of knowledge (“the traditional interpretation of scientific community” in Ellen’s terminology) is helping empowering them.” However, she did not offer a detailed description of how underprivileged students can use their internalized scientific knowledge to empower themselves.
Following the fourth interview, Ellen’s CSTL profile was 46% Individual, 43% Radical, and 11% Social. The social component first emerged in the second interview (32% in the second interview) when Ellen contended that teachers “have to guide institutionalization of scientific activities in the classroom” (Ellen 2). She wanted students to leave her science classroom with the ability to do science. 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 2). However, she was unsure “if she can implement scientific method and scientific tradition in her classroom” and, in turn, had to compromise her preferred ideal approaches to teaching and learning because of external time constraints and the amount of content required to be covered.

On the other hand, Ellen always had an emphasis on subjectivity of students’ learning process, as she continued to be fascinated by “the individual’s being able to be different from what is necessarily just a social construct” (Ellen 2). With this strong emphasis on subjectivity, Ellen described learning as highly individualistic processes whereby an individual personally constructs knowledge in the process making sense of his or her experiences. This fits well with von Glasersfeld’s notion of Radical constructivism. However, “everybody constructs their individual reality based on the acceptance of their social community, also with an influence of social community” (Ellen 2). That is, in the process of an individual student’s constructive activity, Ellen acknowledged, “a social community” as well as “our prior understanding of the way beings work” acts as constraints by determining “the best fit” or “the greatest viability” (Ellen 4).
Within her radical constructivist perspective (35% in the second interview, 54% in the third interview, and 43% in the fourth interview of the total text units), Ellen believed that her job was to “have students learn what the current society regards as having the greatest viability” (Ellen 4) and “the teacher must be concerned with what goes on in the student's head in an attempt to change the student's conceptual structures” (von Glasersfeld, 1995, p. 15). Moreover, according to Ellen, “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 4). One of Ellen’s persistent rationales of science teaching was to lead students towards conventional science ideas, because that is “what the current society regards as having the greatest viability” (Ellen 4).

Summary of Ellen’s CSTL Profile Changes

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 4). As she was fascinated by the epistemology and pedagogical perspective informed by von Glasersfeld’s radical constructivism, she “incorporated the ideas about children as individuals with different perspectives as valid.” She would attempt to “hopefully address different learning styles or different strengths of the individuals and to help them come about making links between their conceptions and the science view” (Ellen 4). When talking about her goals for teaching science, Ellen’s focus was on having students know “the expected interpretation, standard interpretation” (Ellen 1), “think scientifically using a scientific method to explain how the world works” (Ellen 2), and “have an appreciation for science” (Ellen 4).
To achieve these goals, Ellen wanted to make her students “responsible and accountable” in their learning processes (Ellen 1). According to Ellen, this would help students retain more of what they were learning. She viewed “experimenting, discovering and interacting as the most efficient ways for students to learn about different concepts through different trials or different activities using multiple senses” (Ellen 1).

Throughout the interviews, Ellen maintained that there were “some direct relationships between what students were learning and other things that might be going on in other subjects or in their lives” (Ellen 1). Accordingly, she wanted to “link her activities to something concrete for students, whether it would be a home life or something real tangible that they can grasp,” which, she viewed, would “let engage the students, set them thinking about how they can link this back to the real world, and probe them to apply what they already know” (Ellen 4). “To be a better teacher,” Ellen was most concerned about “finding alternatives and introducing ideas in multiple ways that will engage students more” (Ellen 4).

Explainers for Ellen’s Constructivist Profile Changes

Asked to provide the most influential factors in helping her form beliefs about teaching and learning, Ellen offered “the structured coursework” of the MSAT M.Ed. program as the most influential factor that helped her to see “what the alternatives were in terms of different learning theories” (Ellen 4). Ellen contended 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 that people are used to. 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 4). What she needed is to “know and understand how we might be able to implement something else” and the program influenced her beliefs about teaching and learning by providing “alternative points of view, particularly in terms of this program talking about integration and constructivism and active hands-on learning.” When asked to comment on the influence of the M.Ed. program on her beliefs about teaching and learning, Ellen stated, “I really don’t think the M.Ed. program has influenced my beliefs about teaching and learning very much.” 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 do” (Ellen 4). Additional factors that influenced her CSTL included “group discussions with her peers where problems or ideas are being discussed, and actually being in schools, talking to teachers, and teaching myself throughout field experiences” where she could observe “a bunch of different teachers.” She also suggested that “the most practical way to learn as a teacher is to combine coursework with teaching or observing experiences” where 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 "more traditional pedagogical perspective and more realist perspective" after the first interview, and she remembered that she has been fascinated by von Glasersfeld’s perspective.

Regarding the extent to which she was conscious of the relationship between her ontological or epistemological beliefs and CSTL, she acknowledged, "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 “pedagogies based on a radical constructivist perspective” which “identify knowledge as a subjective sense-making activity located in learners’ minds and focuses on developing the experiential fitness of learners’ concepts for making sense of their intersubjective experiences” (Taylor, 1993, p. 283). When asked to comment on how her strong endorsement of von Glasersfeld’s epistemology and ontology will impact her teaching, Ellen contended, “hopefully that goes into my ideas about children as individuals with different perspectives and a lot of their opinions are valid; so hopefully I will address different learning styles or different strengths.”

As discussed earlier, Ellen wanted to encourage 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. That is, although she was aware of “what the idealist and relativist would say” in terms of the role of reality in knowledge construction, in her science classroom she wanted to deliberately encourage students “to learn the theoretical ideas and conventions of the science community.”
because her students, who are members of this Western scientific community, would benefit from knowing “established beliefs and knowledge that a scientific community has agreed upon” (Ellen 4). It is important to note that although Ellen was fully aware of each student’s different construction of reality as well as scientific knowledge in different ways depending on his or her everyday culture or experiences, she, as a science teacher of a Western community, would not only validate the truthfulness of her students’ meaning constructions in light of conventional science ideas but also reinforce the particular view adopted by the science community for her students’ own benefit and survival in this Western scientific community.

Regarding her CSTL profile, Ellen maintained the Piagetian as the largest component, along with the von Glasersfeld’s radical constructivist component from the second interview where she was introduced to various versions of constructivism in the M.Ed. program. Ellen’s high 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 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 30 kids per period, 150 kids per day with a course of study that covers multitude of topics and it's also my responsibility to prepare these children for 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, and I have to have content that goes beyond pure constructivist’s discovery methods or whatever. (Ellen 4)
On the other hand, regarding her awareness of three different versions of educational constructivism (i.e., individual, radical and social), she "most liked the reasoning and argument of von Glasersfeld's constructivism" where "he talked about people's knowledge of reality and everybody constructs their individual reality based on acceptance of their social community, also an influence of social community ... I think he also talked about the individual being able to be different from what is necessarily just a social construct. I agree with him" (Ellen 2). In sum, other than the disappearance of traditional pedagogical beliefs, Ellen maintained a consistent CSTL profile without showing any radical change.

Composite Case of "Young"

In this section, a composite profile for the 10 teachers who did not show any significant change in their ontological and epistemological beliefs is presented. The data analysis used in the previous section is used here to depict one representative, composite character I will call "Young". Therefore, one documented voice may represent a fusion of collective thoughts. The reader is reminded, however, that interview segments presented here are taken from the interview transcripts of 10 teachers. While ignoring each individual's trivial variance, I focus on creating a representative figure that hardly changes one's ontological and epistemological beliefs and is firmly grounded in what I have called scientific realism. However, although expressed by a few of the teachers, any significant features that could speak for other teachers' implicit beliefs were highlighted. That is, a few of these teachers supplied a theoretical foundation and had intuitive, explicit theory of knowing and learning. However, it is important to note that Young's
profile is a composite of the ten teachers in this study and does not necessarily represent any specific teacher as a whole. "Young's" character consists of six female and four male teachers, their ages ranging from early twenties to early thirties.

**Young's Ontological Beliefs**

A collective representation of the ten teachers ontological beliefs profile--Young's profile from now on--following the first interview was 100% Realist. "Young" maintained the realist category as the largest component throughout all interviews and continued to believe in an independently existing real world that "will go along without us and these natural processes are real and they are happening regardless of whether we think about, acknowledge, or understand them or not." According to "Young", we have direct perceptual access to "the things that we know as reality and we perceive and touch and feel. All those things that have been here long before we were as human beings." In addition, "nature is what people are learning from and that is where everything begins, and science is what we choose to focus on" (Young 1). As she put it:

I believe that everything exists and there are laws. I don't know if we understand them, but there are certain ways of that the universe works and I think it is possible for us to understand them. So I mean I think if humans weren't here, the universe would still exist with everything in it. (Young 1)
In our attempt to “discover or explain what is really happening, what the real world is like, and certain patterns out there just happening,” sometimes we “just happen to stumble upon their existence as opposed to something that we develop as a function of our own minds” (Young 1). Furthermore, “Young” contended, “scientific truth would be what you expect to happen, given past experiments did in fact happen” (Young 1). These responses were nearly identical for all interviewees in this composite case throughout the interviews: “there is an independent material world and real objective form that exists” (Young 2). Accordingly, “Young” sometimes explicitly asserted, “I kind of disagree with the ideas of radical constructivism for they’re saying that there is no reality independent of humans. I think that view seems rather conceited. I guess, because there are many other things in the world besides humans” (Young 2). To “Young”, the reality of this human-independent world “existed long before any human and it will be here long after humans are not on the earth; therefore, those objectively existing physical entities are
away from people, away from any kind of interpretation” (Young 3). Overall, “there is an absolute that we don't necessarily have a hold of” (Young 4).

She continued to believe that humans strive to uncover the hidden nature of reality and that “through experimenting, every scientific study gives us another piece of the puzzle. And we can probably go on for millions of millions of years, but I think that with each successive piece we come close to the true picture of reality” (Young 2). However, she was not so naïve as to believe that “science is entirely objective” (Young 3). Accordingly, she acknowledged, “our perceptions sort of skew or alter that reality and how we see it” (Young 2). That is, she contended, “I don’t think if we have ever known an objective reality as it truly exists simply because we are limited by our senses; there is always a little bit of bias in our interpretation, or just that the external world is too vast to really get the complete picture of what's going on, with too many interactions from everywhere” (Young 4). To “Young”, “ultimate truth is more or less the same thing as objective reality. I would say, you could judge the validity of a theory based on how well it agrees with experiments themselves, how good of a job it does in describing what we observe, and how well it coheres with what we actually see” (Young 4). This view resonates with what is called ‘the correspondence theory of truth’. “Young” also seemed to be aware of the underdetermination of theory by empirical evidence (Matthews, 1994) when she acknowledged, “the only way that we can prove whether things are true or false is to disprove them” (Young 4). Overall, Young’s realist ontological beliefs were grounded in years of experience as an undergraduate science-major and were derived through the apprenticeship of experience in the real world of science practice (personal communication, June, 1999).
On the other hand, it is important to note that from the second interview on, "Young's" profile did include Radical ontological beliefs: 3% in the second interview, 4% in the third interview, and 11% in the fourth interview. A typical statement placed in the Radical category for "Young" included: "one person's reality might not necessarily be another person's reality" (Young 4). Young’s radical ontological beliefs were somewhat close to what is sometimes called 'perspectivism' that states, "there is no unmediated access to reality or our knowledge of reality is always mediated by a point of view" (Searle, 1998, p. 18). Aligned with this view, "Young" claimed, "all human beings and individuals create their own world and see the world differently with their own assumptions and preconceptions." Therefore, "no one really can directly access what's going on in reality, or there is no way to directly access that reality" (Young 4). She went on to say, "although there is an absolute reality, I don't think we can ever know it" (Young 4). Accordingly, "what one person believes as reality isn't necessarily what the next person will agree with" in that "what we understand the world to be is our perceptions and each person perceives a reality from one’s particular framework" (Young 3). "Young" seemed to incorporate the radical ontological beliefs to the extent that "although there is the reality of what is actually going on, it may be beyond our ability to really comprehend what it is because how we see things skews those things and our own perceptions alter that reality of how we see it" (Young 2).

Summary of Young’s Ontology Profile

During the member check, "Young" identified herself as "the type of person that is sort of founded in reality. I am not surprised that I haven’t changed [my ontological belief] at all because... that's the opinion I have held for a long time and it hasn't been
really challenged since, so I haven't really changed my mind on that.” In sum, Young’s
ontological beliefs mapped well onto what Harding and Hare (2000) called “scientific
realism,” a view of reality held by many scientists.

Asked to comment on the radical component in her ontological profile in the later
interviews, “Young” offered, “first, I came in always just basically learning science,
learning science knowledge or learning how to solve problems where I did buy into
science as just facts that are out there. However, now it's definitely different, not
substantially yet, but I think that's just a result of now that I have become aware of a
different opportunity. [That is], as I began to really take a look at the processes of science
I started to see the radical [perspective] pop up more.”

As will be discussed in a later section, it should be noted that Young’s realist
ontological beliefs fit well with those of her Piagetian or Absolutist epistemological
category.

Young’s Epistemological Beliefs

Young’s epistemological profile following the first interview was 30% Absolutist,
55% Piagetian, and 15% Fallibilist (see Figure 5.5). Aligned with her firmly established
realist ontological beliefs, “Young” explicated the relationship between scientific theories
and the justifications behind them as “nature is either like the testing ground of your
theory or it is where you gather your observations and interactions” (Young 1):

Because nature is what people are learning from, that’s where everything begins. So
I think it all comes from nature. It all starts with nature. I think there is definitely
some relationship between nature and knowledge and there are certain patterns out
there, certain natural laws that just happen; I don’t think humans imagined the
theory of relativity. Nature is independent of the human mind and there’s something
out there that we want to discover as opposed to something that we just develop as a
function of our own minds. (Young 1)
"Young" believed that "science aimed for the truth about the world, and although it does not always succeed, there is progress in approaching truth" (Harding & Hare, 2000, p. 226). This view fits well with what is called the [progressive] absolutist view as indicated by 30% of the text units in the first interview, 16% in the second, 35% in the third, and 29% in the fourth interview. According to Young, the goal of a scientific theory is to "try to get more accurate, try to get statistically better, to constitute the more complete ideas of scientific knowledge with new discoveries, to get closer to the truth," (Young 1). "To come up with ideas that are more and more consistent with what's really happening, more often correct or predictive in our attempt to gain a better understanding or explanation of our world, to work towards knowing things exactly as it was, and to come close to the true picture of reality through every scientific study that gives us another successive piece of the puzzle" (Young 2). "Young" believed that the body of scientific knowledge continues to develop and "moves towards a greater knowledge and ultimate scientific truth as we have discovered more and more things about the specific
areas studied, such as the atomic theory as well as evolution, with evolved tools and
technologies" (Young 3). She went on to explain, “by doing science, we are moving a
step in the right direction towards at least figuring out one piece of something for
ourselves” and “every scientific discovery helps us get close to that ultimate scientific
truth; therefore, in theory, we could reach the point where we know it all” (Young 3).

Overall, from this Absolutist perspective on knowledge, “Young” had faith in
“some absolute scientific truths that we are slowly but surely discovering” (Young 4).
“Because we know something is there and we think there’s got to be one explanation for
it” (Young 3). Therefore, “scientific theories can be evaluated and appraised just by how
consistent they are with what is actually observed,” where “nature services as an
instructor, and basically we are just learning by what nature shows us by studying it”
(Young 3). This Absolutist component in Young’s epistemological profile gradually
evolved into the Fallibilist perspective throughout the remaining interviews.

Throughout the remaining interviews, “Young” maintained the fallibilist view of
scientific knowledge as the second largest component in her epistemological profile: 15%
in the first interview, 12% in the second, 27% in the third, and 23% in the fourth
interview. “Young” was aware of “a potentially fallible representation of truth” by human
endeavor (Ernest, 1998, p. 46). According to “Young”, theories are vulnerable to change
all the time because “humans cannot get away from bringing their own stands,
perceptions, and a part of themselves to their study of nature” (Young 1), and we cannot
know things exactly as it was because our perceptions shake and filter how we see that
reality (Young 2). Therefore, “we can be looking at the exact same things and see two
different things”, which prevents us from “ever reaching the exact truth of everything on
this Earth” (Young 3). In other words, “there is an objective reality out there somewhere, but our view of that objective reality is limited by our senses, our perceptions, our minds, and the technology that we have to view that objective reality” (Young 3). In sum, “Young” maintained, “when you have scientific truth, what that is saying is that this is a pretty good bet, but it is always subject to change and that's the nature of science” (Young 3).

According to “Young”, we “can never prove a theory correct, but it can be proven to be false so it is always under revision” (Young 2 & 4). Moreover, “as has been proven in many instances over the course of the history where we keep having these scientific revolutions that completely change our views (Young 2), our knowledge is open to be disproved. And open to confirmation, elaboration, revision or change. Otherwise it would not be science” (Young 3). By the end of the fourth interview, “Young” “hesitate[d] to say that scientific ideas are necessarily moving towards truth” in that:

[any explanation, even though it is working for now, might not be right and later on we might find out all that we have done is wrong and then we have to go back to the very beginning. I guess, we can never really get the ultimate truth anyway. (Young 4)

Aligned with her ontological beliefs about the independent existence of an external reality, “Young” maintained the Piagetian category as the largest component in her epistemological profile throughout the interviews: 55% in the first interview, 72% in the second, 38% in the third, and 48% in the fourth interview. Accordingly, “Young” contended, “scientific knowledge is constructed very close to what reality actually is through our very active searching for knowledge” (Young 2). The main point of Young’s Piagetian epistemological beliefs was that, “although our theories are always influenced by our own minds and perceptions, our perceptions do not actually change what we are
observing to such an extent that is completely different from what actually exists. Therefore, the cognitive structure and the actual world are probably pretty similar” (Young 1). “Young” went on to explain, “although it is true that scientific knowledge is supposedly constructed to make sense of the observations and what actually happened, at the same time, there is an outside order to make a choice well among a number of possible viewpoints.’ This makes it possible that ‘different people can come independently to the same conclusions about different aspects of reality’ (Young 1 & 2).

In a sense, according to “Young”, “we could not really construct something that didn't fit with what we've observed, or we are not going to be able to ever discover something within our own realm of experience that conflicts with some outside world” (Young 2). Moreover, “as a natural extension of being humans, we want to know the hows and whys of the things which happen around us, and the scientific ideas and theories are based on this questioning, poking, prodding, and manipulating something in the scientific process” (Young 1).

In sum, “even though the world exists independently, the only way we can really view it is through our own percepts and models. That is, we understand nature through the laws that we construct, and what we know isn't necessarily what the reality is, but it's our way of knowing it” (Young 2). “Young” continued to insist, “science is a study of objectively existing physical entities and science is an active construct, where the human mind plays a more significant role than merely copying or accepting the nature by interpreting things in multiple different ways through culture and social interactions” (Young 4). According to “Young”, “just because you are learning from nature does not mean you are not constructing your own knowledge; furthermore, our scientific
knowledge construction is certainly constrained by what exists in nature” (Young 4). In conclusion, Young’s Piagetian component in her epistemological profile can be summarized as follows:

There is a nature. There is an absolute nature. I don't think we can understand it. I think we attempt to, but our attempts to understand are our constructions of what nature is. I think if there is a coincidence between what we observe in nature, or what we understand to observe in nature and what we think in terms of theories, then you could say that theory is more correct.... [In addition], I don’t know if it’s necessarily true that there is a pinnacle [the ultimate scientific truth] for everything and that there is an ending point for everything. (Young 4)

Summary of Young’s Epistemology Profile

As “Young” acknowledged in her member check, she is “just the type of person that is sort of founded in reality” and aligned her epistemological perspective with Piagetian and Absolutist views of scientific knowledge. For Young case, her ontological beliefs fit nicely with her epistemological beliefs. That is, there was a correspondence between the realist ontological beliefs and the Piagetian—or sometimes Absolutist—epistemological beliefs. When asked to comment on the fluctuation in her epistemological profile during the member check, “Young” explained, “I think my position is more Piagetian than [progressive] Absolutist definitely, [in that] on the grand scheme of things, like humans as a whole, it would be a more progressive epistemology as we are striving closer and closer to this truth. But at an individual level, I would say it's very Piagetian where the individual is striving to make sense of what is happening to them” (Young 4).

Young’s CSTL

Young’s CSTL profile during the first interview contained text units coded as 33% Traditional, 56% Piaget’s Individual, and 11% von Glasersfeld’s radical constructivism (see Figure 5.6). The initial traditional component of Young’s profile reflected her beliefs
about the nature of teaching based on her experiences as a student. She “learned best by listening and was just basically trying to write down everything she heard, and then just memorize it to be able to spit them back out for a test or to pass the exams” (Young 1).

Figure 5.6: Young’s CSTL profile

She remembered some exemplary teachers who “pointed students who were previously inexperienced in the subject, towards the same concept, the end result” (Young 1), which in turn influenced what she wanted to do as a teacher. “Young” contended that the teacher “has to guide what the students should learn and has to expect them to memorize some of the information. [Not only] because there is no way in that short amount of time you could have students learn everything on their own, [but also] most of the lab experiments are just too difficult” (Young 1). Therefore, “I would say that responsibility lies on the teacher, to pull things together after the lab or at the end of the lesson, so as to make sure that students leave with the same concept and everyone is on the same page, and science teaching would involve transferring knowledge effectively.”
(Young 1). She also expected her students to “at least pay attention to everything that a teacher presents to them”, which she “felt important over her career as a student” (Young 1). However, as time went on, the traditional component in Young’s CSTL profile gradually diminished: 2% of the total text units in the second interview, 9% in the third, and 1% in the fourth interview. In the third interview, this traditional component resurfaced as “Young” acknowledged, “because of time constraints, the teacher should let the students know what the teacher expect them to know” (Young 3).

Other than the traditional pedagogical views expressed in the first interview, “Young” maintained the Individual category of CSTL as the largest component throughout all interviews: 56% of the total text units in the first interview, 63% in the second, 61% in the third, and 71% in the fourth interview. In other words, Young’s CSTL resonated with what is assumed by individual constructivism. A typical statement placed in the Individual category for “Young” included: “help the students construct their ideas of science as long as the students are on track with what is accepted in conventional science” through questioning which would point them along the better track by drawing the student’s understanding or misunderstanding out (Young 1). “Young” contended, “it is important to eventually get students to work towards what the accepted scientific interpretation or solution is, just because if not they won’t be able to interact with the natural science community” (Young 2):

The conventional ideas would still be brought forward so that students can converse at higher levels. If they want to pursue science they can be able to talk the scientific language and be on the same page with other people. But yet, it’s still an individual learning process. (Young 1)

In the later interviews, this Piaget’s individual category in Young’s CSTL profile was elaborated as “Young” became aware of students’ preexisting “conceptions (or
misconceptions) of what they are going to learn,” and she was explicit about how she as a teacher could “help her students see the inconsistencies between what they know and what is accepted scientifically” (Young 2). According to “Young”, “although every student has different experiences to relate a concept to, it is possible for them to understand a concept in similar ways to those people, because now we as teachers can speed up the process” (Young 2) by “making decisions about what could be useful learning activities and interacting with students to help them interpret those activities appropriately” (Driver, 1989, p. 104). “Young” went on to explain what she wanted to do as a teacher:

It's definitely important that the teacher is able to get some sense of, or know beforehand, how it is that the students learn a particular concept, or what problems that students might have with a particular concept to set up appropriate experiential evidence. This also goes along with the theory of conceptual change that a part of the teacher's role is to bring inconsistencies in students' thinking to the surface so that maybe they can begin to realize that their thinking was wrong and to move on to more conventional understanding. (Young 2)

In the meantime, “learning is definitely a subjective process” and in that process, “if the students are not confronted with their misconception head on… they won't learn what the teacher wants them to learn, or they might persist with their previous misconceptions” (Young 2). She strongly advocated a conceptual change model, insisting that the teacher “is responsible for giving students a range of experiences that point them in the right direction, and has to engage students in metacognitive discussion so that students can adjust the status of their conceptions” (Young 2). Overall, the major point of Young's Individual pedagogical views is that students “already have much more real world belief systems” regarding what they are going to learn in the classroom (Young 3). Therefore, the ultimate role of the teacher is to “help students move to ideas that are accepted by the
scientific community as a whole either by showing students cases that are discrepant with what he or she believes or setting up a debate in the classroom to see what opinions come out of it” (Young 4). After all, by the time the students leave her classroom, “Young” would want them “to come closer to the accepted norm of what the scientific community says” (Young 4). To “Young”, constructivist approaches for teaching were represented as “fixing students’ misconceptions about science and building up of previous science concepts” (Young 2).

As she maintained the Individual category as the largest component with an emphasis on “learning as a subjective, individual process,” “Young” also showed some of von Glasersfeld’s Radical component in her CSTL profile throughout the interviews: 11% in the first interview, 18% in the second, 19% in the third, and 7% in the fourth interview. From the second interview, when asked to choose among pedagogically distinct options that would most align with the way she thought about science teaching and learning, “Young” chose an option representing a radical constructivist’s position as her second choice and elaborated further:

The teacher is also in part representing society... at least putting out the accepted scientific issues and values. So the students come to learn what current society regards as having greatest viability at that particular time, but emphasizing that that changes all the time [and] that students' ideas are just as valid as other ideas as long as they are again put to the same sort of criteria or test that we put scientists to. (Young 2)

I think students interpret things differently other than just maybe reiterating what I said. Kids have different way of interpreting things.... I think that's because each person looks at that, experiences it and then takes it into their own mind and [using] all the things that make up that person they try to make sense of it. (Young 4)

As the above quotes illustrate, “Young” recognized that “students will understand matters differently, and will relate their new knowledge to what they had previously known in distinctively different ways” (Phillips, 1997b, p. 181). She also contended,
"knowledge is a subjective sense making activity, where the teacher is guiding that process" (Young 1). According to Young, "science teaching is ideal when teaching a student how to think through a problem carefully so that they can think on their own and solve problems in the world. And of course, there are subjects that can be used as tools in order to teach someone how to problem solve" (Young 1). That is, since "the world is changing so much, it is important for students to be able to solve things of their own, but I do think that teachers need to facilitate that by pushing them along a little bit and providing some structure and organizing thought for the students." In the meantime, "Young" maintained that scientific ideas are instruments that "can be used in the processes such as critical thinking or problem solving, and knowledge for its own sake is like knowledge in a vacuum." This is close to von Glasersfeld’s pragmatist—or instrumentalist—views of scientific knowledge: "I think that the most stringent criterion for judging a scientific theory are its usefulness in helping you to understand something" (Young 3).

Overall, Young’s pedagogical views, informed by von Glasersfeld’s radical constructivism, are that “learning, as a really individual process, is searching or developing their own ideas”--taking what they experienced or what they perceived into their own minds and making sense of it (Young 2). Accordingly, “the teacher should be concerned with what goes on in the student’s head, what the student is thinking beforehand, how it is that students learn a particular concept, or what problems that students might have with a particular concept.” Based on that information, a teacher could “set up appropriate experiential evidence” (Young 2) and “try to mediate between students’ minds and the world and society” (Young 4).
The social category in Young’s CSTL profile came into existence from the second interview and resurfaced when “Young” expressed, “the social interaction, the social plane becomes a mediator of” students’ knowledge construction” (16% in the second interview, 11% in the third, and 16% in the fourth interview). Some typical statements placed in the Social category for “Young” included:

I think students do learn best when they construct their knowledge, talk to each other, and get an idea of what everybody else is thinking. And I think that even though everybody individually has different knowledge, they must come to some kind of agreement on what they think is the most consistent view, theory, observation, or what’s the most consistent explanation of it. In B that the students construct their own ideas but they’re mediated by society and the teacher. (Young 4)

In other words, “Young” believed that “as students worked through their own ideas, they come to consensus on what is right ... come to something they can all maybe more agree on. Then, even though their knowledge is slightly different, it's pretty similar” (Young 2). “Young” also contended, “I also think that a scientific classroom should be about guiding students towards having the same criteria for their own ideas as scientific criteria. Perhaps hopefully by the end of the year, they would be parallel and that you wouldn't have that issue of a standard interpretation” (Young 2). According to “Young”, “students need to be geared up to actually see these scientific principles in action through lab experiments” (Young 3). “Young” went on to say, “students have to go a lot further. They need to be able to not just watch the teacher doing what scientists really do, but also to actually practice how science works and learn what would be the equipment of an experiment in a scientific community” (Young 4). Learning from an apprenticeship where the teacher, who has a better idea of what is scientifically accepted, “does represent ways that are scientifically accepted” (Young 4). She wanted to “create a very open-ended environment in which the dialogue from the students can be supported or
have student groups be responsible for defending whether a theory is a scientific theory” (Young 3). Aligned with her view of science teaching as enculturating students into the scientific community, “Young” defined “science learning as the ability to perform scientific tasks using scientific skills, and [producing] outcomes that would be accepted by the scientific community. Science learning is happening when students can think scientifically or analyze the world scientifically” (Young 4).

**Summary of Young’s CSTL Profile**

In sum, Young’s conceptions of science teaching and learning were informed by the conceptual change model of learning. She wanted to compare the students’ and the accepted science points of view by “taking into account students’ prior knowledge, having students confront their misconceptions head on, and showing how scientific principles can explain phenomena while theirs do not” (Young 2). Her role as the teacher was to “reveal the students’ previous conceptions that they walk into the classroom with, and to challenge students’ incorrect conceptions by presenting something that would contradict a student’s theory thus showing that their theories are not quite as consistent as those in the scientific community's” (Young 3). “Young” was most concerned that her students learn “critical components of scientific theories,” which “has a lot to do with accountability of the teacher in terms of proficiency test and using that knowledge later” (Young 4). Thus, although she acknowledged students’ being capable of generating ideas for themselves, “Young” contended, “teaching must involve a process of regular feedback and checking to identify the reasoning students are using so that teaching activities can be adjusted accordingly” (Driver et al., 1994, p. 219). That is, “teachers need to let students explore, but yet still let students be accountable for what they make
sense of." Along this line, she argued, "there will probably be times when I will be doing mini-lectures afterwards to guide them towards the right direction" (Young 4).

**Explainers for Young’s Constructivist Profile Changes**

As asked to provide the most influential factors in helping her to form beliefs about teaching and learning, “Young” mentioned the M.Ed. theoretical coursework as the most influential “because the ideas and theories that were presented to me totally changed the way I thought I would teach and if I had not gone into this program. I probably would teach like the way I had been taught in college” (Young 4). She valued the M.Ed. coursework more than the field experiences in that she was not only unsure of whether she “would have come up with some of those ideas on her own if she had gone out into the field experience first,” but also in the field experience there was a chance that she “could not have been placed with teachers that had the same beliefs with this program and thus she might have just kept teaching like she was taught in college” (Young 4).

However, “Young” further stated, “the problem with the coursework, especially in the summer and in the fall, is that it does not give too much about the real life experiences that you get from the field experience where you actually try out what your philosophy was or what the right pedagogy is going to be, and realize the subtleties of it.” On the other hand, “Young” went on to say, “if I didn’t have this field experience, I wouldn’t have had a big disequilibrium,” between her original idea of what she thought a teacher should be and what was effective in the field. Therefore, “Young” maintained, “without the field experience I would have never really have understood what it was, what a science teacher is, so I think the biggest thing is the experiences.” Overall, “Young” thought, “it’s really a combination of both, the field experience and the
coursework.” In addition, “Young” said that the M.Ed. coursework provided her “some vocabulary, like constructivism, to use in defining my pedagogical beliefs, and allowed me to name my thoughts on the teaching and learning.”

With respect to the M.Ed. coursework, what she mentioned was (1) “definitely constructivism, constructivist theory,” where she “learned a lot about how students actually think and how knowledge is gained,” (2) a lot of learning theories such as the Conceptual Change Model, (3) how to make teaching more student-centered where students are more interactive in their own learning, instead of more teacher-centered with the teacher presenting knowledge, and (4) how to incorporate more group work, although she “did not experience it very much as a student.” In addition, “Young” believed, “the most significant change I made as a teacher is I have gone from focusing on myself to trying to focus on the students more, or trying to shift some of the responsibility from me to my students.” In particular, “Young” was not “predisposed toward lecturing anymore, and even if you tell them, they still get all kinds of misconceptions that I think need to be addressed unless they walk out of the classroom with all sorts of crazy ideas about science.” “Young” contended that she felt “almost guilty about doing lectures after this program because they [the faculty] de-emphasized it so much. But I don't think this program has helped me to figure out how not to do lecture.” Therefore, she hoped, “I still think we need some lecture but to become more interactive and to be rooted in some knowledge” (Young 4). “Young” also remembered an exemplary M.Ed. program professor who “was modeling what we could do as teachers in our own classrooms” and thus, influenced what she wanted to do in her own classroom with what she learned from that professor.
In terms of awareness of her ontological and epistemological profile, she confirmed during the member check that she was not aware of any of her belief changes. Asked to explain apparent minor belief changes in her profile, she offered, “a lot of what they have been telling you in this program, I think, that would explain the shift.” Regarding the relationship between her ontological/epistemological beliefs and her CSTL, “Young” contended, “the way I teach should be the way I believe what science is really about.” However, they “won’t overtly influence how I go about teaching but that always will be in the back of my mind as I teach.” However, “Young” argued, “what you believe will not always come through while you are teaching, either. That is, there is not always going to be a coincidence” between a teacher’s ontological/epistemological beliefs and their teaching practices. She acknowledged that those ontological and epistemological beliefs are hard to change because they are “something you act on unconsciously unless somebody pushes you to think about it” (Young 4).

According to “Young”, “constructivism is a theory of learning that can be applied to teaching. It takes into account students' prior knowledge and it allows students to create their own understanding in a way that relates to their own background, what they do know” (Young 2). By the end of the fourth interview, she stated, “I am a constructivist in that I would help students identify and understand their beliefs, expose students to the more scientific ideas and then relate those to what they themselves understand, refocus how what we learned actually applies in life by connecting it to real examples, let the students do the learning and thinking in the classroom, and allow the students to direct the way the classroom goes” (Young 4). In the meantime, “Young” remained critical of
radical constructivism because "it throws out reality, which I don't really agree with completely" (Young 2):

According to the radical constructivism, there really is no true reality and only what we perceive is reality. However, I do believe that there is a reality outside the human mind. (Young 2)
I think constructivism is a really useful idea. I think at its extremes where you are talking about there is no reality that I don't think it's appropriate for a classroom. (Young 3)

Other than her objection to the radical constructivist's ontological position, "Young" was not quite aware of the ontological/epistemological commitments of different versions of constructivism. "Young" contended, "a lot of what we have learned in the M.Ed. program, a lot of what they have done for me is to put words to things that I already believed." That is, although she did not "really understand the philosophical background of constructivism," she felt, "in large part, I already had generated the basic tenets of constructivism in terms of active learning, students making connections to the real world, students making connection to their own lives, from my own experiences as a student before I came into this program" (Young 2):

When we're learning about constructivism, it always seemed like kind of an obvious thing to me, or an intuitive thing to me. I guess I always felt that the students in a way need to take responsibility for their own learning, so the idea that they construct their own knowledge kind of fit in with that. (Young 2)

On the other hands, Young's ontological/epistemological beliefs seemed to fit with her CSTL. That is, throughout the interviews, she maintained a realist ontological belief and Piagetian (sometimes [Progressive] Absolutist) epistemological beliefs as the largest components. She thus had Piaget's Individual category of pedagogical beliefs as the largest component throughout all interviews. Overall, her beliefs system might map well onto what is called scientific realism in individual constructivism. In accordance with her
individual constructivist epistemology, the following quotes epitomize her ontological and epistemological position:

On the grand scheme of things humans as a whole would be more progressive epistemology as we are striving closer and closer to this truth. But, at an individual level I would say it's very Piagetian where the individual is striving to make sense of what is happening to them. [Although] students' ideas are important and we need to take them into consideration, we want to steer them towards the scientific truth that humans have been striving to obtain. (Young 4)

After clarifying differences between different positions of ontological and epistemological beliefs, she also acknowledged, "sort of the realist, absolutist, progressive, those ideas, there may be a tendency for me to say there is a right answer. This is right and you are wrong. And that's true as well because the students' ideas have to be aligned with scientific ideas. If it were not, then I have not done my job as a teacher" (Young 4).

During the member check, "Young" was fully satisfied with a profile configuration that showed "complete moving away from Traditional, which is an accurate reflection of my beliefs." On the one hand, she contended, "as I look back, whenever I was frustrated, that [Traditional pedagogy] was my default, giving out information through lecture. I think that's where I have been taught and I am obviously comfortable with that. I still have that latent traditional concept of teaching." Therefore, she acknowledged, "if I get uncomfortable with trying other nontraditional ways of teaching, I will probably revert back to what I was taught, or what's worked in the past." On the other hand, "Young" expressed her frustration with "the amount of content to cover and the amount of lecturing" that she felt required to do, as well as "more traditional teaching of her mentor teachers" that she has been observing all the time in her field experiences. In addition,
“Young” continued to insist that “based on a little teaching what I have done, I would say that Conceptual Change Models of learning are definitely how I teach” (Young 4).

Ben’s Case

Ben’s Past Experiences

Ben is a White American male in his early fifties, requesting certification in high school chemistry. He already had MS and Ph.D. degree in chemistry and worked in research for the past ten years before enrolling in the M.Ed. program. Ben thought his past experiences equipped him with the fundamental knowledge he needed to solve problems in that he had honed his problem solving skills. Ben said he “always has had a desire to teach”, which had its “routes in his upbringing where his parents emphasized social responsibility tempered by practicality” (personal communication, June, 1999). In particular, through his experiences in mentoring chemists who worked in his research groups he found out that “teaching was always the most gratifying and brought out the best in me” (Ben 1).

In addition, as will be discussed in a later section, Ben “actually went to graduate school for a semester in philosophy” in addition to “having an undergraduate degree in psychology with a minor in philosophy” (Ben 1). However, after figuring out that he “was never going to get a job doing a philosophy major,” he “went to graduate school in chemistry after taking science courses for one and a half years” (Ben 1). After years of work as a research scientist, Ben “got tired of it and decided to do what I really enjoy doing,” which was teaching (Ben 1). Now, he “has come full circle and was seeking a career in high school teaching to make a contribution in developing the minds of today’s 221
students for the technologically based work culture of the future by using his previous experiences as a catalyst” (personal communication, June, 1999).

Ben remembered having had two wonderful teachers who “really keyed me into the Socratic method of teaching and listening responses from students” (Ben 1). In addition, one of his graduate mentors in chemistry taught him “the amount of input that the teacher gives the student should be to some extent up to the student” (Ben 1). In accordance with what he learned from these teachers, Ben wanted to “guide his students, to get them to look in a different way, not discouraging students’ observations, through Socratic dialogue and questioning” in his own future instruction (Ben 1).

Ben’s Ontological Beliefs

Throughout all four interviews, Ben consistently maintained Idealist ontological beliefs (100%) and continued to insist that “all we have is phenomena that present themselves, and through our thought processes if you reflect on it and then you give meaning to those phenomena or to the sense. Outside of that, we can think of nothing.” Moreover, “the world does not exist outside of myself. The world outside only exists for me personally, for each individual, as I define it for myself” (Ben 1):

Okay, basically I feel that we're exposed to stimuli or phenomena, about which their existence we really do not know. All we have is our stimuli. We define our interests or whatever…. We do not know that for sure a real world independently of us and our interest. [For example] I put my hand on this desk. I sense there is solid here, but it is just my sense and my thinking, and I say, ‘oh, that's a solid surface there’, by reflecting on my sensing of that feeling in my hand, going up to my brain and then reflecting on what I've learned. (Ben 1).
Ben went on to explain, "by interacting with other beings, I have learned to associate that feeling and meaning to a subject, and then we can say that it is a solid surface. Whether there is actually a real solid surface there that exist separate apart from me, no, I can't tell you that" (Ben 1). Asked to comment on why we have such a strong impression that the scientific objects exist independently of us, Ben stated, "they come in our mind as phenomena that present themselves to us ... over and over again, so we have become to believe strongly in them." However, "the only thing I have, all that I know is about this phenomena that I see, feel, smell, taste, touch, or whatever. Those are the only things that I can say really exist. After I get those senses, my thought processes reflect on them and I give meaning to them" (Ben 3). That is, "just because the sun came up yesterday, the day before, the day before that. We take that it will come up tomorrow. But we don't know for sure a priori. We just base this on inductive observation" (Ben 3 & 4). In other words, "there is no a priori knowledge that there is a real world and every
individual is responsible and active in taking knowledge into themselves, and constructs their own reality so to speak” (Ben 2).

However, Ben contended, “yet, through the phenomena of social interaction, the social plane becomes a mediator of our phenomena or knowledge through culturally sharing of our ideas and recognition of similarities in our interpretation of a phenomenon” (Ben 2). That is, “as we grow up, we become acculturated and accept the meanings that our culture attaches to things.” In a sense, “we are giving meanings to those collections of phenomena together” (Ben 3):

We are giving meaning, you and I give the same meaning to [what's white]; that's a culturally reliant thing, what the word 'white' represents. But, if I really look at the situation, what am I really seeing? I am seeing white and I am getting some white with the connection of input I have been taught. My mom or my dad said, that's white so I am calling that white too, regardless of whether it appears to you exactly the same as it appears to me or to the next guy. Whatever I am seeing, I have just been taught to call it white.... Now whether it's the same thing you are seeing or not, there is no absolute; there is nothing a priori that says that's true. There is nothing a priori about saying there is a true object out here (Ben 3).

Ben went on to say, “you define something as blue because you have learned that blue from the sense that you have. However, there is nothing in this card, the thing in there, that is blue other than I said that's blue and culturally it has been defined as blue” (Ben 3).

Culturally we have defined it as blue so I am going to call that blue too. Just you have learned that's blue. I am a phenomenologist. There is idealist who more interprets back to Platonic philosophy rather than we have an ideal form and so on. I would like to think of it more as a phenomenon [as a] phenomenologist. We have this stimulus coming from a phenomenon that presents itself, and then our brain looks on that through reflecting process and says that's blue. (Ben 3)

Accordingly, Ben maintained, “science is an interaction between humans and the phenomena that present themselves. You are the one who is saying what it is to you” (Ben 4). In addition, although “you and I were to see the commonality or similarities in
these phenomena when I do science, you don't know whether there is a real world out there other than what's in your head. There are only these phenomena that present themselves” (Ben 4).

Summary of Ben’s Ontology Profile Changes

Throughout the interviews, Ben maintained Idealist ontological beliefs (or a phenomenologist in Ben’s terminology) which is seemingly incompatible with his prior experience as a research chemist. When asked how and where he formed a unique perspective about the role of reality and status of scientific knowledge, he contributed his familiarity with philosophers’ sayings to “having been to graduate school for a semester in philosophy” in addition to “having an undergraduate degree in psychology with a minor in philosophy” (Ben 1). Whether he achieved a consciousness of his own profile and was able to decide how each category is applicable in an appropriate context will be discussed after reviewing his epistemological profile in the following section.

Ben’s Epistemological Beliefs

As is the case for other interviewees, Ben’s epistemology is intimately related to his ontology (Prawat, 1997). That is, in accordance with his Idealist ontological beliefs, Ben endorsed a Relativistic view of knowledge: 97% in the first interview, 100% in the second, 83% in the third, and 71% in the fourth interview (see Figure 5.8). According to Ben, this view entailed, “what we call knowledge is, in effect, just an interpretation or view which reflects one’s perspective or framework” (Harding & Hare, 2000, p. 226). Ben argued, “everybody tends to try to define his or her own world and science becomes part of that, a subjective sense making activity” (Ben 1):

It leans back to my previous statement that we give meaning to phenomena. And we try to describe occurrences in nature, how do we know that the sun will come up
tomorrow? We just, the way we know that is, it's come up yesterday, the day before and so and so forth. So we induce it. It's more inductive knowledge. Sort of that, how we create some science, it's based on observations and perpetual observations and then from that we say, we create a theory. (Ben 1)

Figure 5.8: Ben's epistemological beliefs profile

According to Ben, although "every individual is responsible for their own learning, and constructs their own reality" (Ben 2), it is possible to have knowledge and terminology in common "through a learning process where I interact with other beings out there, including parents and teachers. I have learned to associate certain feelings and meanings to a subject" (Ben 1). In other words, it is possible for "you and me to give the same meaning to what the word 'white' represents through culturally sharing our ideas and recognition of similarities in our interpretation of phenomena that we have seen" (Ben 2). After all, Ben contended, "we culturally have defined what is blue and what is white regardless of whether it appears to you exactly the same as it appears to me or to the next guy" (Ben 1). A meaning we give to a phenomenon is "a culturally reliant thing" that we have learned within "the social plane, as a mediator of our phenomena or
knowledge” (Ben 2). Ben consistently argued against realism and maintained, “there is nothing outside that exists apart from me and there is no a priori knowledge that there is a real world” (Ben 2); therefore, neither is there the thing in there that is blue other than I said that’s blue and culturally it has been defined as blue” (Ben 3). Along this line, “science is an interaction between human and the phenomena that present themselves”; however, “our interpretation cannot go against the observation and those senses that we made about phenomena” (Ben 4). Overall, Ben contended, “theories are our social constructs, and the observations fit with the context of everybody in” (Ben 4).

In the meantime, Ben was also alert to the fallible nature of scientific theories and consistently maintained a Fallibilist component as a minor portion of his epistemological profiles: 3% in the first interview, 17% in the second, and 29% in the third interview. As Ben put it, “we are always modifying, changing theories throughout the course of time as we get new insights into the structure of the world” (Ben 4).

Summary of Ben’s Epistemology Profile Changes

Matthews (1992) contends, “epistemology is important to constructivism, indeed I believe it drives the rest of constructivist theory and practice” (p. 301). Therefore, it is necessary to examine how Ben’s Relativist definition of scientific knowledge and his Idealist ontological beliefs were reflected on his conceptions of science teaching and learning. During the member check, Ben commented, “I think, deep down philosophically the program hasn't changed me. Nothing has presented itself as a reason for any change” (Ben 4). Further consequences of his unique ontological and epistemological beliefs as a science teacher will be discussed in the explainer section after reviewing his CSTL profile change in the following section.

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Ben’s CSTL

Ben’s CSTL profile following the first interview was 54% Piaget’s individual and 46% von Glasersfeld’s radical constructivism (see Figure 5.9). It is important to note that in Ben’s CSTL profile it was hard to locate any statements related to the traditional category even in the first interview.

Figure 5.9: Ben’s CSTL profile

As can be seen in Figure 5.9, Ben’s CSTL profile resonated well with his Relativist epistemological beliefs where he strongly subscribed to von Glasersfeld’s radical constructivist category: 46% in the first interview, 10% in the second, 56% in the third, and 30% in the fourth interview. That is, Ben seemed to have the pragmatic or instrumentalist views of knowledge as well as a rather strong individualistic philosophy as the backbone of his conceptions of science teaching and learning. As Ben put it, “knowledge for its own sake is like knowledge in a vacuum” and it should be used “in processes such as critical thinking and problem solving” (Ben 1). This fits well with von
Glasersfeld’s pragmatist views of knowledge, according to which “ideas are instruments whose purpose is to lead us fruitfully among our existences and to resolve problems and blockages of action that confront us” (Phillips. 1997b, p. 180). Furthermore, according to Ben, “learning is a constant process, extending your context or your world. It is almost like existential” (Ben 4).

The main point of Ben’s views about learning was that, “students with a lot of new data can organize or structure their inputs to fit with their prior understandings and knowledge in a process of extending their world, in a sense of self-organization” (Ben 4). However, Ben contended, “still students will do that for themselves and they do not all organize their inputs in the same way” (Ben 4). In the meantime, “these processes or information is just mediated and organized by teachers in such a way that fits into the context that the person learns and therefore becomes an extension of his or her own context” (Ben 4). That is, although “the learner constructs his own knowledge” (Ben 3), “the teacher needs to assess the context of the students and then he kind of can organize, transform the content knowledge into various forms so that the learner can take it into himself to construct his own knowledge” (Ben 3). In addition, according to Ben, “through the process of giving meaning to my own world, I as an individual may have scientific theories of my own that are not yet accepted” by the scientific community (Ben 3).

On the other hand, Ben maintained a significant portion of the Individual category in his CSTL profile, which fits well with views of science teaching and learning informed by the Piaget’s individual constructivism (54% in the first interview, 33% in the second, 44% in the third, and 20% in the fourth). This Individual category came into existence whenever Ben recognized that although “knowledge is a subjective sense making activity
[where] the students construct their own ideas, the teacher should try to guide them in a more proper direction, more acceptable interpretation through dialogue and questioning and try to get them to look at in a different way onto that observation or that thought” (Ben 1). Accordingly, asked to describe his role as a teacher, Ben offered, “I want to steer, mediate or facilitate them so that they have experiences that will lead them to construct knowledge in a more culturally accepted view’ (Ben 2 & 4). For Ben, learning still remained as an individual process.

On the other hand, as Ben put more emphasis on initiation of students into scientific traditions (Matthews, 1994), which is “mediated by society and the teacher” (Ben 2), the social category in his CSTL profile emerged starting from the second interview (57% in the second interview and 50% in the fourth interview). According to Ben, although each of us is “giving meaning to one’s world, a certain amount of that is mediated by others in a culture; otherwise, we will be solipsistic” (Ben 4). As Ben put it:

Science is a dialogue between people, which has been going on through centuries, and each individual is not going back and, so to speak, reinventing the wheel [because] the teacher facilitates, mediates that learning of those scientific concepts in such a way they don’t have to spend the same amount of time to learn it as the people originally constructed those concepts.... We know gravitational pull but a kid doesn't yet know that. It's not going to take them the same amount of time to learn it as the people originally discovered, not discovered but found out gravity. And that's because the teacher facilitates, mediates that learning of those concepts in such a way they don't have to spend many centuries in figuring out gravity… Again, the teacher is mediating the process by assessing the context of students. (Ben 4)

In other words, accordingly to Ben, “science is a constant move in a direction and so much of that has come from the past.” Therefore, to “participate in science and dialogue, we have to have mastered the information that came before you” (Ben 4). Overall, the main point of Ben’s pedagogical beliefs informed by social constructivism was that,
although “each individual is responsible for their own learning and construction of their own reality” (Ben 2), “any individual who went into a society or a culture may be learning to give meaning to phenomena of the world outside of themselves where there is a shared meaning” (Ben 4). Ben asserted, “the founding principles of teaching is acculturation” according to which he wanted his student “to become, not necessarily career wise, but a scientist. The person who can form hypotheses, develop experiments, learn the scientific processes and also master a certain amount of knowledge” (Ben 4).

Accordingly, Ben defined science learning as “learning to be observant, to form hypotheses and questions, how to perform adequate experiments to answer to those questions, and eventually come up with some explanation for some phenomena” (Ben 4).

In sum, as Matthews argued, Ben recognized, “children are not going to discover this world merely by private inquiry” (Matthews, 1994, p. 155), and “a valuable tradition is passed on, not reinvented by each generation” (p. 159). That is, as Ben recognized “the apprenticeship dimension of education,” he gradually moved away from individual constructivism to social constructivism (p. 159):

We felt the social interaction, the social plane and that becomes a mediator of our phenomena or knowledge. (Ben 2) We coax it in scientific disciplines, biology, chemistry, physics or science whatever environmental science. And there is a certain amount of content, fundamental information students need to master because obviously we are not starting from the day one and there is a lot of science of the centuries or millennium or whatever… we have to have mastered the information that come before you for the last centuries. (Ben 4)

Summary of Ben’s CSTL Profile Changes

By the end of the fourth interview, Ben settled down with a coexistence of individual constructivism and social constructivism, depending on the context. On the one hand, as far as an individual level of learning was concerned, firmly grounded in the
Idealist ontological—Relativist epistemological—beliefs, Ben asserted that learning is primarily an individual process. Each individual “constructs his or her own ideas through a subjective sense making activity” (Ben 1). Accordingly, Ben argued, the ultimate goal of learning on an individual level was to “extend your context or to give meaning to your world through organizing and fitting in new experiences with one’s prior knowledge and experience” (Ben 4). Moreover, according to Ben, “learning is almost existential and it is up to students, with their set of experiences and prior knowledge, to learn about these things through constructing themselves” (Ben 4).

On the other hand, when Ben talked about his role as the teacher, he strongly subscribed to “sort of Vygotsky in terms of acculturating students” so that they can “learn a scientific method, learn to give meaning to phenomena of the world outside of themselves where there is a shared meaning, master the scientific information that has come before them for the last centuries and participate in and dialogue in science” (Ben 4). The major point of Ben’s social constructivist views was that “because we are living in a culture and in a society, a certain amount of learning processes are mediated by others, such as parents and teachers, in a culture; otherwise, we will be solipsistic” (Ben 4). In addition, Ben further acknowledged that, in his role as a “mediator or facilitator in students’ learning processes, the teacher should organize processes, content or ideas in such a way that fits with the context of the learner, considering where they are coming from and what are their prior experiences or knowledge” (Ben 4). Eventually, “learning is up to each student to take new data in and fit it with his or her prior knowledge and experiences through a process of self-organization” (Ben 4). Ben went on to say, “after my classes, I want my students to become thinkers and problem solvers, to be able to use
scientific methods, and eventually to come up with some explanation for some phenomena” (Ben 4).

Ben recognized not only individualistic learning processes, but also the need of teachers to mediate or acculturate students into scientific traditions. Therefore, depending on specific contexts, he would emphasize one or the other. This explains his pedagogical beliefs shift between individual constructivism regarding how students learn and social constructivism regarding the role of the teacher.

**Explainers for Ben’s Constructivist Profile Changes**

Asked to provide the most influential factors in helping him form beliefs about teaching and learning, Ben stated, “field experiences are more beneficial than M.Ed. methods courses because teaching is a practice type of profession, just like being a doctor; there is nothing like being out there and practicing teaching in a true life setting because it exposes you to the actual processes of teaching and learning” (Ben 4):

Asked to reflect on the significant changes in himself as a teacher throughout the M.Ed. program, Ben commented, “deep down philosophically the program hasn't changed me. Nothing has presented itself as a reason for any change” (Ben 4):

I guess, I still see myself teaching the way I have always taught and my basic philosophy of teaching is still the same. The M.Ed. program has never changed any aspect of my teaching or philosophy. My basic philosophy is the teacher is a facilitator. I felt that belief for a long time. You have to understand the context of each of your students. (Ben 3)

Moreover, Ben asserted, “my theoretical framework in teaching is more from my prior experiences. I learned how to put names and theories to my previous ideas and views, such as constructivist or conceptual change” (Ben 2). By the end of the third interview, after the autumn quarter field experiences, asked to comment on the feasibility
of constructivism in the real classroom, Ben asserted, “I would like to be able to take a constructivist approach since that is how I believe people learn” (Ben 3):

Another thing, how I can implement constructivism in my teaching depends on how much control I have to do that. Doing that requires still a lot of efforts. You learn it theoretically in the classroom and then you go out and literally experience teaching, can you really make it happen? … It’s still a question I raised to my own mind. It’s still a leap of faith. The essence of what it [Abraham’s story in the bible] is, Abraham is making this leap of faith and then the right thing would be done. (Ben 3)

Asked to explain the apparent lack of belief changes in his profiles, Ben offered that because ontological and epistemological beliefs are “some very core ideas and concepts, I don’t think those change radically.” In addition, Ben asserted that, “in terms of things that I am actually doing in a classroom, I can’t see that I have changed from when I first started” (Ben 4). After examining his CSTL profile, Ben acknowledged, “my beliefs about ontology and my view of how people know things affect the way I teach, the methods and pedagogy and lots of methodology of teaching” (Ben 4).

Concerning how Ben reconciled his Idealist ontological and strong Relativist epistemological beliefs with his science teaching practices, he indicated that his Idealist and Relativist beliefs surfaced “when we get more into a metacognitive pattern of thinking, where we begin to think about how do I really know that.” Ben went on to say, “we all go about everyday lives and we do not constantly say ‘oh, what is that thing? Is that really a door, or whatever?’” That is, Ben contended, “in everyday lives, we do go out and think that, yes, there is an objective world out there that exist independently of our minds” (Ben 4). That is, according to Ben, unless we get a metacognitive level, where we think about ontological and epistemological issues, we just assume that there exists a real world, independently of us and our interests (Ben 4). Accordingly, although Ben’s “true
ideas of our world” were aligned with the Idealist beliefs and he “espoused Relativist epistemological beliefs,” he seemed to assume an independent existence of an external world in his teaching practice (Ben 4).

In the meantime, regarding Ben’s awareness of the three different versions of educational constructivism (i.e., individual, radical and social), he explicated different ontological and epistemological assumptions for each version of constructivism:

Individual constructivism is that individuals construct their own knowledge of the real world through experiences and interactions with the world out there, and metaphysically speaking there is a world out there. That will be individual constructivism. Radical constructivism is more an individual constructing his own reality, but we have no a priori knowledge that there is a real world out there. And social is that through social experience, which mediates construction of our own knowledge, and again we don’t know; there is no a priori knowledge that there is a real world. (Ben 2)

Based on the above interpretation, Ben asserted, “my position is probably more of social, which is probably more close to the Idealist ontological beliefs” (Ben 2).

Overall, although Ben was firmly grounded in the Idealist ontological beliefs and strong Relativist epistemological beliefs, in his real world of science teaching practices, he seemed to take a Realist stand. Accordingly, as a teacher Ben wanted to “mediate and facilitate” student’s individualistic knowledge construction in such a way that student can “construct knowledge in a more culturally accepted view” (Ben 2). Along this line, Ben asserted, “science is a constant move in a direction and so much of that has come from the past; there is a lot of science of the centuries or millennium that has come before you” (Ben 4). Therefore, with the teacher’s enculturation of students into the ideas and models of scientific tradition (Matthews, 1994), “students are not starting from the day one in figuring out gravity” (Ben 4).
Ben compartmentalized his philosophical thoughts under the theoretical, ideological, and metacognitive domain so that his Idealist, Relativist beliefs would not interfere with his everyday teaching practices which seemed to support scientific realism. Therefore, in Ben’s case, it was hard to find any direct connection between his ontological, epistemological beliefs and his views of science teaching and learning. That is, Ben did not directly transfer his Relativist definition of scientific knowledge and idealist ontological beliefs to his conceptions of science teaching and learning. Moreover, this apparent incompatibility did not cause any conflict or uneasiness in Ben’s constructivist profile. By the end of the third interview, Ben expressed, “since so much older than other cohorts, I have had a lot of more real world experiences and understanding... I still want to be a teacher very much. I like to observe human beings.”

Final Summary of the Research: Common Threads Running Through All of the Case Stories

Throughout the study, I have indicated that for the preservice teachers who did experience change in this study, that process was more like conceptual capture rather than conceptual exchange (see Hewson, 1981). That is, in tracing these preservice teachers’ pedagogical perspective changes, I postulated there will be evolutionary conceptual capture processes, rather than revolutionary conceptual exchange processes, understood as a washing out of their previous views of learning, replacing them with constructivist views of teaching and learning. Using the notion of a conceptual profile (Mortimer, 1995) as a theoretical framework, as noted at the beginning of Chapter 3, this study attempted to trace the direction of preservice teachers’ ontological, epistemological, and pedagogical perspective changes that are consistent with constructivist views. What emerged from the
result presented in this chapter corroborate the claim that “a teaching process does not lead to a conceptual change, but to a change in the student’s conceptual profile” where the students “would retain all the ideas that they had before” (p. 282). 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. Thus, being introduced to different ontological as well as epistemological commitments of different versions of constructivism, the preservice teachers in this study revealed some sort of constructivist profile changes as their pre-instructional beliefs coexisted with the new views that are consistent with constructivist ideas through a reorganization of the conceptual structure. Although these preservice teachers shifted to more sophisticated language, provided through their M.Ed. courses, in describing ways of conceptualizing reality and ways of understanding knowledge, different ways of conceptualizing reality coexisted in their constructivist profile to different extents. “Even if individuals move from one category to another on different occasions” (Mortimer, 1995, p. 270), these qualitatively different ways of understanding their reality (i.e., realist, radical, and idealist) apparently coexisted in a preservice teacher’s constructivist profile. For example, in Rob’s case, he held apparently contradictory beliefs in his conceptualization of reality as he incorporated Idealist ontological beliefs without abandoning his previously-held Realist beliefs. These previous beliefs continued to form part of his ontological profile.

In the meantime, when presenting any individual's constructivist profile, we needed to consider the complexities and difficulties that ensue for an individual when trying to express changes in his or her ontology and epistemology. Moreover, the internalization
process of a constructivist epistemology should not be assumed as a total exchange with existing views of teaching and learning. Recall that the preservice teachers in this study were not followed into their student teaching experiences. Therefore, interpreting the fact that this science teacher education program did affect change for five of sixteen students must be done cautiously. While the changes in five students are encouraging, the lasting effects of these changes into student teaching needs to be studied. Likewise, the lack of change in eleven subjects in this study needs to be studied further to determine why these subjects retained their previous views on science teaching and learning.

In conclusion, in examining each preservice teacher’s belief changes using the notion of a constructivist profile as the backdrop, it is important to note that a preservice teacher’s internalization process can hardly be assumed as a total, stark exchange with their traditional teaching and learning paradigm. In other words, although some preservice teachers ontological, epistemological, and pedagogical beliefs profiles did change during the portion of the MSAT program studied here, these preservice teachers remained attached to previous beliefs for a variety of reasons, such as emotional attachment, low status of an alternative theoretical framework (i.e., constructivism) or influences from individuals outside the MSAT faculty. When there was belief change, there was a coexistence of different versions of perspective as each individual continued to differentiate and select a compatible version depending on a given specific context. In addition, upon looking at each preservice teacher’s constructivist profile in light of their conceptual ecology, I needed to consider the complexities and difficulties in changing some of the conceptual ecology components—in particular, difficulties in changing ontological or epistemological beliefs as noted by Hewson (1982), Chinn & Brewer
(1993), and Mortimer (1995). As has been shown in the previous case analyses, some preservice teachers found it difficult to comprehend radical constructivist’s ontological and epistemological perspectives, which in turn led them to reject this version of constructivism.

In the next chapter, the complete study will be reviewed, and the outcomes of the analyses reported in this chapter are summarized.
CHAPTER 6
CONCLUSIONS AND IMPLICATIONS

Introduction

This study investigated preservice science teachers' ontological and epistemological understanding of constructivist notions of science teaching and learning. In particular, this study focused on identifying profile changes in the ontological and epistemological characteristics of each preservice teacher's developing views of learning as they participated in core courses for a science teacher education program. Explainers were sought to determine which activities and experiences in this part of the MSAT M.Ed. program influenced preservice teachers to develop ontological and epistemological beliefs about constructivism and the degree to which these beliefs had implications for pedagogy.

This study was conducted during the first three quarters of enrollment in the MSAT M.Ed. program during which preservice teachers were first introduced to constructivism by MSAT faculty. Views of constructivism formed the basis for much of the instruction that faculty presented throughout the MSAT M.Ed. preservice teacher education program. This chapter contains three major sections. In the first part, conclusions from the investigation are reviewed and significant findings for each research question are discussed. The second part focuses on the implications that this study has for teacher
education programs that present constructivism as a significant component of their programs, as well as research-related connections and issues. In the final section, the limitations of the study are acknowledged, and the consequences of these limitations for further research are discussed.

Conclusions of the Study

A central purpose of this study was to identify changes in the ontological and epistemological characteristics for each teacher's developing view of learning during the first three quarters of enrollment in the MSAT M.Ed. program. Program faculty interview results showed that the majority of the MSAT M.Ed. preservice teacher educators explicitly stated in their syllabi that one of the goals and objectives of their methods courses was to "promote constructivism as a way of understanding how students learn concepts and as a teaching strategy for improving and stimulating students' conceptual changes" (a methods course syllabus, July, 1999). Courses were considered to present constructivist philosophies as one of the major principles guiding the program. Sample course texts included Brooks & Brooks (1993), Ernest (1995), and Tobin (1993). In addition, by allowing the preservice teachers to participate in activities that are blatantly constructivist in nature as learners of science content, the methods instructors wanted these preservice teachers not only to gradually move away from viewing teaching from a student's viewpoint to viewing teaching from a teacher's perspective (Vellom, personal communication, 2000; Hawkey, 1996), but also to implement constructivist-based approaches in their classroom practices. The conclusions to each research question posed in Chapter 1 will be discussed in light of this constructivist preservice teacher education program. The research questions posed in this study were:
1. What are the developing notions of constructivism with respect to ontological, epistemological and pedagogical commitments for the subjects of this study? That is, what are the epistemological and ontological characteristics for each preservice teacher's developing view of learning with the influence of constructivism taught in the core MSAT M.Ed. courses?

2. What experiences including each teacher's prior experiences as well as those within the program contributed to the development of ontological and epistemological views that are consistent with constructivist views of teaching and learning? That is, why do some preservice teachers capture and subsume constructivist ideas while others ignore this position on learning in favor of retaining their previous views of learning?

3. How did changes in the ontological and epistemological beliefs help preservice teachers understand the concepts--constructivist epistemology--better and, in turn, change their views of science teaching and learning?

The conclusions of this study will be discussed in terms of these questions.

Question 1: Preservice Teachers' Profile Changes over Time

Of the 16 interviewees, five significantly changed their ontological and epistemological beliefs throughout the period of this study, which in turn caused changes in their conceptions of science teaching and learning (CSTL). Results from analysis of these five cases in Chapter 5 illustrated which beliefs these teachers held and how their profiles changed. Eleven other interviewees remained unchanged over time and will be discussed as one composite case and one outlier case later. Five preservice teachers, who
showed ontological and epistemological belief changes, shared the following common themes that emerged from the data and a discussion of the findings:

**Constructivist Profile Change**

Throughout the interviews, the five teachers did not go through a conceptual exchange process, but rather a constructivist profile change. This was evident by the coexistence of qualitatively different and sometimes contradictory ontological (e.g., realist and idealist) and epistemological (e.g., absolutist and relativist) beliefs as they incorporated new perspectives without abandoning previous beliefs. This is to say that there was a coexistence of different versions of ontological, epistemological, or pedagogical perspective as each individual continued to differentiate and then select a compatible version depending on a given specific context.

For example, in the interview with Ginny (see Appendix E), although she was aware of and endorsed an idealist ontological position in the third and the fourth interviews, she always reverted back to a realist ontological position whenever she talked about knowledge in the context of natural science or theoretical objects of science such as electrons, viruses, and tectonic plates. That is, when Ginny talked about scientific knowledge, she presupposed the existence of the human independent world that “exerts some influence over the character of knowledge that is constructed about it” (Phillips, 1997, p. 162). When she commented on ontological questions, such as the form and nature of reality, however, she advocated the Idealist position defined in Appendix C. Accordingly, she contended, “only what we can think of can exist; otherwise, it is not there until we have put our language to something” (Ginny 3). Therefore, for Ginny from the third interview, seemingly incompatible Realist and Idealist--and sometimes Radical--
ontological beliefs coexisted in her profile. Depending on phrasing and context of questioning, she swung back and forth between these two incompatible perspectives.

In sum, subjects in this study shifted back and forth between two incompatible perspectives (e.g., the realist and the radical ontological beliefs) depending on what they were talking about. On the one hand, in the context of a philosophical question on the status of an outside world, they endorsed an idealist position. On the other hand, as a science teacher they endorsed scientific realism, according to which scientific theories are subjected to the natural world for verification.

Diversification of Profile Components over Time

After the first quarter in the M.Ed. program, five teachers' ontological and epistemological profiles diversified into more categories showing their awareness of different ontological and epistemological positions other than the Realist or Absolutist positions with which they began the program. For example, after the first quarter, when these teachers were introduced to ontological and epistemological commitments of different versions of constructivism, the preservice teachers in this study revealed constructivist profile changes as evidenced in their pre-instructional Realist ontological beliefs coexisting with the newly incorporated Radical or Idealist ontological beliefs. Overall, the direction of these changes were toward a gradual decrease in the Realist and Absolutist perspective and, correspondingly, a gradual increase in one of the other categories, such as Radical or Idealist ontological position—Piagetian, Fallibilist, or Relativist categories in terms of epistemological beliefs (see Rob’s profiles in Chapter 4 for an example).
**Relationship Between Ontology and Epistemology**

Each teacher's epistemological beliefs were to some extent related to his or her ontological beliefs with the exception of Len's case, which is discussed later in this section. In other words, epistemological differences in the approaches favored by all five teachers fit well with their different ontological assumptions. This conclusion corroborated Prawat's (1997) claim, “If one makes a different ontological assumption about the ‘what’ of knowledge, then a different set of epistemological issues surface” (p. 236).

For example, aligned with his realist ontological beliefs, Rob maintained epistemological beliefs that were consistent with Piagetian--or Absolutist in the second interview--position as the largest component of his profiles during the first two interviews. However, as he articulated his awareness of radical or idealist ontological beliefs, he revealed a relativist epistemological belief during the third and the fourth interviews. For example, in the third interview Rob articulated an idealist ontological position as he claimed that depending on different cultures and societies where people have grown up, people “construct different realities” and have different “perceptions” of an external world (Rob 3). Along this line of argument, he endorsed a relativist position arguing that one’s reality “has meaning in his culture” just as “the witch doctor in the Amazon is accepted within his community even though it might not be accepted within the larger scientific community” (Rob 3).

In Ellen’s case, the Piagetian epistemological position was the largest component in her epistemology profile during the first interview. This position is compatible with the Realist ontological position in her profile (refer to Ellen’s profile in Chapter 5). However,
as time went on, the Piagetian position of Ellen's profile gradually decreased and was replaced by Fallibilism and Relativist beliefs, which reflected and fit with her ontological belief shift away from the Realist and toward Radical and Idealist positions.

In Len's case, in the first and the third interviews, there was consistency between his through and through realist ontological position and his Piagetian or Absolutist epistemological position. In the third interview, aligned with his realist position, Len maintained an Absolutist position as the largest component as he showed faith in current knowledge that moves towards ultimate scientific truth. On the contrary, in the second and the fourth interviews, regardless of his strong endorsement of a Radical or Idealist ontological position, Len consistently maintained a Piagetian or Absolutist epistemological position. Therefore, there was an apparent incompatibility between Len's idealist ontological beliefs with his scientific realism, according to which scientific theories are subjected to the natural world for verification. In addition, during the member check, Len indicated that this incompatibility did not cause any conflict in his constructivist profile and he was not conscious of this inconsistency. As far as I could tell, this inconsistency has not surfaced as a problem in Len's constructivist profile because, to him, those two realms (i.e., thinking of reality in a philosophical sense, and thinking of reality in a science teaching or conducting scientific investigation context) are totally independent and belong to different dimensions. He seemed to be fully comfortable with keeping a boundary between them.

Recovery of Prior Beliefs

After their Autumn quarter coursework and field experiences, where they mainly participated in classrooms as observers and taught at least five full-class lessons, some of
these teachers reverted back to previously held ontological, epistemological, as well as pedagogical beliefs that they brought with them to the teacher education program. In other words, these teachers reemphasized their realist, absolutist, and traditional pedagogical beliefs right after their autumn quarter field experiences. During this first field experiences, they were frustrated by real classroom settings in which students’ resistance to new ways of teaching, time constraints, a certain amount of curriculum they felt required to cover, the amount of lecturing they felt required to do, pressure to prepare students for standardized tests, and missing connections between theory and practice when they met “negative role models” or observed their mentor teachers’ traditional ways of teaching. The six teachers who reverted back to their prior beliefs included Lynda and five of the teachers included in the composite case.

**Awareness of Fallibilism**

All of the sixteen teachers were aware of and endorsed Fallibilist epistemological theses to a certain extent, where Fallibilist views imply that “observations themselves are theoretically dependent or determined,” scientific knowledge is in principle open to revision, and “theories are always underdetermined by empirical evidence” (Matthews, 1994, p. 140).

All the teachers acknowledged that, since the context of discovery as well as the context of justification of scientific knowledge involves humans, scientific theories are vulnerable and tentative. Even the ten teachers who had not shown any significant change in their ontological or epistemological beliefs and thus were subjected to a composite case were not so naïve as to believe that “science is entirely objective” (Young 1). The composite case of “Young” presented in Chapter 5 supports the conclusion that these
preservice teachers were at least aware of the fallible and tentative nature of human knowledge although they endorsed a thesis that "over the course of history, science approaches the truth more closely" (Ernest, 1998, p. 58). The major points of the participating preservice teachers' fallibilist perspective were: no unmediated access to reality (i.e., "no real world except relative to a conceptual scheme" [Searle, 1998, p. 23]); or the theory or value-ladenness of facts, the underdetermination of theory by empirical evidence (Matthews, 1994), supporting the notion of theory falsification over theory verification, our subjectivity in perception or interpretation of the objective physical reality, and representation of the external world by our senses.

Features of the Teachers' CSTL Profile Changes

With the influence of constructivist epistemology, these preservice teachers' conceptions of science teaching and learning evolved and were refined over time as they incorporated various constructivist ideas. The following is a discussion of the common trends within the participating teachers' CSTL profile changes.

Traditional pedagogy as the default. In the first interview, all 16 participants revealed a traditional view of teaching and learning (i.e., a transmission model of science instruction) to a certain extent, which was constructed based on their prior experiences as students in classrooms (Kagan, 1992; Richardson, 1996). In the second interview, 14 out of 16 participating preservice teachers, with the exception of Ben and one of the teachers in the composite case, completely replaced their traditional views with constructivist notions of science teaching and learning in light of the role of the teacher, how to teach, and how to learn. Accordingly, it was rare to find any text unit coded within the traditional pedagogy category for these 14 teachers' CSTL profiles during the second
interview. In addition, it is interesting to note that all the participants, after examining their profiles presented during the member check, expressed their satisfaction with their individual changes that they had gotten away from the traditional category of conceptions of science teaching and learning over time (see Young’s comment in p. 220).

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

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

**Individual constructivism as conceptual change learning.** With the influence of the MSAT M.Ed. program, where most of the faculty taught methods courses using approaches informed by constructivism as noted earlier in Chapter 5, all 16 participants
aligned their CSTL with those recommended by individual constructivism that were represented to them as conceptual change learning.

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

Radical constructivism as a strong individualistic philosophy. As a minor component of their CSTL profile, 13 teachers had von Glasersfeld’s radical constructivist conceptions of science teaching and learning during the second interview (12 teachers in the third interview, and 11 teachers in the fourth interview) as they endorsed von Glasersfeld’s pragmatist (or instrumentalist) views of knowledge as well as a rather strong individualistic philosophy. As Ben stated, "knowledge for its own sake is like knowledge in vacuum" and it should be used "in processes such as critical thinking and problem solving" (Ben 2).

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

Social constructivism as being too ideal to be practical. The social category in these teachers’ CSTL profiles, informed by Vygotsky’s social constructivism, emerged from the second interview during which 13 participating teachers out of 16 held the social component in their CSTL profiles to differing degrees. It is important to note that for 12 teachers out of these 13, the percentage of the total text units coded under the social category gradually decreased from the third interview as they went through the autumn and the winter quarter field experiences where they were frustrated by the constraints of real classroom settings. Regarding pedagogical implications of social constructivism, although many of the participants were fascinated by the way of teaching embodied in social constructivism where students “develop certain common perspectives with regard to objects and events in the world” through communicating with each other (Prawat, 1996, p. 220). The preservice teachers argued that ‘the teacher’s being in a small role as in the social constructivism is too ideal to be practical in the schools’ considering time constraints, the amount of content required to be covered, and what they are supposed to be doing as teachers in classrooms. They also expressed their frustration with student’s
resistance to new ways of learning that were aligned with what social constructivists supported, such as students’ autonomy in knowledge building processes through communication with each other. Refer to Appendix F for major themes of the participants’ CSTL informed by Vygotsky’s social constructivism.

**Constraints on implementing CSTL.** All of the teachers talked about their perceived constraints on implementing their beliefs about science teaching and learning acquired in the methods courses. Some selected constraints include standardized tests, the amount of lecturing and content to cover, time constraints, student resistance to new ways of learning, and the society to which the teachers belong (e.g., “specific beliefs held in society; for example, if you are in Kansas, you probably won’t be able to teach evolution”(Rob 4)). Accordingly, they mentioned that they want to wait until they have full control over their own classrooms. Several teachers indicated that implementing what they learned in the methods courses would be extremely hard in the beginning of their career, not to mention in the field experiences and in others’ classrooms. As Lynda put it:

> My field experience is just ultra-practical, and those methods classes are ultra-not [laughter]. I think the methods courses were fantastic for me just to keep in mind, and to kind of, say [there is a different way and there could be a better way to teach], but in the end, at least in my field experience, I couldn't make a 180 degree turn and try taking some complete constructivist view, so perhaps when I have my own classroom, methods classes might be more useful. (Lynda 3)

This quote indicates that academic elements of the MSAT M.Ed. program could have an impact on these teachers but with a possible lag time (Richardson, 1994).

**Being overly confident in themselves as teacher.** As has been noted by Richardson (1996), three of the participants--Ellen, Ben, and one teacher from the composite story--were “highly confident of their own abilities as teachers” from the beginning, and contended, “there is not much they can learn in preservice teacher education” except
during their field experiences (p. 108). In other words, “deep down philosophically the program hasn't changed me. Nothing has presented itself for a reason for any change” (Ben 4). Moreover, they argued that their ‘theoretical framework in teaching is more from their prior experiences, and they learned how to put names and theories to the ideas and views that they already believed before they came into the program, such as constructivist or conceptual change’ (Ben 2 & Young 2). Overall, they valued the MSAT teacher education program only in that it “helped them to put some vocabulary and words, such as constructivism, to their previously-held beliefs about science teaching and learning, and have put their ideas a little bit more concrete because of readings.” Ellen contended that she came into the program “with a certain perspective and it has been enlightened and enlarged, but not a dramatic change” (Ellen 4). In the meantime, her profile indicated gradual changes in her CSTL, such as a complete replacement of traditional pedagogy with constructivist ideas in the second interview along with a rather strong endorsement of Radical and Social constructivist ideas from the second interview on (see Ellen’s profile in Chapter 5).

Question 2: Explainers for Preservice Teachers’ Profile Changes

The second question of this study addressed the causes of these teachers’ ontological, epistemological, and pedagogical beliefs changes that were presented to answer the first question. In this section, I am interested in exploring what experiences including each teacher’s prior experiences as well as those within the program influenced all 16 participants to develop deep understandings of constructivist ideas. The evidence presented in Chapter 5 supports the following conclusions.
Teachers’ Unawareness of Their Profile

Regarding whether each teacher was conscious of features of his or her profiles and was able to decide where each component is applicable in an appropriate context, all five teachers were not conscious of their ontological and epistemological profile or changes in different components of their profiles. In part, this explains the coexistence of seemingly incompatible ontological as well as epistemological beliefs in these five teachers’ profiles.

As counter examples, Ben and “Young” attributed lack of their belief change to the fact that ‘ontological and epistemological beliefs are some very core ideas and concepts that I have held for a long time and I do not think those change radically’ (Ben 4 & Young 4).

Influences of Prior Experiences on Profile Changes

Each teacher’s ontological and epistemological profile was strongly influenced by prior experiences, such as his or her undergraduate major, courses taken, cultural background, and the opportunities that one had to think over ontological or epistemological issues.

For example, Ellen, Ginny and Ben had once been philosophy majors in their undergraduate studies (or majored in philosophy even in graduate school in Ben’s case) or had taken philosophy-related undergraduate coursework, which led them to gradually relinquish a Realist or Absolutist perspective in favor of an Idealist or Relativist perspective. Rob’s unique cultural background as a Mexican American allowed him to be aware of culturally bounded representations of reality, which in turn led him to endorse a Relativist and Idealist perspective rather than an Absolutist perspective in the third and
the fourth interviews. Similarly, Young’s realist ontological beliefs were firmly grounded in her years of experience as an undergraduate science-major (or science majors in graduate school for some of the participants who were included in the composite case) student and were derived through the apprenticeship of experience in the real world of science practices (“Young”, personal communication, 1999).

**Influences of the M.Ed. Coursework on Profile Changes**

Of the selected factors related to the MSAT M. Ed. program—such as, coursework, field experiences, group discussions with peers, interactions with families, their student-teaching supervisors, and a teacher educator—that helped them to form their beliefs about teaching and learning, the teachers put a great emphasis on the M.Ed. theoretical coursework in that (1) they were ‘unsure of whether they would have come up with some of those ideas on their own if they had gone out into the field experience first’; (2) in the field experience there is a chance that they ‘could not have been placed with teachers that had the same beliefs with this program and thus they might have just kept teaching like they were taught in college’.

In the meantime, Ginny, Lynda and “Young” acknowledged one M.Ed. program professor who taught preservice teachers as “they want us to teach” as one of the most influential factors that helped them to form beliefs about teaching and learning (Lynda 2). In Lynda’s own words:

"He has really challenged me in this area, maybe teaching and learning is not at all what I came in thinking it was. He put some of his theories and ideas into practice and it works in the classroom. He used all sorts of different ways of teaching and he actually incorporated those ways of teaching into his classroom.... he has provided so many different methods and ideas and just general classroom management, and small, little things that he has used and he will use it with us. He will be an example of what he is teaching. And so far, he has been the main one who was an example when he starts teaching. So I think that's what's speaking the loudest. (Lynda 4)"
Influences of Field Experiences on Profile Changes

Some of the teachers particularly valued field experiences—“learning to teach can only be accomplished through experience” (Richardson, 1996, p. 108). They valued the field experiences over the M.Ed. methods courses in that (1) the field experiences provided groundwork for translating theory into practice, where they could actually try things out and do their experimenting with ideas presented in the coursework and then make a link between practice and theory such as constructivism and conceptual change theory; and (2) some were able to watch positive role models (i.e., mentor teachers who have taken the conceptual change theory and implemented it in their own classrooms in practical ways and showed the feasibility of conceptual change model or other theories and ideas in real classrooms). Ben summed up the participants’ belief that “field experiences are more beneficial than M.Ed. methods courses because teaching is a practice type of profession, just like being a doctor; there is nothing like being out there and practicing teaching in a true life setting because it exposes you to the actual processes of teaching and learning” (Ben 4).

Regarding “the most practical way to learn as a teacher,” some of the participants (Ellen, Ginny, & “Young”) recommended the combination of coursework with teaching or observing experiences where they could not only apply theory to practice, but also understand why they needed to know a specific learning theory. This theme corroborated one of Kagan’s (1992) evaluations drawn from her review of ‘learning-to-teach studies’: “the separation of theory--university coursework--and practice was unproductive” (p. 148).
Awareness of Different Versions of Constructivism

Acknowledging having been introduced to constructivist ideas through the M.Ed. program, some of the participants articulated their perceived differences between different versions of educational constructivism (i.e., individual (or weak), radical and social constructivism) in light of von Glasersfeld’s ontological as well as epistemological commitments (Rob, Young, Ellen, Ginny, & Lynda), and different ontological and epistemological assumptions for each version of constructivism (Ben).

In the meantime, prior to their field experiences, most of the teachers identified themselves as social constructivists or endorsed a social constructivist’s ideas in that (1) “Vygotsky perspective” acknowledged, “you can’t separate your environment from your learning experience” and your learning is “determined by the social context which you are developing in” (Rob 2); (2) “My position is probably more of social because it is probably more close to the idealist ontological beliefs” (Ben 2); and (3) “My adopted version of constructivism fell close to the social end because it does take peer interactions and teacher-students interactions to construct their knowledge” (Ginny 2).

Question 3: Relationship between Preservice Teachers’ Ontological/Epistemological Profiles and CSTL profiles

The final question of this study dealt with the relationship between these preservice science teachers’ philosophical beliefs about reality and knowledge and their conceptions of science teaching and learning. In answering this question, these teachers’ developing ideas about teaching and learning were determined to be consistent or inconsistent with their ontological and epistemological commitments. The evidence presented in Chapter 5 supports the following conclusions.
Radical Constructivism's Philosophy

As has been shown in previous case analyses, ten of the participants who were included in the composite case (“Young”) had a hard time comprehending or did not comprehend radical constructivist's ontological and epistemological perspective. This led them to reject this version of constructivism. For example, “Young” sometimes explicitly asserted, “I kind of disagree with the ideas of radical constructivism for they're saying that there is no reality independent of humans. I don’t think it is appropriate for a classroom. I think that view seems rather conceited, I guess, because there are many other things in the world besides humans” (Young 2).

On the contrary, in Ellen’s case, fascinated by von Glasersfeld’s ontological as well as epistemological commitments from the second interview on, she replicated von Glasersfeld’s argument word for word (refer to Ellen’s case in Chapter 5 for a detailed description of her ontological and epistemological position in her own words), and furthermore strongly endorsed pedagogical implications informed by von Glasersfeld’s radical constructivism, which “identify knowledge as a subjective sense-making activity located in learners’ minds and focuses on developing the experiential fitness of learners’ concepts for making sense of their intersubjective experiences” (Taylor, 1993, p. 283).

Perceived Association Between Philosophical Beliefs and CSTL

Most of the participants contended that there should be consistency between their ontological and epistemological beliefs and their conceptions of science teaching and learning expressing comments such as: (1) ‘ontological and epistemological beliefs will always be in the back of one’s mind and they will probably unintentionally come out through one’s teaching and will influence one’s instruction’; (2) ‘how one views the
world definitely influences how one views science and then how one sees science is
obviously going to affect how one presents science to the students'; (3) 'a teacher’s
conceptions of teaching and learning are grounded in one’s beliefs about the nature of
knowledge and how people know things, and that a teacher’s ways of teaching are
intimately related to his or her beliefs about the nature of knowledge’. “Young” summed
up how they think of the relationship between teachers’ ontological/epistemological
beliefs and their conceptions of teaching and learning as follows:

   If you think there is a reality, if you are actually searching for one thing, one way of
   thinking that you think your students should know that reality, then you are
   probably going to do it in lectures. I mean, there is no point in doing group work
   and socializing your students if what you are going to say is what needs to be said
   and what needs to be believed. (Young 4)

Rare Correspondence between Relativist Epistemology and CSTL

It was rare to find a direct correspondence between these two beliefs systems—
Relativist ontological/epistemological beliefs and CSTL—with the exception of Rob’s
case. That is, although five teachers showed significant ontological and epistemological
belief changes, none transferred his or her Idealist ontological and Relativist
epistemological beliefs to his or her views of science teaching and learning, with the
exception of Rob’s case which is discussed later in this section.

In other words, although four (Ben, Ellen, Ginny & Rob) out of 16 teachers
endorsed a Relativistic view of knowledge and had Idealist and Relativist epistemological
beliefs in their profiles to differing degrees, it was hard to find any direct transfer of their
epistemological or ontological beliefs to their CSTL for a variety of reasons.
Accordingly, I could hardly locate any pedagogical statement that was reflective of or
consistent with specific Relativist beliefs. Ellen, Ginny and Ben seemed to reconcile this
incompatibility by compartmentalizing these two belief systems into two different dimensions: endorsing Relativism as a philosopher while enacting Realism as a teacher in their teaching practices. That is, they did not directly transfer their Relativist definition of scientific knowledge and Idealist ontological beliefs to their CSTL. Moreover, as far as I could tell, this apparent incompatibility did not cause any conflict or uneasiness in their constructivist profile.

For example, in Ellen's case, although Ellen subscribed to the Idealist ontology and the Relativist epistemology in the later interviews, in her science classroom, she as a science teacher in a Western society wanted not only to validate the truthfulness of her students' meaning constructions in light of conventional science ideas but also to reinforce the particular view adopted by the science community for her students' own benefit and survival in the Western scientific community. Therefore, it was rare to find any direct correlation between Ellen's Relativist epistemology and her expressed ways of science teaching and learning situation. In Ginny's case, although she strongly endorsed an Idealist and Relativist position as a thinker, she intentionally switched back to and adopted scientific realism as a science teacher. During the member check, Ginny confirmed that she subscribed herself under the Realist ontology in an attempt to show why scientific realism was more appropriate than the Idealist or Relativist views of scientific knowledge within education and within her science teaching methods.

On the contrary, among the four teachers, Rob was the only participant who showed any correlation between his Relativist epistemological beliefs and his conceptions of science teaching and learning. His epistemological preference was reflected on his conceptions of science teaching and learning, particularly on how he viewed how people
learn and how to teach. That is, on the one hand, aligned with his Relativist epistemological beliefs, Rob contended that one of the goals of his science instruction was not to have students 'exchange' their preconceptions with accepted scientific concepts, but to have them know that "they can believe whatever they want to believe as long as they are open to other people's explanations and they come up with justifications and rationales for their points of view" (Rob 3). On the other hand, aligned with his Fallibilist epistemological beliefs, he put more emphasis on teaching accepted ways of doing science by the general scientific populations rather than teaching specific scientific principles and content knowledge. In addition, acknowledging "the acceptance of the witch doctor within his Amazon native community" as well as "different realities constructed by a creationist and an evolutionist", Rob preferred to introduce established scientific theories as no more than an alternative "structure or framework which makes it easier for you to relate to the world around you" (Rob 3). In other words, although every established scientific knowledge claim is validated and accepted by the scientific community, "the non-scientific community does not necessarily always agree with the scientific community" (Rob 4). Along this line, Rob contended that it is important for a teacher to provide "as wide a range of experiences as possible" so that "the student [not only] knows what is the most accepted theory but also knows what other alternative possible theories to something are" (Rob 4).

A Direct Connection between Fallibilist Epistemology and CSTL

The 16 preservice teachers who endorsed Fallibilist epistemological beliefs wanted their students to leave their science classroom "with an open mind to accept that things should be subject to further questioning and possible modification" (Rob 4). That is,
these preservice teachers’ awareness of the fallible, tentative nature of scientific knowledge led them to encourage their students “remaining open-minded by assuming that theories may change in the light of new evidence” (Harding & Hare, 2000, p. 233). This suggests that the participants’ articulated epistemological beliefs about scientific knowledge could directly influence how these preservice teachers wanted to approach their science teaching.

Significance of the Study

This study demonstrated the feasibility of analyzing development of and change in preservice teachers’ constructivist ideas based on the notion of a constructivist profile. The significance of this study is that it attempted to explore different ontological and epistemological assumptions of preservice teachers’ notions of constructivism and the implications of these constructs on their developing views about science teaching and learning.

Grounded in different ontological and epistemological assumptions of educational constructivism, the essential characteristic of this study was that it traced preservice teachers’ development of ontological, epistemological, as well as pedagogical conceptions during the influence of the MSAT M.Ed. preservice teacher education program. That is, the MSAT M.Ed. program provided a personal experience with constructivist views of learning and teaching. The participants who evidenced significant changes in their views of teaching and learning attributed their perspective changes to those who taught the MSAT preservice program by “putting some of [their] theories and ideas into practice” and by incorporating those ideas into the M.Ed. methods classes (Lynda 4). This finding corroborated one of the implications recommended by Gunstone
et al. (1993): “those teaching the preservice program should behave pedagogically in
concert with their principles” (p. 53).

This study provided valuable insights into the feasibility of changing and revealing
preservice teachers’ ontological and epistemological beliefs that are aligned with
constructivist ideas. One of the most significant outcomes of this study was tracing
preservice teachers’ ontological and epistemological belief changes using the notion of a
constructivist profile. The profiles generated through this study have shown the
possibility that a constructivist-oriented preservice teacher education program can
influence not only teachers’ conceptions of science teaching and learning but also their
ontological and epistemological beliefs by explicitly introducing constructivism as an
epistemology--or a specific theory of learning with profound philosophical assumptions
that are different from alternative, traditional behaviorism framework--rather than as a
specific method of instruction. By stating explicitly different ontological and
epistemological commitments of different versions of constructivism, constructivist-
oriented preservice teacher education programs can promote a deeper understanding of
constructivist ideas including constructivist-oriented pedagogical practices.

Before a preservice teacher can adopt and ultimately apply constructivism to
students’ learning, which I argue is inseparable from their views of teaching and learning,
I wanted to know the extent to which these teachers internalize the ontological and
epistemological characteristics of their views of constructivism. For example,
pedagogical implications such as sensitivity to a learner’s previous constructions,
attention to metacognition, and so on should follow from particular views of
constructivism. Along this line, the development of a deeper understanding of changes in
preservice teachers’ developing views on constructivism will be instrumental in
“providing a framework for considering both the learning processes involved in changing
[preservice teacher’s] conceptions, as well as providing a framework for designing
instruction that [might] facilitate those changes” (Hewson & Kerby, 1993, p. 5). That is,
such knowledge is “fundamental to efforts to design preservice models that will be
successful in helping individuals acquire more appropriate conceptions of science
teaching” (p. 6). The findings of this investigation have considerable potential to make
contributions to both instruction of teacher education programs and research.

Implications for Science Teacher Education

The implications for preservice science teacher educators as well as for the
instructional practices of preservice teacher education programs can be summarized in
three points. First, instructors of preservice methods courses should model constructivist
teaching and learning approaches advocated in their programs rather than presenting
constructivist principles and ideas as propositional statements. The importance of this
was indicated by the participants in this study through positive evaluations of their
program and instructors. These preservice teachers identified both as contributing to their
pedagogical beliefs. These participants clearly indicated that consistency between the
teacher education program’s espoused constructivist principles and teacher educators’
actual practices not only challenged their views, but also provided exemplary role models
for learning to teach in a constructivist manner.

Another implication of this research is that preservice teacher education programs
should purposefully place preservice teachers in classrooms with experienced teachers
who not only understand but also use new ways of teaching, such as conceptual change
learning or cooperative learning approaches—and be prepared to discuss opposing beliefs rather than demand blind conformity. The participants were frustrated upon meeting the inconsistency between what was advocated in the university methods courses and what was practiced in their field experiences by their mentor (or cooperating) teachers who favored traditional teaching and “wanted the preservice teachers to become more like them” (Len 4). Faced with this inconsistency and pressure from their mentor teachers, the participants reverted back to their default approaches (i.e., traditional pedagogical beliefs about teaching and learning). It is interesting to note that one participant identified his supervisor as the most influential person who helped him to form his beliefs about teaching and learning in that this supervisor not only “provided experiences from teaching” but also “was open to new ways of teaching with a broad knowledge base in research and instruction” (Len 4). It is also important at this point to recall Lynda’s high inspiration upon meeting her constructivist-oriented cooperating teachers who had taken the conceptual change theory and implemented it in their classrooms in practical ways. These mentors demonstrated the feasibility of the conceptual change model in their classrooms. To reduce the discrepancy between university methods courses and field experiences, a possible approach would be to reeducate in-service teachers through staff development programs that approach learning-to-teach in a constructivist manner (Hollingsworth, 1988; Guyton, 1989; Borko & Mayfield, 1995). Through staff development that is designed to inform experienced teachers about what students teachers learn on campus (i.e., the content and philosophy of university teacher education program) and effective mentoring practices, cooperating teachers could be expected to provide “both an opportunity and an expectation to apply important ideas presented in
methods courses” (Hollingsworth, 1989, p. 181). With the support and encouragement of cooperating teachers, preservice teachers could make the transition between theory learned in the university program and classroom practice by taking risks and experimenting with new forms of pedagogy (i.e., university-sponsored practices) (Hollingsworth, 1989; Bey, 1992; Sudzina, et al., 1997). In trying to teach in different ways than how they were taught throughout their own schooling, preservice teachers could apply new theories and methods (e.g., the constructivist concept of learning) that supplant traditional curriculum (Hollingsworth, 1989; Borko & Mayfield, 1995).

Third, considering the coexistence of different views of teaching and learning documented in this research, teacher educators’ efforts should be exerted so that less emphasis is put on replacement of preservice teachers’ initial traditional pedagogical beliefs and more effort on enhancing preservice teachers’ awareness of different views within their profiles. This in turn would allow them to judge when it is appropriate to use one or another depending on a specific time and context. Accordingly, preservice teaching should focus on changing a preservice teacher’s constructivist profile—increasing constructivist views and restricting other undesirable categories such as traditional pedagogical views—rather than on a conceptual exchange. Moreover, teacher educators should encourage preservice teachers not only to recognize different components of ideas in their profiles but also to apply appropriate components according to each situation. Therefore, although preservice teachers who emerge from this teaching process “would retain all the ideas that they had before” or would have “apparently contradictory ideas coexisting” in their profiles (Mortimer, 1995, p. 282), they will be in a position to decide when and where to use each component of their profiles.
Implications for Research

The development of a system of categories for identifying constructivist ideas (i.e., ontological, epistemological, and pedagogical profiles), and its use in tracing of the development of preservice teachers’ beliefs changes throughout their university coursework, has the potential to contribute to a better understanding of how preservice teachers learn to teach. Thus, two contributions of this study can be anticipated. First, by successfully tracing the participants’ changes in ontological beliefs, epistemological beliefs, and conceptions of science teaching and learning by means of constructivist profiles, this study has validated the feasibility of the notion of constructivist profile and constructivist profile changes as a consequence of instruction in a preservice teacher education program’s methods courses. With more empirical results, the notion of constructivist profile as well as constructivist profile changes will be a valuable theoretical and analytical framework with which to reveal and describe the development of students’ beliefs or ideas where different interpretations and alternative views have been documented.

Second, this study provides a demonstration that different ontological and epistemological stands taken by a preservice teacher have not only on his or her learning of new conceptions of science teaching and learning, but also on her projections of ideal pedagogical practices. That is, specific ontological and epistemological assumptions that a participant held fostered (in Ellen’s case) or hindered (in Young’s case) the development or incorporation of new ideas that were presented in university coursework. One of the initial theoretical frameworks of this investigation was that there are epistemological and ontological differences between different versions of educational...
constructivism. Therefore, some of the participants screened a certain version of educational constructivism that is assigned to different ontological and epistemological categories than their own ontological and epistemological beliefs. On the other hand, it is important to note that, as some of the participants claimed, a given ontological or epistemological belief could support many different pedagogical practices or no practices at all regardless of whether or not the teacher is conscious of the configuration of his or her ontological and epistemological profiles. With the constructivist profile as an analytical framework, a better description of the relationship between a teacher's beliefs about nature of knowledge (or reality) and his or her conceptions of science teaching and learning can lead to a restructuring of science teacher education methods courses based on this understanding.

Limitations of the Study

This study is limited by a number of factors. This was the first attempt to use the notion of a constructivist profile to trace the development of preservice teachers' constructivist ideas. For the purpose of this study, constructivist ideas include not only the constructivist learning theory part of the epistemology, but also ontological issues in any analysis of constructivist epistemology. When presenting any individual's constructivist profile, we needed to consider the complexities and difficulties that ensue for an individual when trying to express changes in his or her ontology and epistemology. Considering each version of educational constructivism is ontologically as well as epistemologically different from the others, the ontological and epistemological commitments of each participant led to unique responses as he or she developed understanding of constructivist ideas. As a participant moved through his or her unique
profile configurations, the difficulties in incorporating the ontological and epistemological categories that a specific version of educational constructivism is assigned impeded or fostered his or her internalization process of that constructivist idea.

Another limitation of this study resulted from unique characteristics of the MSAT preservice teacher education program. The MSAT M.Ed. program not only introduced the vocabulary of constructivism such as individual (or weak), radical, and social constructivism with which the participants defined and named their pedagogical beliefs and their thoughts on teaching and learning, but also provided philosophical groundings in constructivism including ontological and epistemological backdrops of constructivism (see Chapter 4, Contexts of the study: the MSAT M.Ed. program). Modeling approaches to constructivist teaching and learning strategies (e.g., conceptual change learning, cooperative learning, etc.) in constructivist-oriented preservice teacher education programs are not rare (Richardson, 1996; Gunstone et al., 1993). However, I could not locate any learning-to-teach research that documented a preservice teacher education program that entailed the introduction into ontological and epistemological commitments of three different versions of educational constructivism and professional vocabulary of constructivist ideas (e.g., viability or no unmediated access to reality of radical constructivism, apprenticeship of social constructivism, etc.) through course readings and whole class discussions. This uncommon characteristic as well as the exemplary instructors of the MSAT M.Ed. program may or may not exist in other constructivist-oriented preservice teacher education programs.

Another limitation occurred as a result of the design of this research. Recall that the preservice teachers in this study were not followed into their student teaching
experiences. In other words, although some preservice teachers’ ontological and epistemological beliefs did change during the portion of the program offered by MSAT faculty, the other 11 teachers remained attached to their previous ontological and epistemological beliefs for a variety of reasons. For the preservice teachers who did experience change during the course of this study, that process was more like constructivist profile change through the process of conceptual capture rather than conceptual exchange (see Hewson, 1981). Interpreting the fact that this science teacher education program did affect change for five of sixteen students must be done cautiously. While the changes in five students are encouraging, the lasting effects of these changes following exposure to constructivism by MSAT faculty need to be studied. Likewise, the lack of change in eleven subjects in this study needs to be studied further to determine why these subjects retained their previous views on reality, scientific knowledge, and science teaching and learning.

Recommendations for Further Research

What can be summarized from this research is that a constructivist-oriented preservice teacher education program can help preservice teachers change the configuration of their constructivist profiles that represent their ontological, epistemological and pedagogical belief systems. Moreover, the features of this constructivist teacher education program were that it was firmly grounded in constructivist epistemology and had exemplary methods courses instructors who behaved pedagogically in concert with constructivist epistemology or constructivist theories of learning.
Continued examination of changes in preservice teachers' beliefs towards constructivist ideas (epistemology) will provide important implications for understanding the extent to which future teachers can internalize contemporary constructivist epistemology, which in turn lead them at least to try to implement constructivist theories of learning and teaching in their science classrooms. Therefore, further research is needed to inquire more into characteristics of constructivist teacher education programs, including the settings and the dynamic interactions that occur between teacher education faculty and preservice teachers, curriculum, and instructional activities (e.g., topics of discussion, logistics and patterns of discussion, group activities, group evaluation, etc.) throughout the programs that approach learning to teach in a constructivist manner.

Further research is also needed to answer questions such as would the participants’ ontological and epistemological beliefs and their beliefs about teaching and learning be consistent throughout their student teaching as well as teaching practices in their own science classrooms? That is, longitudinal, extended studies of teachers who move from preservice teacher education into teaching practice are needed to understand the relationship between beliefs and practice, and to what extent teachers could translate (or transfer) their changes in conceptions of science teaching and learning into changes in teaching practices. Moreover, how do changes in teachers’ beliefs and practices towards constructivist ideas affect students’ learning? To answer this question, as Richardson (1996) contends, further research that “moves beyond descriptions of preservice teachers’ beliefs and conceptions and toward the observation of teachers’ actions in the classroom and their students’ developing understandings” (p. 114) is necessary.
Finally, as noted earlier in the conclusion section, 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 is needed to find out characteristics of exemplary teacher educators or what factors are associated with exemplary teacher educators in terms of their beliefs about teaching and learning, dispositions and practices.

Concluding Remarks

This study has demonstrated that the notion of a constructivist profile change has significant potential for informing the analysis and description of preservice teachers’ ontological, epistemological, and pedagogical beliefs that are aligned with constructivist ideas. On the one hand, this study has corroborated the assertion that each individual’s deeply entrenched ontological and epistemological beliefs are very hard to change (Chinn & Brewer, 1993; Chi, 1992). On the other hand, the possibility that change in a preservice teacher’s profile can occur has been verified. Although these ontological and epistemological profile changes were limited to five teachers out of 16 participants, these changes were possible with an explicit discussion and evaluation of variations in constructivist epistemology through theoretical coursework in a preservice teacher education program that attempted to advance constructivist philosophies—or a program designed to develop a constructivist perspective on teaching and learning.

The overall conclusions drawn from this research are that introducing preservice teachers to the constructivist epistemology is more than encouraging preservice teachers’
internalization of constructivist teaching methods. For teacher educators in constructivist-oriented preservice teacher education programs, it is trying to provide preservice teachers with not only a language of constructivism, but also challenges that allow preservice teachers to evaluate and change their ontological, epistemological, and pedagogical conceptions and beliefs in a worthwhile direction. For the researcher, it is trying to understand the reconfiguration of teachers’ constructivist profiles throughout their ongoing learning-to-teach processes. The overall implications of this research are that preservice teachers should be aware of coexisting different categories of their ‘learning-to-teach’ profiles, and that teacher educators should provide these preservice teachers with instruction designed to affect change in their ontological and epistemological beliefs as well as change preservice teachers’ profiles towards increasing constructivist views of teaching/learning and restricting other undesirable categories.
APPENDIX A

Letter of Exemption from Human Subjects Committee Review and Participant Consent Form
APPLICATION FOR EXEMPTION FROM HUMAN SUBJECTS COMMITTEE REVIEW

All research activities that will involve human beings as research subjects must be reviewed and approved by the appropriate human subjects review committee, or receive exemption status, prior to implementation of the research.

Principal Investigator: Beeth Michael E. (Must be OSU Faculty) (Typed name) Last First Initial (Signature)

Academic Title: Associate Professor Phone No. 292-5377 Fax No. 292-7695

Department: School of Teaching and Learning Department No. 1275

Campus Address: 333 Arps Hall Room Number Building 1945 N. High St.

Co-Investigator(s): Kwak Youngsun Last First Initial (Signature)

PROTOCOL TITLE: Preservice Science Teachers' Pedagogical Perspectives on Constructivism

THE ONLY INVOLVEMENT OF HUMAN SUBJECTS IN THE PROPOSED RESEARCH ACTIVITY WILL BE IN ONE OR MORE OF THE EXEMPTION CATEGORIES LISTED ON THE BACK OF THIS APPLICATION.

CATEGORY: (Check one or more) #1 XX #2 XX #3 #4 #5 #6

SOURCE OF FUNDING FOR PROPOSED RESEARCH: (Check A or B)

A. OSURF: Sponsor RF Proposal/Project No. NOV 5 1993

B. Other (Identify) Private funds of PI and Co-Investigator

EXEMPTION STATUS: APPROVED DISAPPROVED* *

Date Chairperson

* Principal Investigator must submit a protocol to the appropriate Human Subjects Review Committee.

** IMPORTANT NOTICE TO INVESTIGATORS: Exempting an activity from review DOES NOT absolve the investigators of the activity from ensuring that the welfare of human subjects in the activity is protected and that methods used, and information provided, to gain subject consent are appropriate to the activity.
Preservice Teachers Consent Form
MSAT M.ED. Program Preservice teachers
1999-2000 Academic Year

Youngsun Kwak, a doctoral student, and I, a faculty member at The Ohio State University, are interested in studying how preservice teachers construct their teaching pedagogy throughout their M. Ed. coursework. We invite you to participate in a research study that will attempt to determine how you internalize the constructivist pedagogy that will be taught in your M.Ed. methods courses. In order for us to conduct this study we would like to ask all of you to participate in four times of individual interviews about how you respond to the constructivist pedagogy implemented in the M. Ed. methodology courses. Your participation is voluntary and we will not give you any extra assignments or be involved in determining your grades for the classes. Our involvement in your M. Ed. methods courses will last for three consecutive quarters and you will be interviewed periodically throughout the three quarters.

Interviews will be conducted at each of four points during the next three consecutive quarters of the M.Ed. program: in the first week of the first quarter of course work (maximum 45 minutes), at the end of the first quarter of course work (maximum 30 minutes), at the end of the second quarter (maximum 45 minutes), and at the end of the third quarter (maximum 60 minutes). Additional time, outside of scheduled class time, will be requested of science preservice teachers volunteered for the interviews (approximately total 180 minutes/subject). Youngsun Kwak will conduct all interviews outside of the scheduled M.Ed. courses at each interviewee’s convenience. Only the interviewee and Youngsun Kwak will be present during the interview. All interviews are to be conducted in the office of Youngsun Kwak, Arps Hall Rm. # 258 of the Ohio State University.

In addition to voluntary interviews, all of the science preservice teachers, agreeing to participate in the study, will complete a survey of the CLES (Constructivist Learning Environment Survey) questionnaire, requiring approximately 5 minutes of class time at each of three points during three consecutive quarters in their M.Ed. program: on the first day of the first quarter, at the end of the first quarter of course work, and at the end of the third quarter.

We would very much appreciate your agreement to participate in this study. If you agree to be in the study, please sign your name on the line below. You are free to withdraw consent at any time and to discontinue participation in the study without prejudice to yourself.

Please sign your name in the space below if you want to volunteer for the interviews. This form should be returned to Youngsun Kwak by the end of the week. If you have any questions about this study, please contact Michael Beeth or Youngsun Kwak at the phone number or e-mail address below.

Date: ___________________ Signed: ___________________

(Participant’s Signature)
Information for Participants:

This study is approved by the section head of the MSAT section (Dr. Karen Zuga).
No participant will be identified in any publication arising from this study.
The study will occur for three consecutive quarters.
No student will be evaluated by us for the purpose of assigning grades and we will not
influence any course grades given by the methods courses instructors.
A copy of the results of the study will be made available to the Ohio State University.

Respectfully,

Michael Beeth
333 Arps Hall
1945 N. High Street
Columbus, OH 43210
(614) 292-5377
beeth.1@osu.edu

Youngsun Kwak, ABD
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APPENDIX B

Interview Protocol for the First Interview

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

Protocol:

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

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

P2: What do you think the students learn in each situation?

P3: How is he learning it?

P4: Could this kind of learning happen in a classroom?

P5: How do you judge if students have learned?

P6: Can and should everybody learn the same things in school?

P7: If you had to help students learn science, what approaches (strategies) would be most helpful?

Items:

1. [Handing out crystals] Teacher in a middle school at the start of a topic on crystals, asking the class, "What can you tell me about the crystals I've passed around the class?"

2. [Student watching TV] A student at home watching a TV program on chemical plants which produce new plastics from coal. (Or, watching the Discovery channel which shows El Nino and related global weather anomaly).

3. [Students in library doing problems] Two 10th grade students in a library working on a set of vapor pressure problems from the chemistry textbook given for homework.

4. [College professor and first graders] College professor lecturing on molecular orbital theory to a small group of first graders. Or, College professor lecturing on integral calculus to find the areas of regions bounded by curves for which no standard area formulas are known to a small group of the gifted (ages 5 to 6).

5. [Teacher describes algorithm] Teacher in front of 10th grade chemistry class, describing the steps used in balancing oxidation-reduction equations by the method of half-reactions.

6. [Teacher questioning student statement] Teacher reads a 10th grade chemistry student's statement that "Ideal gases have no volume" and asks, "Were you referring to the gas particles or the gas as a whole?"

7. [Teacher asks students to label diagram] Teacher at end of a demonstration of the electrolysis of water distributes a drawing and asks students to label the apparatus used in the experiment from memory.

8. [Student asks question] Junior high school student in class, watching an experiment on the electrolysis of water which has been going for some time asks the teacher, "Do you think you've got all the oxygen out of there yet?"

9. [Student making muffins] A student at home following a recipe for blueberry muffins.

10. [Teacher locating error sources for the following day's experiment] A teacher, conducting an experiment by himself to locate possible error sources after school.

11. [Teacher searching for weather map data] A teacher, searching Internet Web site at home to locate local weather map raw data that is to be analyzed meteorology class.

Part 2: Ontological Beliefs

[Open-ended questions]

O: What is scientific knowledge?

P1: How is scientific knowledge arrived at?

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

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

--- And if there is, how does it exert its influence?
P4: Does the natural world in some way constrain what we can believe about it?
P5: In your view, what is the difference between the real objects of science (the world such as falling apples, planets, or a rusting iron bar) and the theoretical objects of science (the material and events as described by the theory such as a point mass, gravity, mutation, inertia, or photosynthesis)?

[2a: Preferred argument: Provide the preservice teachers with alternatives]
Protocol:
In your view, which of these two positions is similar to your own perception of the world? Would you be able to choose one argument over the other as your own opinion?

A: The material world (objects of knowledge) as a real structure exists independently of our knowledge of their existence. Therefore, theories refer to real features of the world and science has discovered a human-independent world, including the world of unobservable entities such as electrons, viruses, and tectonic plates. Reality here refers to whatever it is in the universe (i.e., forces, structures, etc.) that causes the phenomena that we perceive with our senses.

B: The world (reality, real objects) does not exist independently of minds. Either there is no world outside of human experience, or such a world (including human experience) is all ideational and is constructed or constituted by our discourse and theorizing. The world is always interpreted through mind and there is no unmediated access to the world. That is, our representations, regardless of individual or social, are all we really have.

[2b: Forced-choice questions: Provide the preservice teachers with alternatives]
Protocol:
In your view, how does the knower come to know about the world considering the status of the world of nature external to the knower? Would you be able to choose one argument over the other as your own opinion? Discuss or comment on these options one by one and then finally choose one as your own position?

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

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

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

D: The world, like a literary text, is open to multiple interpretations. The language members of particular discourse communities agree on what is considered reality. The objects of science are taken to exist only within these systems of thought and culture. It is meaningless to speak about the absolute reality of scientific objects. A reality existing outside of language may exist but there is no way to get at it other than through a community’s way of talking about it.
Part 3. [Epistemology: How do preservice teachers view scientific knowledge]

[Open-ended questions]

O: Are science principles in textbooks always true?

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

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

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

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

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

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

P7: Learning science for you is more like.... Following a recipe/ a mixture of memorizing words and facts/ understanding things that didn’t make sense before/ etc.

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

[Forced-choice question]

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

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

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

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

D: External nature plays a decisive role in shaping what we know about it. Nature somehow “leaks in” and acts as a constraint in our knowledge-constructing activities. As a result of interacting with the real world, we only construct those ideas that are in some logical sense “isomorphic” with nature.

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

Part 4: View of learner: the process by which knowledge is constructed

[3a: Preferred argument: Provide the preservice teachers with alternatives]

Protocol:

In your view, how does each learner learn knowledge?

What are the mechanisms by which a learner learns?

Would you be able to choose one argument over the other?

A: The student is really a solitary inquirer, valiantly struggling to build up a cognitive apparatus and a set of cognitive content on his or her own.
B: The learner is guided in these personal cognitive labors by teachers, parents, and peers. That is, individuals are influenced in their knowledge-learning efforts by members of the social group (social influences) to which they belong.

Part 5: In terms of conceptual change theory (or approach): on CCM itself, based on the difference between children's science and scientists' science

O: Compare scientists' doing research in a new area of scientific inquiry (scientists' construction of scientific knowledge), in which no one knows about something therefore there is no one to tell them the answer, with students' lab experiment (students' constructivist learning or teachers' constructivist teaching of science)?

P1: Do you see any difference?
P2: In the lab experiment situation, in your view,
   What's the role of teacher?
   What's the role of students?

Part 6: The role of teacher

[6a: Open-ended questions]

O: In your view, what's the ideal role of the teacher?
P1: How would you describe yourself as a classroom teacher?
P2: What role model do you have for yourself as a classroom teacher?
P3: What do you consider to be the founding principles of teaching?

[6b: Forced-choice questions: Provide the preservice teachers with alternatives]
Protocol:

In your view, what's the ideal role of teacher?
Would you be able to choose one argument over the other as your own opinion?
Discuss or comment on these options one by one and then finally choose one as your own position?

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

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

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

D: The teacher, as a more knowledgeable other, structures the learning experience in a way that allow students to overcome whatever limitations might impede their attainment of a desired learning
goal. The teachers, as cultural representatives, present “ideal forms” for the child to emulate.

**[Teacher's role]** Teachers, as experts, model scientific methods for students, highlighting the verbal and physical moves that constitute mastery of the process. Teachers mediate between students and the public standard. Scientific understanding and modes of thought require initiation into a scientific tradition, an initiation provided by school science teachers.

E: To steer or funnel the students towards the accepted scientific interpretation or solution by deciding what is sense and what is nonsense. In doing so, the teacher evaluates the students' ideas (solutions) with respect to a standard interpretation that the teacher has in mind. Or, the teacher is obligated to acculturate her students to the scientific ways of knowing of the wider community.

**[Teacher's role]** If the teaching is to lead pupils towards conventional science ideas, then the teacher's intervention, both through providing appropriate experiential evidence and making the theoretical ideas and conventions of the science community available to pupils, is essential.

**[6c: Past experience of teacher’s role: Provide the preservice teachers with alternatives]**

P1: Do any of these describe your previous teachers?
Can you tell me about that?

**Part 7: Metaphors**

O: Do you have any preferred metaphors of teaching?
P1: Do you have any preferred metaphors of learning?
P2: What role do you see yourself playing as the teacher?
P3: When you picture a good learner in your mind, what characteristics of that person lead you to believe that he or she is a good learner?
P4: What role did you adopt as a student during your own schooling?
P5: Could you give me some exemplary situation when should the teachers exert their authority in terms of learning (knowledge)?

**Part 8: Personal History**

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

Structure of Analysis Scheme: Definitions of Coding Categories and Exemplary Quotes for Each Category

<table>
<thead>
<tr>
<th>Coding/Analysis Category</th>
<th>Definition/Exemplary Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontological Beliefs</td>
<td>Ontological beliefs include any statements related to the status of the mode of existence of types of entities in the world. This category included any statements in which preservice teachers are commenting on the status of reality or the existence of scientific objects. That is, any comments concerning “the issue of the relation between our ideas and the nature behind them” (Phillips, 1997b, p. 176) and any philosophical claims about reality.</td>
</tr>
<tr>
<td>Realist: an ontological position advocated by Piaget</td>
<td>According to the realist, the material world (objects of knowledge) as a real structure exists independently of human experiences and knowledge. Realists maintain that science has discovered a human-independent world, including the world of unobservable entities such as electrons, viruses, and tectonic plates (Matthews, 1994; Nola, 1997). Realism consequently presupposes a ‘representational correspondence’ between mental representations and whatever they represent in the world (Bickhard, 1997).</td>
</tr>
<tr>
<td>[Exemplary Quotes]</td>
<td>I think that there’s some sort of material universe and that human perception might change that reality, but there’s still an independent reality that still exists…. So I mean I think if humans weren’t here, the universe would still exist with everything in it. I only believe that the world will go along without us and these natural processes are real and they are happening whether we think about them or not. (Young 1) Yes, the objects are there and they're here before we're here. The objects are there whether we see them or not. (Len 2) If humans weren't on the earth, it seems logical and reasonable to me, that the earth could still be here, and it would still exist…. human experience has not been around for that long compared to the age of universe. There is a world out there, real objective form that exists. (Young 2) There are existing physical entities and those entities are independent of humans…. and we may not be able to know that objective reality completely, but that doesn't mean that there is not an objective reality out there. (Young 3) I would say, yes, there is an objective reality... [and] ultimate truth is more or less the same thing as an objective reality. (Young 4)</td>
</tr>
<tr>
<td>Radical: an ontological position advocated by von Glasersfeld's radical constructivism</td>
<td>This ontological preference is newly developed in this research to depict von Glasersfeld’s radical constructivist’s ontological position according to which there is a reality but there is no way to directly access that reality (no extraexperiential reality). In a sense, what radical constructivism denies is the possibility of any certain knowledge as a representation of the world, not the existence of the physical world; therefore, radical constructivism could be assigned an ontologically neutral position (Ernest, 1993).</td>
</tr>
<tr>
<td>[Exemplary Quotes]</td>
<td>I most liked the reasoning and argument with von Glasersfeld's constructivism [where] he talked about people's knowledge of reality and everybody constructs...</td>
</tr>
</tbody>
</table>
their individual reality based on acceptance of their social community, also an influence of social community. I thought that again von Glasersfeld explained it well that it probably, there is a reality that exists independently, but there's no unmediated access to the world... The reality that everyone is seeing is based on their experiences, their conceptions, and their interpretations. (Ellen 2)

I think it's the best fit; whatever theory best fits with the information that we receive from different technologies is the best scientific theory. (Ellen 3)

I would say, you have your world of images and you never really have access to the reality... everything is a construct, everything is, whatever interpretation we give it, we do agree on things, but we all have different filters, and that's going to affect the way that we assimilate information. (Rob 3)

To begin with, a reality is merely an agreement on a particular idea and so people don't agree then maybe each reality is real to that individual, but you can't say more about it than that. (Len 4)

**Idealist:** an ontological position advocated by Social constructivist

**[Definition]**

Idealists maintain that either there is no world outside of human experience, or that such a world, including human experience, is all ideational and is constructed or constituted by our discourse and theorizing.

**[Exemplary Quotes]**

Basically I feel that we're exposed to stimuli or phenomena, about which their existence we really don't know, all we have is our stimuli, and throughout thought processes if you reflect on it, and you give meaning to those phenomena to the sense, and outside of that meaning that we can think of nothing. (Ben 1)

Every individual constructs their own reality [where] the social plane and that becomes a mediator of our phenomena or knowledge. (Ben 2)

I am not saying actual objects do or don't exist; we don't know.... All that I have is the phenomena that present themselves.... All that I know is about phenomena that I see, I feel, I smell, taste, touch, whatever, those are the only things that I can say really exist, then I get those senses I reflect on my thought processes reflect on them, and I give meaning to them. We, you and I give the same meaning to [that's white]; that's a cultural reliant thing, what the word 'white' represents.... We culturally have defined it as blue so I am going to call that blue too regardless of whether it appears to you exactly the same as it appears to me or to the next guy. I am a phenomenologist. (Ben 3)

If we can't talk about it, then they can't exist but until we find the language, until we're able to talk to someone else about it, they don't exist in a true sense. (Ginny 3)

Our reality is defined by humans, so, if all humans agree on something, on one particular thing then that is reality as humans know it, but if there is some other form of life that can show us that we are wrong then we are wrong, but reality is merely an agreement by humans whether something is real or not. (Len 4)

I also think that we are determined more or less by our social interactions, by environments that we grow up in, the negotiation, and all of this forms our world; our language sculptures our world; our relatives, our family, friends and all those things have an influence on who we are and how we come to see the world. (Rob 4)

**Epistemological Beliefs**

This category includes any statements related to epistemological issues such as "what counts as knowledge, how this is produced and warranted or justified" (Phillips, 1997b, p. 162), and the role of reality in knowledge construction, as well as any statement revealing what each interviewee's view of the relationship of her own epistemological commitments to each version of constructivism.
(Progressive) Absolutists hold that over the course of history, science approaches the truth (Truth) more closely. That is, the replacement of old scientific theories by new ones is a progressive step toward the ultimate truth about the world and how it works (Ernest, 1998). Moreover, scientists could work in science because they have faith in progressive absolutism, and tend to believe that “increasingly accurate approximations can be made to account for the world and how it works” (AAAS, 1989, p. 26; Harding & Hare, 2000).

According to Piaget, “as a result of interacting with real structures in the real world, the inquiring child will come to construct his or her internal cognitive structures that, while not copies of those in the world, will be logically isomorphic with them” (Phillips, 1997b, p. 183). Piaget “is admitting that external reality is playing a role in constraining and shaping the views we construct about it” (p. 184), but “nature does not uniquely and unequivocally determine” our interpretations or 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).

Our sense or perceptions don't actually change what we're observing to such an extent that is completely different from what actually exists... and so the cognitive structure and the actual world are probably pretty similar, but not exactly the same. (Young 1)

I don't think that our knowledge of that world is passive thinking... we are constructing that knowledge, we've interpreted our reality and imposed sort of with most viable interpretation of what we interact with. (Ellen 2)

We judge whether a theory is valid or invalid based on how well it supports the evidence of what we know of the world.... human beings are creating scientific.

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theories to explain what's in nature... and I think you have to come to terms with nature and nature is probably our defining criteria. (Ginny 4)

I don't think there is ultimate scientific truth. I think there is a point where you integrate more and more things and you expand your base of knowledge but I don't know that there is an ultimate scientific truth. I do think that the nature does play a role and shaping what we know about it because we base ourselves on phenomena that we observe to create laws and explanations. We are trying to come up with, say, a dictionary of explanations for things and we have to change things in that dictionary. We have to cross things out or we have to add parentheses and put something more in there or maybe we have to put a little drawing of something new that has come about. So it's kind of like a book that we are constantly editing. We are changing things in the book all the time based on things that are happening. Some things have made more constant over longer period of time. Other things are more susceptible to change. There is no absolute, ultimate scientific truth. There is no final answer. (Rob 4)

Fallibilist

[Definition]
Fallibilism is “an epistemological position that is opposed, on the one hand, to (the epistemological position of) relativism and, on the other hand, to absolutism” (Matthews, 1994, p. 37). Fallibilists maintain that scientific knowledge is fallible and controvertible (tentative), and can never by regarded as beyond revision. Our knowledge is always provisional in that it is always open to confirmation, elaboration, revision or change.

[Exemplary Quotes]
I believe that everyone filters that reality through their senses in different ways, depending on what they know, what they don't know, their current emotion state, and some other factors like that. (Young 2)
I think that the knower must interfere what he or she was hoping to know. (Ellen 2)
I think that scientists bring their own perception to a problem, so they can be looking the exact same thing and see two different things.... Science is not entirely objective. I believe that scientific truth is fallible and controvertible. It's been proven in many instances over the courses of the history that our knowledge is open to confirmation and elaboration or revision or change.... But definitely the fact that it's never beyond revision and I guess that's one of the things that science is, that it's open for confirmation, open to be disproved. Otherwise it wouldn't be a science. (Young 3)
Scientific truths are just things that have not been disproved. Just because we haven't been able to disprove, it doesn't mean that it's absolutely true. (Len 3)
Science by definition never really reaches as fact so that we can never prove anything, we can only disprove it. So I do think it's always in a revision. (Young 4)
We should not stick to something and say this is never going to change.... so you want to always leave them with an open mind to accept that there is nothing that is absolute or setting stone. Things should be subject to further questioning and possible modification. (Rob 4)

Relativist: an epistemological position advocated by social constructionism

[Definition]
Relativists hold that knowledge is constructed within a particular community. Following from Kuhn's picture of science, relativists maintain that no reliable comparison can be made between competing views since different paradigms construct different natural universes and there is no one way that the world is. At an extreme end of this position, some strong social constructivists contend, "the natural world has a small or non-existent role in the construction of scientific
knowledge" (Phillips, 1997b, p. 190).

[Exemplary Quotes]
We give meaning to phenomena, the outside world.... everybody tends to try to define their own, define their own world and science becomes part of that. (Ben 1)
Social experience mediates construction of our own knowledge and again there is no a priori knowledge that there is a real world. I think every individual constructs one's own reality so to speak. But yet through social interaction, the phenomena of social interaction, through seeing the similarities, we felt the social interaction, the social plane and that becomes a mediator of our phenomena or knowledge. (Ben 2)
What you consider to be rational or logical depends on the culture and society.... for example, the witch doctor in the Amazon or medicine man in the Amazon, would you call it subjective scientific knowledge? It's not accepted in the sense that nobody has done studies to see, you know certain drugs have, but, I would call that accepted within his community. If you have a witch doc, a medicine man, who cures people because he knows a lot about interactions of plants and stuff. It is accepted within his community even though it might not be accepted within the larger scientific community. (Rob 3)
I think that's true for the scientific community.... that would have to be the scientific community that decides the acceptance of every knowledge claim .... [however] the non-scientific community doesn't necessarily always agree with the scientific community. (Rob 4)
The observations fit with the context of everybody in... [and] theories are our social constructs. (Ben 4)

CSTL/Options
Driven by their ontological and epistemological perspective, individual, radical, or social constructivists have different sets of ideals in terms of their views of science teaching and learning, views that guide their instruction. Each set of ideals include statements related to how they think people learn, what is involved in learning and teaching science, what the central focus of planning instruction is, what an individual (radical or social) constructivist teacher would be like, and, sometimes, what instructional approaches they adopt, which has to do with their view of how people, specifically students, learn.

Traditional
[Definition]
Inferred pedagogical implications adopted by the authoritarian, teacher-centered, transmission model of science instruction, so called ‘banking model’ of education (Matthews, 1994, p. 138).

[Exemplary Quotes]
[the teacher] try to organize the material because for most of these fields there are such a variety of information.... [the teacher] try to condense, nicely round a variety of topics and organize them so that the students can understand them... give them real taste of all the fields, each science. Science teaching would involve transferring knowledge effectively; at the end of the lesson, it’s important to grab things together and make sure that people leave with the same concept. (Young 1)
If they're paying attention, they will learn it... teaching is transferring knowledge or skills or concepts from one person to another... learning is receiving the same things, information, and concepts. (Ellen 1)
The founding principles of teaching is passing on knowledge [because] the students need the knowledge to live their everyday world. (Ginny 1)
I think the teacher should let the students know what the teacher expect them to
Piaget's Individual

Know and I think because of time constraints the teacher needs to use expert accounts provided by other disciplines.... the role of the teacher can be a mentor, I feel often times, the role model of students, for the students to look up to, and a source of information. (Young 3)

Learning occurs basically through students' taking in knowledge that I try to pass on to them. And I plan on, I like to set up an environment where students know what's expected of them, and they can just come in and perform an activity after I show them what they are supposed to do. (Young 4)

[Definition]
In this view, the teacher is obligated to acculturate her students to the scientific ways of knowing of the wider community. In other words, the teacher is necessarily an authority in that she has to guide the institutionalization of scientific activities in the classroom. This is because many, if not most, things in science are beyond the experience of students and the capabilities of school laboratories to demonstrate (e.g., the cellular, molecular, atomic, and most of the astronomical realm). Students cannot generate these ideas for themselves. If the teaching is to lead students towards conventional science ideas, then the teacher's intervention, both through providing appropriate experiential evidence and making the theoretical ideas and conventions of the scientific community available to students, is essential (Driver, 1989, p. 92). “Many of the constructivist teaching programs, such as Driver's work at Leeds, and much of the conceptual change literature” fall within this category (Geelan, 1997, p. 21).

[Exemplary Quotes]
Learning is a process, which goes through some sort of conceptual change, and that misconceptions need to be restructured in order to for children to really understand what's going on. (Ellen 2)

I think that it is important to eventually get students to work towards what the accepted scientific interpretation or solution is, just because if they won't be able to interact with the natural science community.... a part of the teacher's role is to bring inconsistencies in students' thinking to the surface.... You really have to show students... how the scientific principle can explain while theirs doesn't fit... to fix students' misconceptions, they need somebody to confront that misconception head on.... You'd have to separate the ideas from the students and engage them in metacognitive discussion. (Young 2)

Their knowledge has to be guided by the teacher so that their knowledge that they're constructing stays within parameters that are acceptable within the science community. (Len 2)

I think students have much more real world beliefs systems.... the teacher should present something that would contradict the students' theory to show that it's not quite as consistent as the scientific community's theories. (Young 3)

I guess my focus of my science class would be on the conceptual change aspect.... if any meaningful learning is to take place, I need to know what the student knows already and then work from there in order to modify what they know.... by the time they leave your classroom that you would want them closer to the accepted norm of what the scientific community says. (Young 4)

von Glasersfeld's Radical

[Definition]
From a radical constructivist's view, the cognizing subject generates cognitive schemes to guide actions and represent its experiences. In his suggestions for the practice of teaching, von Glasersfeld contends, “the teacher must be concerned with what goes on in the student's head.... try to build up a model of the student's conceptual structures” to modify “the student's conceptual structures” (1995a, p. 15). Pedagogies based on this perspective identify knowledge as a
subjective sense-making activity located in learners’ minds and focus on developing the experiential fitness of learners’ concepts for making sense of their intersubjective experiences” (Taylor, 1993, p. 283). From this view, the teacher, representing society, must structure and facilitate learning environments with a greater range of experiences so that students could learn what current society regards as having greatest viability at that particular time (Taylor, 1993; Tobin & Tippins, 1993; Wheatley, 1991, 1993).

[Exemplary Quotes]
The teacher is at least putting out the accepted scientific issues and values, so the students come to learn what current society regards as having greatest viability at that particular time, but emphasizing that that changes all the time that students’ ideas are just as valid as other ideas as long as they are again put to the same sort of criteria or test that we put scientist to. (Young 2)
I think that the most, the stringent criteria for judging a scientific theory is its usefulness and helping you to understand something. (Young 3)
The role of the teacher is to help, bring along the thought progress of the students. (Ginny 3)

Students are leaning to organize themselves, the idea of self-organization. I also believe that my job is to for students to learn what the current society regards as having the greatest viability... that's an accurate description.... I guess of all communities, I want to work with underprivileged kids and acknowledging that there is a system and that there is, in terms of politics, a scientific community that has agreed upon something, and it's to your benefit to know what are established beliefs and knowledge.... that type of knowledge I think is helpful in empowering kids. (Ellen 4)

I think for the most part at least in the Western world, we do build plans in our head and then we try to relate things in our head to the outside world based on those plans that we make. So therefore the teacher should definitely know what is going on in the student's head and try to understand what the student understands. (Rob 4)

Learning processes or information is just mediated and organized in such a way that fits into the context that the person learns and therefore becomes part of their own, become extends of their context. It's a constant process, extending your context or your world. It's almost like existential, kind of giving meaning to your world. (Ben 4)

**Vygotsky’s Social**

“The pedagogy of this position could hinge on the notion of apprenticeship, or legitimate peripheral participation. This involves admitting novices into social practices at the periphery, and then letting them take up full player roles as they develop mastery” (Ernest, 1995, p. 471). “Because of the historically constituted nature of the objects of science as the discourses in which they persist, scientists join and learn to participate in a preexisting and already populated realm of discourse” (Ernest, 1998, p. 193). From this view, “the teacher, as a more knowledgeable other, structures the learning experiences in ways that allow the students to overcome whatever limitations in skill might impede his or her attainment of a desired goal by modeling tool use for novice, highlighting the verbal and physical moves that constitute mastery of the process” (Prawat, 1996, p. 222). In this view, “at issue is the question of how members of the classroom community can reach consensus about objects and events in the world. The role of the teacher is to help students construct ideas by themselves and students are viewed as being scaffolded or apprenticed as they gain understanding of scientific ideas.

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[Exemplary Quotes]
The teacher should help students construct ideas by themselves, just as scientist learns. (Young 2)
The teacher never really shows what the standard is so the students then have to really think about what it is that they're doing, and make decisions about what's right or wrong on their own rather than being told what that right or wrong thing is. (Ginny 2)
Just discussions amongst the students and not so much my answer as being the right way or the wrong way, but maybe have students groups being responsible for defending whether a theory is a scientific theory or not. I guess that's how I would try to do that. (Young 3)
I am kind of there to link students and the scientific community, between students and the public standard. In a way you would help them interpret things from a scientific community back and forth until they have enough of conceptual framework to do their own interpretations and go off on their own. (Rob 4)
Science is a dialogue, which has been going on through centuries and each individual is not going back and, so to speak, reinventing the wheels.... To participate in the dialogue, we have to have mastered the information that has come before you for the last centuries. Learning is acculturation, I mean, any individual went into a society, to a culture, maybe learning to give meaning to phenomena of the world outside of themselves where there is a shared meaning. Learning is mediated by others in a culture otherwise we will be solipsistic. (Ben 4)

CSTL (Teaching & Learning)

Role of the Teacher

This category includes any statements in which preservice teachers are commenting on inferred practical pedagogical outcomes and principles based on their differing ontological and epistemological standpoints, as well as the means to facilitate learning according to an epistemology. Each preservice teacher's conceptions of science teaching and learning could include statements of ideals which includes behaviors, values, dispositions, the role of herself as a teacher, the expected role of students in her science class, how to teach, how she thinks students learn, rationale of her way of teaching, as well as rationale of expected learning outcomes.

Role of the Learner

This category includes any statements related to the learner characteristics, and the expected, ideal role of learners in each teacher's future classrooms.

How to Teach

This category includes any statements which refer to the strategies, techniques, methods, practices that each teacher would use to effectively teach science.

How to Learn

This category includes any statements which refer to the strategies, techniques, methods, practices that a teacher would expect students to use to effectively learn science.

Rationale

This category includes any statements which refer to the reasons each teacher may give for using a particular instructional method, the content to be taught, and the intended object of the teaching, which the teacher intends the student to learn.
APPENDIX D

Rob's Coded Transcript

Selected nodes coding none of document Rob 4:
(2 1 1) /Ontology/Preference/Realist
(3 1 1) /Epistemology/Preference/Absolutist
(4 4 1) /CSTL/Preference/Traditional
(30)/constructivism (definition)
(30 1)/constructivism (definition)/viability

Margin coding keys for selected nodes in document Rob 4:
A: (2 1 2) /Ontology/Preference/Radicai
B: (2 1 3) /Ontology/Preference/Idealist
C: (3 1 2) /Epistemology/Preference/Piagetian
D: (3 1 3) /Epistemology/Preference/Fallibilism
E: (3 1 4) /Epistemology/Preference/Relativism
F: (4 1 1) CSTL/T&L/Role of the Teacher
G: (4 1 2) CSTL/T&L/Role of the Learner
H: (4 1 3) CSTL/T&L/How to Teach
I: (4 1 4) CSTL/T&L/How to Learn
J: (4 1 5) CSTL/Teaching & Learning/Rationale
K: (4 4 2) CSTL/Preference/Piaget's Individual
L: (4 4 3) CSTL/Preference/von Glasersfeld's Radical
M: (4 4 4) CSTL/Preference/Vygotsky's Social
N: (40)/Conflicts
O: (50 1) /Explainers/Past Experience
P: (50 2) /Explainers/M. Ed.
Q: (50 3) /Explainers/Other Knowledge
R: (60)/Member Check

+-+ ON-LINE DOCUMENT: Rob's 4th interview

++ Document Header:
* Constructivist Epistemology:
* 4th interview:
* Interviewee: Rob: male: Major: Biology
* March 10 (Friday), 2:30
* Interviewer: Youngsun

++ Retrieval for this document: 581 units out of 581, = 100%
++ Text units 1-581:

* Q: How do you define science teaching? What is science teaching?
  * Rob: Science teaching is sharing of knowledge regarding what is
    currently known about science and related fields, however many
    things that include, so sharing things that one knows with the
    students and also receiving feedback from them regarding what they
    know or think they know about science and also inviting people to
    come in or more experts in certain areas and communicating that as
    well to students.

* Q: How do you define science learning? What is science learning?
  * Rob: Science learning is a process of acquiring the information that
    makes up different fields of science so that you can answer
    different questions that might occur to you or that ever occur to
    other people, and knowing what answers other people came up with
    at different times to explain things that you see.

* Q: What do you consider to be the founding principles of teaching?
  * Rob: Knowing how to communicate experiences or knowledge that you have,
    knowing how to stimulate interest in those who will be learning,
    having them be able to explain what they are learning or not
    learning to you, having them be confident in asking questions, or
    telling that they don't understand, establishing a working
    relationship in both directions between the teacher and the
    students.
Q: In your view, what is the learning outcome of science teaching?

Rob: To allow people to have enough information to make wise decisions and not be manipulated and to understand things so that they can make decisions based on their understanding and not on information that is provided to them without their ability to actually judge the quality of that information.

Q: What are 3 to 5 most important things that you want your students to get out of your science classes?

Rob: I want them to get an appreciation for science or for events, or things that happen. I want them to be able to ask questions. I want them to be able to analyze information that is presented to them through either television or the medium to be able to question the quality of the information that they are viewing with regard to how factual or how true it might be or how misleading it might be, and to just for them to enjoy science and all the things that are related with it and find it useful to them somehow.

Q: In your science classroom, could you describe how learning occurs?

Rob: Learning occurs by the interactions between the teacher and the students, between the students with other students, people asking questions, people volunteering information they know, what they have heard, what their parents say, what they saw on television or the newspaper, asking questions about whether or not what they saw relates to what we are seeing, why are things different what they on TV different from what we are studying now, bringing things up relating it to their everyday experiences directly. If someone knows somebody who has a certain illness and we are covering that topic. You know they have more information that ties in directly.

Q: In your science classroom, what are the mechanisms (processes) by which a learner learns?

Rob: Asking questions by knowing how to look up answers on their own, by explaining to others what they think they know or have understood and basically by knowing how to ask questions and knowing how to try to find answers to those questions.

Q: In your science classroom, how do you know when your students have learned something? (learning is achieved when ...)

Rob: I would say I know they have learned something when I can present them with a situation that somehow parallels or simulates the situation that we have been covering even though it's not exactly the same and they can somehow transfer the information they acquired and use in this situation and apply it in a different situation that is somewhat similar and they can make that connection themselves without me having pointed out to them.

Q: In your science classroom, what teaching strategies (or methods) are you going to implement? What approaches would be most helpful in promoting science learning?

Rob: I like the cooperative learning. I like the group thing although I understand that that's not useful for all students at all times. Some students do not like or appreciate working in groups. Some are tyrants, some are very passive so it depends you don't put any students in a disadvantage by always making that be the way. I also want my students to present things. I want them to do research on their own on certain subjects that I would select then I want them to present that in a coherent and well prepared way for their fellow students. I want them to interview people outside on different topics so that they can also answer questions. I want them to give me questions that they have and we will try to answer.
them together, things that they see everyday, what is the explanation of this or that, then we can work together and I will try to provide an answer. And students mentoring is something that I would like to try at some point having the students work with lower level or younger age students.

* Q: In your science classroom, what would be the (ideal or expected) role of the teacher?

* Rob: To facilitate the transfer of information as it is known at the moment in an age appropriate way to students, to clear up possible naive conceptions that they may have, to teach them to be independent thinkers, to have them question most things that they see and hear including what the teacher tells them, to make sure that the teachers are supporting their information as well as any other sources of information that they are getting.

* Q: In your science classroom, what role do you see yourself playing as the teacher?

* Rob: That would be my role.

* Q: In your science classroom, what role do you see for students playing in your classroom?

* Rob: I would want them to play according to certain rules that I would provide for a certain game or something to try to address a certain topic.

Throughout lab activities, it could work for either. It could be for an inquiry, it could be for a discovery learning, an activity, you could have them play an activity or lab activity and then something would happen in that activity then they would have explain why that happened and then that could be part of what the unit covers, explaining why certain things are the way they are, or why things happen in this way not a different way.

* Q: [Ontology] Discuss or comment on these options one by one and then finally choose one as your own position?

* Rob: Okay here again, my preferences are C and D. I don't like A because I don't necessarily think it's an objective existence, we are subjective beings and we tend to interpret things subjectively. Our personality plays a lot even if you are a scientist and you will always, there always be passions and things involved so objectivity is tough one.

[There is a reality but there is no way to directly access that reality] but how do we know that there is no way to directly access that reality, how do we know that there is a reality or, you know, the reality is subjective thing. My reality is different from your reality. I don't think there is one objective reality. What I like about C is that we are co-participants in a socially shared activity and I also think that we are determined more or less by our social interactions, by environments that we grow up in. The negotiation, all of this forms our world, our language sculpture our world, our relatives, our family, friends all those things have an influence on who we are and how we come to see the world. So I like that one.

I like the last one because it also says that things are open to multiple interpretations which I think definitely the case. And I like the fact, you know, language I think is very important part of defining your reality or your world. And I don't think it's meaningless to speak about the absolute reality of scientific objects. I just 'absolute' is a very narrow word, which I don't think has much to do with science. So both last two are the ones that I like the most.

I don't know that one (reality) IS, that's why you have in the top of the C, social interaction and social negotiation. You can negotiate your reality with somebody else's reality and hopefully reach a compromise or at least an understanding of someone else's reality and why their reality is X and your reality is Y.
don't necessarily, I think, have to say that mine is better than yours or yours is better than mine. We just have different realities and as long as we are trying to understand those of other people, I think, things are okay. I think there is a reality. There is a physical reality that we all perceive in different ways. We all see stars and we all see the sun and we all see the moon but the way we interpret our daily laws and everything, we don't really think in-depth about those things. I don't think nobody is going to argue with me that the sun provides heat, for example, or that the moon shines at night or that would be kind of a concrete reality, that is not much subject to discussion, I think.

Reality that each individual constructs, evolution could be one, for example, religious beliefs that are not accepting an evolution or a creationist theory. Those are different realities. My reality is, I see things and I think well those things came from other things. And if you speak with someone who is a creationist, that's not the case. Their reality is that everything is here the way it was created and there has been no change, right? That would be their perception and their use. That's cultural differences as well. People see things with different uses, or different focuses and, I think, that's the way it should be. If we all saw the same thing it would be a very boring world.

So like you can think of like, say, Plato. So Plate says that there is a cave and that all the real objects exist in that cave and all you see are just reflections of that reality. Well that's one philosophical point and I prefer to think of this as a desk for me in my culture. This is made of plywood. The function of this thing is to keep things in there. If somebody wants to use it as a table to eat on, that's fine. You can use it as a table too. But at some point it was designed to be a thing that you would use to store pencils and rulers, to write on, put a computer on maybe. Most people who come from a western culture who have seen a desk before. If you show it to somebody who has never seen a desk, then it's completely different interpretation. Maybe they will give, you wouldn't know how they are going to interpret its use if they have never seen that.

* Q: [Epistemology] Discuss or comment on these options one by one and then finally choose one as your own position?

* Rob:
A, I don't like the use of [ALL science theories are fallible and liable to refutation] and that concept of [older scientific theories by newer ones is a progressive step toward ultimate scientific truth] because that's like absolute, I don't think there is ultimate scientific truth. I think there is a point where you integrate more and more things and you expand your base of knowledge but I don't know that there is an ultimate scientific... what would an ultimate scientific truth be, would that be to be a god or something, but I don't think there is an ultimate scientific truth. I don't like the second one that it says never. I think science should always be open to revision, but I don't like the use of the word never in that it's a bit harsh. And I think our knowledge should be revised and we should attempt to confirm it, revise it or change it based on new information that comes around. We should not stick to something and say this is never going to change.

I don't agree with C in the sense that I don't think that we merely copy in a relatively passive fashion because I think that sometimes people have come up with ideas that go beyond what has currently been observed, I mean all the time if you think about atoms things like that, a lot of these things are not seen. They are the results of inferences and speculations and it's the best explanation that we have of something but nobody can prove that this is so physically, but I think one of the aims of science is to try to understand and explain what's going on in our world. In D, well I do think that the nature does play a role and shaping
The teacher representing society, I am not sure I understand what many students seem to not like science at all and find it boring, understanding. You have to have faith in what other people are comes in. You share your experiences with others and they share telling you in that case. What you do is you try to leave things in and throw out things somehow, and try to spark an interest in your students. You ensure information based on what your curriculum is. The curriculum is what decides what is important or not important. What you do is you try to leave things in and throw out things together that you think are practical and useful applications of science. Things that we are also making interesting to a student because many students seem to not like science at all and find it boring, dark, and difficult to understand, so you would try to clarify it somehow. And then in the last one, I think that's true for the scientific community. Yes, they do go through a validation process. People try to replicate experiments, see if they come up with the same results. If they don't then the theories tend to lose ground or favor and the community where you say the community in the third sentence, that would have to be the scientific community decides the acceptance of every knowledge claim blur, blur... because the non-scientific community doesn't necessarily agree with the scientific community.

No, I don't think scientific knowledge is invented. I think it's building on, or laying process, we see things and then we try to devise tests to see whether our interpretations or explanations hold true for certain things that we observe, but I don't think it's inventing necessarily. I don't know if you can get to a true picture of reality. If you think of Isaac Newton's laws, those laws are pretty much setting stone and they still hold for many general interpretations and principles, but when Albert Einstein came out with his theory of relativity that affected a lot of Isaac Newton's laws which were more of absolute and Einstein showed that none of those things, with time is relative, the speed of light, all of these things, which we have no proof for. These are nobody have traveled at the speed of light. We don't really know what happens. Does time move slower when you travel? All of these are inferences. Or like Hawking talks about warm holes and spaces, these are all our inferences. We don't know if those things are true or not. We are trying to come up with, say, a dictionary of explanations for things and we have to change things in that dictionary. We have to cross things out or we have to add parentheses and put something more in there or maybe we have to put a little drawing of something new that has come about. So it's kind of like a book that we are constantly editing. We are changing things in the book all the time based on things that are happening. Some things have made more constant over longer period of time. Other things are more susceptible to change. There is no absolute, ultimate scientific truth. No I don't think so. There is no final answer.

Q:

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

Rob:

You ensure information based on what your curriculum is. The curriculum is what decides what is important or not important. What you do is you try to leave things in and throw out things together that you think are practical and useful applications of science. Things that we are also making interesting to a student because many students seem to not like science at all and find it boring, dark, and difficult to understand, so you would try to clarify it somehow. And then in the last one, I think that's true for the scientific community. Yes, they do go through a validation process. People try to replicate experiments, see if they come up with the same results. If they don't then the theories tend to lose ground or favor and the community where you say the community in the third sentence, that would have to be the scientific community decides the acceptance of every knowledge claim blur, blur... because the non-scientific community doesn't necessarily agree with the scientific community.

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that means, a cultural representative, so what that means, somebody who was, what would somebody who isn't, like what would person have to teach science differently, or because that's kind of what I understand a cultural representative, would he represent his culture, or would he have to represent this culture or... that's kind of difficult interpretation form there. Because my culture, for example, I am from Mexico, so that is identified with a Western culture so there is not much problem, but if you think about math for example how do they teach in the Arabic world or in Asia, there are many things they do differently than the way we do here so. I guess you are a cultural representative of where you are more or less. Then the second one, okay, I do think that there are certain principles that has already been a consensus reached in the general scientific populations and you would want you, encourage your students somehow directed so that they reach that same consensus. If they reach a completely different consensus then you have problems because there are certain accepted consensus, I guess. And you would definitely want to encourage your students to explain and justify, that's good for any field, math or science whenever a person tells you some belief, you want them to justify and support it somehow, articulate it. Whenever possible, I would want students to participate actively in scientific activities so that they can discover things on their own instead of me telling them what happens and why. I do think teachers should 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. Yes, I think learning is a process of self-organization and I also think knowing is trying to make sense of things. See those are one of those absolute words that I don't like [unvarying] that makes it difficult to accept that particular sentence. I think for the most part at least in the Western world, we do build plans in our head and then we try to relate things in our head to the outside world based on those plans that we make. So therefore the teacher should definitely know what is going on in the student's head and try to understand what the student understands. I do agree that learning environment should try to include a range of experiences so that the student knows what is the most accepted theory but also knows what other alternative possible theories to something are or alternative explanations. And in D, as a more knowledgeable other, okay, I guess a more advanced learner, but not necessarily knowledgeable, because everybody brings their own experiences which we can't really share. Everybody's own experiences create their person. I mean if you want to teach them how to do scientific inquiry or investigation, you would have to teach them how to do scientific method because that is the accepted model for how to do things. If you want to get a paper published in science you are going to have to do an experiment in a pretty inflexible way so it depends what you want for students to do ultimately. It would be good for them to understand it, that is the process. But I think it's kind of boring process. If you read most research, the results are always the most interesting part and the interpretation, but actual doing of the experiment can be really tedious and take a real long time. I never found that to be too much fun, but you have to know how to do that. [Teachers mediate between students and the public standard], what does that mean, the public standard? So that means if I mediate between students and the public standard, so I am kind of there to link students and the scientific community. In a way you would help them interpret things from a scientific community back and forth until they have enough of conceptual framework to do their own interpretations and go off on their own. No, I think people discover constantly on their own. And I disagree with the last one because it says to steer or funnel the students towards the accepted scientific interpretations, that sounds like steering cattle or something. You would want them to
understand why a certain interpretation is the most accepted, why is it the one that have the most evidence in favor, is that the one they have not been able to disprove, but you definitely don't want to say what is sense and what is nonsense because you never know if things will change what we are discussing, so you want to always leave them with an open mind to accept chat there is nothing that is absolute or setting stone. Things should be subject to further questioning and possible modification. I don't like the use of the word. I don't like [steer, funnel or lead] that much. Those words I don't like much the way they are used in there. I think your role is at least to present with the information and explain and justify why the information is accepted the way you are presenting it, present alternative view points, and that's why it would be important to bring in like other speakers who can address issues from different directions, and present them with this broad pictures possible to allow them to make their own decision ultimately, but that they know all the information.

Do I have to pick one, or can I pick kind of a mix? Okay, I like in A where it says that time and circumstance do not allow sufficient knowledge, blur, blur, blur, in that sense I like A because you are providing them with short-cuts or maybe things that they will not be able to do on their own. You are telling them what is happen if what other people have done it. So that makes A sometimes.

In B, I like the idea about a consensus, reaching a consensus. I would also agree with the idea of encouraging students to explain themselves, justify their positions, and the fact that you are not giving them to practice routines or standard interpretations. I like that you are leaving them open and I like the teachers facilitates and support as students construct their own ideas. In C, I like that it says it's a process of self-organization and then knowledge in most cases attempting to explain which we observe, making sense of the world around you, so I like that. And I also like the fact it says, teachers must try to understand what's going on in a student's head.

D, I didn't like D that much. I am not sure I understood exactly what it says, but I seemed a little on, the more knowledgeable other, all those wordings, I didn't like that much. Ideal forms, I don't know exactly what that means, but.

And then E, I didn't like E much either, because of that steering and funneling and leading and all of that. That seems very, very too definite. So basically I like some of A, some of B, and some of C, but not much of D or E.

Q: In your opinion, which of the following is the most influential in helping you to form your beliefs about teaching and learning? [M.Ed. Course Work, Field Experience (mentor, cooperating teachers), Peers, Others]. Why was that important?

Rob: I would say the most important would be field experience, and peers and daily living situations, jobs, family about teaching and learning. Because many in my family are teachers and I have had a chance to hear and talk to them about how they teach, why they teach that way, what their opinions are, so they have also influenced me. I would say my field experience, interaction with my peers, and family and their living situations. And they are important because you get to see that know you are, people tend to do things in a certain way that they used to or comfortable and then it's really good to see people do things in completely different ways, and see how something that works for someone might not for another and just comparing, having as many different experiences as possible.

Q: Specifically, in the M.Ed. program what have you learned that you feel will influence your role as a teacher?

Rob: I have learned different techniques, teaching techniques, a lot of different methodologies, and I have learned different techniques, teaching techniques, a lot of different methodologies, and
theory that we have had about rubrics and lesson plans.

[Your instructional practices?] all the theories that we have seen about what is known as cooperative learning, what is known as discovery learning, hands-on experience, all of that.

[Your beliefs about Teaching and learning?] regarding my beliefs about teaching and learning, what have I learned, the different schools of learning, the age thing, what things are learned at certain ages, what things change at different ages.

* Q:

What have you learned most (best?) throughout M.Ed. coursework?

* Rob:

I guess, you should try to be as organized as possible and different ways that you can organize yourself, to plan ahead, I guess of organization of time, time management, I guess what I would say.

* Q:

What's the significant change in yourself as a teacher throughout M.Ed. program?

* Rob:

I guess I have never really thought much about how people learn and what they find interesting. Now I find myself being a lot more observant of the students and see how they react to different situations, or different materials or different ways of working in the classroom, to see which one is they see more interested in, which ones make them more enthusiastic, to try use those more in the future, or to apply those techniques in different areas, try to come up with different ways to incorporate things to spark their interests and enthusiasm.

* Q:

Where do you learn the most about being a science teacher?

* Rob:

in the classroom of the field experience, I guess, in your interactions with the students. Yeah, it would be definitely with field experience where you learn most about being a science teacher.

* Q:

[After showing them their profile], What are your reactions to this profile?

* Rob:

I guess I would need more time to study to really come up with the reaction. I don't really know how I would interpret it since I don't have any comparison with others. There is no point of reference for me to really see. So you are saying that there was none of the realist and none of the... okay, I guess I could make sense.

I mean interactions with my peers, interactions in the classroom, I guess I could understand the shift towards the social in that case. I don't know passing through radical would necessarily be the way to get from here [realist] to here [social]. It seems I have a very little of progressive, I don't have much in the way of believing that. I kind of like the way that, it seems that from my third interview, that it seems kind of well distributed so I don't know if that again is an advantage or not, but I guess I wouldn't like to see too much in one particular place. I would rather see it's spread out over different areas like here it's a lot here. I don't know if it's important to have it in the other two as well. But I would like spreading more. And then preference [pedagogical beliefs], so what happens here is, let's see, for the first interview, so there was a lot of conceptual change in the first and that's lost, so no conceptual change later. The last one is what... very little conceptual change.

It seems okay, don't seem nothing really looks scary to me, I guess [laughter].

* Q:

Do you notice any changes in your beliefs?

* Rob:

Based on this, it definitely seems like. There does definitely seem to be a change.
* Q: Could you explain this change (or lack of change)? [to find out whether they are conscious of their ontological and epistemological beliefs]

* Rob:

Yeah, I guess, you know, the teaching experience, my interaction with my peers, the reflections, I guess, all of that would have some effect on whatever change there has been registered there.

* Q: How do you think this profile will influence your instruction (in the future)?

* Rob:

I have no idea because I imagine that just like this has changed wouldn't last... so I imagine that, as you teach every year, you will probably shifting back and forth depending on what's your experiences are at a given time. Maybe even from class to class, your focus might change depending on what the interactions with those particular students are, and also what's happening in your personal life. So I think, my profile is probably going to continue to change constantly, I hope. I don't hope it stays the same forever.

* Q: Do you believe that there should be consistency between this profile and your instruction? If a teacher has this type of ontological and epistemological profile, can it influence their teaching practices?

* Rob:

I don't really know. This profile would somehow reflect what my instruction would be like? In an instant maybe, but since it has obviously changed in that period, I think, your instruction would change as well as your profile was dynamic.

It seems like social is strong in all three of them. I don't know what that means exactly but it seems like the social aspect is important in all three of those. Because I have contacted with people who have a lot of experiences outside of the United States and that's not the majority of the population inside United States. The majority of population in the US they don't really see much except they go on the vacation. But with my wife, she has lived in Brazil, she has lived in Mexico, she speaks three languages. My brother in law went to the Peace Corp in Africa and my other brother in law spent four years in Japan. So that definitely changes your perception of reality because you get to see other people's perceptions of reality. I am from Mexico so maybe that's why...

I guess if this is any accurate reflection, if this could be considered an accurate reflection of who I am with regard to my interpretation of teaching and learning then it should be an accurate representation of what my instruction will be like, I guess. It depends on the accuracy of the interpretation basically.

* Q: What do you think might be constraints on implementing your beliefs about instruction (or pedagogical beliefs)?

* Rob:

Proficiency tests would be a good constraint, possible society, certain things like for example, an easy one as evolution, depending on where you are. If you are in Kansas, you probably won't be able to teach evolution because it's not in the curriculum. I mean they took it out, so. Constraints could be societal in general because that would be proficiency, that would be beliefs held in society, and that sort of thing.

I guess for the social aspect like what we were saying, it seems that social determination plays a strong role and that seems to be reflected in the pedagogy as well. It receives the big share of the influence with regard to pedagogy. So I think that the relationship would be just to see... there is concordance between that here [ontological and epistemological beliefs] and that's reflected over there [pedagogical beliefs] as well, I guess.

* Q: Any other comment?

* Rob: No.
APPENDIX E

Cases of Ginny, Len, and Lynda

Ginny's Case

Ginny's Past Experiences

Ginny is a White American female in her middle twenties, requesting a certification in high school biology. Her undergraduate major was biology, focused on animal behavior. She wanted to be a teacher because she “realized that she was a lifelong learner herself... and she was able to reiterate a concept in a way that the teacher himself wasn’t able to do it” (Ginny 1). In particular, she chose to be a high school biology teacher because in high school biology she could take a more holistic approach than in college biology where it is more compartmentalized with a narrow focus. As a teacher, she would have a chance to “instill lifelong learning skills in students that would assist them in and out of the classroom” (Ginny, personal communication: Statement of Intent in her M.Ed. application, June, 1999). Ginny recalled having had some teachers who were influential role models, both positive and negative, who influenced what she wanted to do in her own future classrooms. She thus contended, “the teaching and learning is not always imparted to the students, sometimes the student teaches the teacher [by] helping the teacher to see an old idea a new way” (Ginny, personal communication, June, 1999).

I had an English teacher that was very authoritative and just his way was the only way. That really bothered me because I didn’t think that his interpretation of the text was not necessarily what mine was, and I felt like I was writing and doing things to fit his way not my own, and I am not sure I was ever really learning my own thing. Whereas I had lots of teachers where they helped the students understand their own concept, not trying to hold them accountable to their own opinion, they may have stated their own opinion, this is what I think, but not necessarily we need to learn.

Ginny’s Ontological Beliefs

Ginny’s initial ontological belief profile was 83% Realist and 17% Idealist (see Figure A.1). She explicated her realist position when she talked about the relationship between scientific knowledge and what can be known.

Scientific knowledge to me is, knowing about the world around you. My view of science is that it applies to the world, you’re searching for how the world works, so the knowledge comes in as you understand how interactions in the world happen and how science can be applied to the world.... I think maybe the goal of scientific knowledge is to understand nature and how we play a role in it, and how we interact with nature, and I think the creation of laws help us, we humans to understand nature. We have a way of verbalizing and understanding them. (Ginny 1)

As can be seen in Figure A.1, this realist category was maintained as the second largest component throughout the interviews: 50% in the second interview, 29% in the third interview, and 39% in the fourth interview. It is important to note that the Realist beliefs came into existence whenever Ginny talked about knowledge in the context of natural science and theoretical objects of science such as electrons, viruses and tectonic plates. Regarding the status of scientific knowledge, Ginny supposed that nature “exerts some influence over the character of the knowledge that is constructed about it” with a mind-independent (or language-independent) existence (Phillips, 1997, p. 162). Some typical statements placed in the realist category for Ginny included:

[material world, as a real structure exists independently of our knowledge], so for me, I see that as something that even though we haven't experienced it, it's there. When I talk about human independent world, even though we can't experience or see electrons, viruses, and tectonic plates, we know it by some version of testing. (Ginny 2)

Even though we can't see them [like genes and tectonic plates] we know that they are there... because we test them indirectly. We can't see with naked eyes, but we can test indirectly so they exist in that sense. (Ginny 3)
The feature of Ginny's ontological profile was that from the first interview she had the Idealist category, which reflected her undergraduate coursework in “evolution of mind and intelligence.” She “did not study pure biology [and] had some side ways” (Ginny I). She remembered having had one of “animal behavior” classes where she “had to provide a detailed description of what the whole body did as the monkey sneezed [so that] someone from another planet would know some had sneezed” (Ginny 4). In the first interview, this idealist category coexisted with the Realist category in her ontological beliefs profile. As above quotes illustrate, when she talked about scientific knowledge and scientific objects, she presupposed the existence of “the human independent world” that “comes in and works on you” (Ginny I). However, when she commented on ‘the ontological questions’ such as what the form and nature of reality was, she advocated the Idealist position.

I will choose B [The world (reality, real objects) does not exist independently of minds]. In that you're making... we do not know anything unless we thought of it. Probably not, yeah, probably not [there is no reality]. (Ginny I)

Ginny’s Idealist perspective got elaborated and enriched in the later interviews. She began with simply denying existence of the world saying, “we do not know anything unless we thought of it” (Ginny 3). During the third interview her idealist perspective got stronger as she further explicated the role of language in reality formation. According to Ginny, “until we're able to talk to someone else about it [the object of science such as black holes or planets], they don't exist in a true sense” (Ginny 3). Furthermore, “only what we can think of can exist; otherwise it is not there until we have put our language to something.” She also acknowledged how sometimes different realities could be shaped and “how things have changed in science over time depending on what group of individuals was in charge [who] made up language to describe things that they want” (Ginny 3). The existence and reality of an object could be shifted from a planet to a comet or something else depending on who “decides if that is the word in a language they want to call it” (Ginny 3). Fortunately, “scientists typically talk with the same language, the same definitions of things” (Ginny 4). By the end of the fourth interview, she had an opinion about how “a culture has to do with defining the language”; thus, “how things change and [how people] do make for different interpretations of sometimes the same concept” (Ginny 4). Ginny contended, “Larmark’s culture that he developed his theories for evolution and Darwin’s [culture]” were “reflected how things change and how they interpreted [differently] how the world change” (Ginny 4). Accordingly, Ginny knew that “this a desk” because it “got a similar shape to other things that as a culture we define as a desk” (Ginny 4).

The Radical category of Ginny’s ontological profile came into existence in the second interview when she claimed, “there is no extraexperiential reality,” which was well aligned with the ontological stands taken by von Glasersfeld’s radical constructivism (Matthews, 1994, p. 155):
And so the conclusion that reality is what we perceive with our senses, anything that we can touch, feel, taste, or smell, ... and then that's reality. If you don't experience it, there's no way possible it can exist. (Ginny 2)

Summary of Ginny's Ontology Profile Changes

From the third interview, seemingly incompatible Realist and Idealist (or Radical in the second interview) ontological beliefs coexisted in Ginny's ontology profile. Depending on phrasing and context of questioning, she swung back and forth between the two incompatible perspectives. Whether she achieved a consciousness of her own profile and was able to decide where each component is applicable in an appropriate context by the end of the interview process will be discussed after reviewing her epistemological profile in the following section.

Ginny’s Epistemological Beliefs

"If one makes a different ontological assumption about the "what" of knowledge, then a different set of epistemological issues surface" (Prawat, 1997, p. 236).

As is the case for the other interviewees, Ginny’s epistemology is intimately related to her ontology (Prawat, 1997) to a certain extent. In the first interview, Ginny’s epistemological beliefs profile was 89% Piagetian and 11% Absolutist, which came into existence when she claimed “there are some absolute truth [or] theories are true if they can’t be disproved” such as “Newton’s law where an object always falls to the ground” (Ginny 1).

As can be seen in Figure A.2, the Piagetian category in Ginny’s epistemological profile was maintained as the second largest component in the second interview (33%), disappeared in the third interview, and then reappeared as the largest component in the fourth interview as Ginny returned to the idea that “you can’t go against the nature no matter what the [scientific] community might say” (Ginny 4). As can be seen in the following quotes, Ginny’s Piagetian epistemological category was strongly aligned with her Realist ontological beliefs where she admitted mind-independent existence of external reality “playing a role in constraining or shaping the views we construct about it” (Phillips, 1997, p. 184). Her exemplary statements related to the Piagetian category (i.e., the scientific realism of individual constructivism) are as follows:

I think the B statement is the external world in some way constrains what we believe about it, that one, is a good one for me because I think the nature kind of comes in and works on you and you build a lot of your own knowledge from interacting with nature.... and I think the creation of laws
helps us, we humans to understand nature. We have a way of verbalizing and understanding them. (Ginny 1)
For me, I see that as something that even though we haven't experienced it, it's there. So when I talk about the human independent world that like even though we can't experience or see electrons, viruses, and tectonic plates, we know by some version of testing, we've been able to create that. (Ginny 2)
Yeah, you need to go back to the nature when you try to validate a theory. Ultimate criteria of the theory... I would have to say the observations that you make of nature... you can't go against that no matter what the community might say.... I think you have to come to terms with nature and nature is probably our defining criteria. (Ginny 4)

The assumption implicit in Ginny's approach to scientific truth is that through “our shared experience [with nature] a lot of people can talk about the same things” (Ginny 4), which in a sense reminds of capturing of a transcendent reality that is built into the world.

In the meantime, the decreased portion of the Piagetian category in the second and third interviews was replaced by the Fallibilist and Relativist categories as Ginny gradually shifted her ontological position from the Realist to the Idealist (sometimes Radical) position. Her claim about the absolute truth in the first interview was gradually replaced with the Fallibilist view from the third interview where she contended, “if you look through time, there can't ever be one true thing... I don't know if they approach truth more closely.” She further elaborated this fallibilist perspective in the third and fourth interviews as she acknowledged ‘the theory-ladenness of facts’ and ‘the under-determination of theory’ by the same set of facts:

Two groups of scientists can meet different conclusions based on their own beliefs and that's where science gets tricky. Even though there are the truths and the facts, people interpret things differently and a belief comes in one direction or another... So even though you can have the same set of facts, you can come up with two different theories, which is an interesting thing in science. (Ginny 3)
When you have subjective knowledge, maybe some way you have changed what is written in a book so that it fits what you already understand, whether that is accepted way of thinking about it, may or may not change what's correct. (Ginny 3)
You are looking at things objectively but you do bring in experiences. We are not infallible. (Ginny 4)

On the other hand, Ginny had the Relativist sector as the largest component in the second (67%) and the third interview (47%), which thus fit well with her Idealist (or Radical) ontological beliefs during this time. When asked to align her own epistemological beliefs with one of the given preferences, she chose the Relativist views and further explicated it:

We have made up laws, theories, explain things we see over and over, but in nature, there are laws and theories which may not exist in some way, so it's something that we've made, that humans have thought about and done.... you can't consult with nature if you see right or wrong (Ginny 2).
Knowledge is a social construct because things don't get explained unless groups of people come together on something. One person can be the center, but there are theory may not get even looked at unless someone else says [hey, that's right] and they build up to it (Ginny 3).

One of the features of Ginny’s profile is that there is an apparent inconsistency between her ontological profile and epistemological profile in the fourth interview where she had the Idealist ontology and the Piagetian epistemology as the largest component at the same time. According to Ginny’s Piagetian epistemological beliefs in her fourth profile, there should be an external reality that was experienced more or less alike by “a lot of people so that [they] can talk about the same things” (Ginny). That is, as she admitting that external reality is playing in the development or construction of scientific knowledge, Ginny seemed in some sense to be a Realist who argued that we “need to go back to the nature when [we] try to validate a theory.” Accordingly, it is by interacting with the nature and through a direct contact with reality that human beings have been able to construct scientific theories.

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This seemingly incompatible coexistence of the Realist and Idealist ontology as well as inconsistency between strong Idealist ontology and Piagetian epistemology is partially explained when she revealed her complex understanding of reality and how to handle that complexity in science teaching:

Even the movie Matrix, ... the whole movie questions how do we define reality.... It does question reality, but I think to be able to teach it, to be able to understand it myself, I have to say this is a desk because I defined it as a desk, and I know nothing else but it is a desk. (Ginny 4)

Summary of Ginny’s Epistemology Profile Changes

From the first interview, Ginny kept shifting back and forth her ontological position between the realist and the idealist. A tension exists between her idealist ontology towards her everyday value and her realist ontology as a science teacher. She tended to endorse an idealist view of reality and a relativistic view of knowledge when she contended that a particular language or cultural community determines what sorts of things are regarded as existing by defining the ontological categories, such as a desk, a planet and the theory of evolution. Contrary to these views, however, she endorsed a realist view of the role of reality and a Piagetian view of scientific knowledge, according to which she wanted her students to learn “the truth of well-accepted concepts” and to “make sense of what they see in the world” (Ginny 4). Although she was fully conscious of “a multiplicity of ways in which the world is constructed” depending on different cultural groups (Phillips, 1997, p. 188) and “the vulnerability of scientific theories to new evidence or interpretation” (Harding & Hare, 2000, p. 231), “to be able to teach it, to be able to understand it herself,” she had to say “this is a desk” and accepted evolving scientific knowledge represents mind-independent reality (Ginny 4). During the member check, she acknowledged, “how I view the world definitely influences how I view science.... and then how I see science is obviously going to affect how I present science to my students” (Ginny 4). This leads her to conclude, “I need to define how I see the world and how that affects how I see science [because] I think, these two things [ontology and epistemology] come out when I teach” (Ginny 4). She committed to defining her ontological and epistemological beliefs because these beliefs not only “may influence [students] in one direction or another unintentionally” but also may provide students with “an example of how to think about and define the world or science” (Ginny 4). As far as I could tell, Ginny subscribed herself under the realist ontology in an attempt to show why scientific realism is more appropriate than the idealist or relativist views of scientific knowledge within education and within her science teaching methods.

Ginny’s CSTL

Ginny’s CSTL profile began with 33% Traditional, 44% Piagetian individual, and 23% von Glasersfeld in the first interview (see Figure A.3). The initial traditional category of Ginny’s profile reflected her beliefs about the nature of teaching based on her own experiences as a student, where she “was mainly listening and doing things outside of the classroom” (Ginny 1). From her own experience as a learner, she expected her students’ ideal role as “good listeners, usually working outside of the class,” which is exactly the same with what she did throughout her previous schooling. In the first interview, Ginny’s self-image as a teacher was strongly related to her self-image as a learner (Kagan, 1992). Having observed teaching models, both positive and negative, Ginny’s initial conceptions of teaching and learning was well aligned with traditional views, where “the teacher is someone that commands or starts by once students giving you the respect, [as well as] teachers exert their authority in terms of learning and knowledge and tell students this is what you should do and teaching is “passing on knowledge [because] the students need the knowledge to live their everyday world” (Ginny 1). Accordingly, the goal of teaching is “passing on knowledge [because] the students need the knowledge to live their everyday world” (Ginny 1). Regarding students’ learning failure, Ginny argued that the probable “reason why the student doesn’t get it” should be searched not from a defect of the students such as lack of attention but from a defect in the teacher such as lecture-only classroom structure or the authoritative figure of the teacher (Ginny 1). This traditional component of her CSTL profile was untraceable in later interviews.
On the other hand, the rest of Ginny's CSTL profile resonated with those of Piaget and von Glasersfeld. Asked to choose one of the given preferences that would most align with the way she thought about science teaching and learning, she aligned her role as a teacher with that of von Glasersfeld's radical constructivist teacher, where she wanted to “facilitate learning environment with a great range of experiences” (Ginny 1). While resenting one of her previous teachers who “was very authoritative and just presented his way was the only way” and recalling that she “was doing things to fit his way not my own,” she wanted to be a teacher who was willing to examine “why students don’t get what the teacher expect them to know” (Ginny 1).

Ginny believed that learning is occurring simply through assimilating (or incorporating) new, external events into existing thoughts and then structuring of the adapted mental material, which to some extent reflected Piaget’s adaptive function of cognition except “accommodation” component. Along this line, she wanted to be a teacher who “guides the person along the right direction, help them search out the direction that they want to go on” (Ginny 1). In the first interview, Ginny was not yet aware of “knowledge restructuring, conceptual exchange, or accommodation’ facets of learning. The Piagetian sector—in a sense of a weak, trivial form of constructivism—of her profile came into existence when she valued not only “students' understanding of the scientific theory,” but also students' “construction of ideas by themselves” (Ginny 1). Although she would encourage students “to expand and construct ideas by themselves,” she insisted, “teachers still have to hold them at least by putting them [students] accountable for that particular scientific theory.” She wanted students to “understand the scientific theory for itself” not because it was presented by the teacher, but because it is well accepted by scientists.

In the second interview, Ginny’s CSTL profile was 39% Piagetian and 61% Social. The Piagetian sector appeared as Ginny strongly advocated the role of a teacher as “helping students to construct the particular ways of seeing adopted by the science community” by drawing upon supportive evidence for the science view preferentially (Driver et al., 1994, p. 219):

Science teaching is showing the students, getting what their ideas on the concepts are, and then showing them what the science concepts are, and getting them closer, so that they can understand those in their own words. (Ginny 2)

This Piagetian category was maintained as the largest component with 51% text units in the third interview and 72% in the fourth interview as Ginny aligned her own conceptions of science teaching and learning with Driver’s enculturation process. Ginny elaborated her Piagetian sector suggesting an instructional strategy which involves “getting out what students know from the start” and using that as a starting point to teaching, and thereby she wanted to assist her “students in making links between things that students have experienced everyday and the scientifically acceptable viewpoints” (Ginny 3). By the end of the fourth
interview, Ginny not only recognized "typically students coming with ideas that may or may not be close to what is scientifically been shown" but also further elaborated her instructional approach where the teacher "provides a structured form [of learning activities]:

I think most kids need to come to some terms.... they need to compare what they know with what is acceptable. It's good to steer students towards accepted scientific interpretations.... teacher facilitating and supporting students as they construct ideas by themselves, and providing a structured form.... you would probably have to give them an experience where what they have constructed doesn't fit with this new experience and so they have to again come to a changing of an understanding. (Ginny 4)

Ginny's initial von Glasersfeld's sector was mitigated in the later interviews (5% in the third interview and 11% in the fourth interview). However, she continued to insist that learning is an individual process of experiencing and developing the knowledge construction process; therefore, it is essential that the teacher should have an adequate model of the student's thinking or what goes on in the student's head within which the student assimilates what he or she is being told (von Glasersfeld, 1995):

The role of the teacher is to help, bring along the thought progress of the students... It makes sense to me that learning is self-organization. You have to kind of fit things in as you get them where it makes sense in our heads, otherwise I don't think you can understand what's going on. (Ginny 3)

The social category in Ginny's profile first appeared in the second interview as the largest component (61%), and was maintained throughout the interviews (44% in the third interview and 17% in the fourth interview). In the second interview, asked to choose one of the given preferences that would most align with the way she thinks about science teaching and learning, she aligned her way of teaching with that of social constructivist teachers, where she insisted students [should be] granted more autonomy in their own meaning construction "in their own personal way," communicate with themselves about "the socially shared activity" (Ginny 2). Accordingly, her role in this socially shared activity was a "facilitator of learning and asker of questions that prompt children to move toward socially accepted meanings" (Ernest, 1995, p. 479):

I think my version falls close to the social end, because it does take peer interactions and teacher-students interactions to construct their knowledge.... The teachers are looking to get the students' explanations and then to justify their explanations, but the teacher never really shows what the standard is.... So the students are, then began to really have to really think about what it is that they're doing, and make decisions about what's right or wrong on their own rather than being told what that right or wrong thing is. (Ginny 2)

As the above quote illustrates, a feature of Ginny's social sector was that she wanted to grant her students a certain amount of autonomy as well as responsibility of validating co-constructed meanings in the process of interaction between themselves, without using externally imposed criteria introduced by the teacher as an authority. In addition to these features, in the third interview, Ginny's social sector put a new emphasis on apprenticeship dimension of science teaching where the teacher representing the community of scientists modeled "the conversational and work practices of the field" through shared participation (Roth, 1993, p. 165):

Pedagogy C is more aligned with what I am thinking [At issue is the question of how members of the classroom community can reach consensus about the nature of subject matter objects and events]. I would like the teacher being a facilitator, encouraging to explain, and to interpret what they are explaining. I would certainly tell my students that students need to learn about how to observe the world, so, in that, it does not just have to be about science. When they come into a situation, out in their everyday lives it is really important that they can observe it, and make hypothesis, take some data and make an interpretation of that data is really important. (Ginny 3)
In the fourth interview, Ginny’s social category drastically decreased (17%) as she found, “the teacher being in a small role in social [constructivism] is hard after this quarter [the winter quarter]” (Ginny 4). However, she still wanted students to “take the conversation and to let them make connections themselves” as she was “helping them along the way if they need it” (Ginny 4). That is, in the process of students’ construction of new conceptual and procedural knowledge, she wanted to function as a facilitator rather than a source of knowledge. As a facilitator and mentor, the teacher could provide settings in which students as community members have to “negotiate not only the meaning of cognitive objects but also the social norms under which these negotiations take place” (Roth, 1993, p. 166).

On the other hand, asked to explain the gradual decrease of social component in her profile with time, Ginny expressed her frustration with students’ resistance to her new ways of teaching that were aligned with what social constructivists supported, such as students’ autonomy in knowledge building processes through communication with themselves (Prawat, 1996).

I think because I probably have been in the classroom like all times. I have to say that the teacher being in a small role in the social is hard after this quarter. The kids so much want to be spoon-fed. It’s so odd. They want you to tell them what’s right and what’s wrong and it’s almost like you have this conflict. You don’t want to tell them, but they are so insistent about it. Sometimes you just give in. I tried to make myself [in] a small role…. So I don’t know how social I really am in the classroom. I am trying to be, but I think it’s hard when you actually practicing to be fit into one of these. (Ginny 4)

Summary of Ginny’s CSTL Profile Changes

In sum, throughout the interviews, Ginny has “gotten away from the traditional, [her] being the pillar of knowledge in the classroom” (Ginny 4), “someone telling students where to look at,” and someone deserving students’ respect as an authority figure (Ginny 1). In this process, her role as the teacher has settled down as being a guide who “brings along the thought progress of the students” (Ginny 3), “guides them through students’ search for information, decides what structures learning this experience, and helps students along the way” of their knowledge building processes “if they need it” (Ginny 4). Again, she wanted to “let the students guide [the teacher] what [she] need to do to help them” (Ginny 4).

Aligned with her Piagetian epistemology, Ginny’s conceptions of science teaching and learning thus fit with Driver’s acculturation process and the conceptual change learning. When she talked about science teaching and learning, she seemed to assume well-established scientific knowledge as true and attempted to implement conceptual change approaches for teaching, whereby she wanted to help her “students in making links between things that students have experienced everyday” and the scientifically acceptable viewpoints” (Ginny 3). Since being introduced to constructivism in the M.Ed. program, she wanted to align her way of teaching with that of social constructivism whose “focus is on the social interactions which occur in classrooms” (Geelan, 1997, p. 21). However, as she had more experience with students in real classrooms through the field experience, the social category in her CSTL profile decreased gradually.

Ginny thought “learning is achieved when students can put a scientific concept into their own words and reapply that in a different situation” (Ginny 4). To achieve these goals, Ginny wanted to use analogies to “relate the topic to something students already have experience with and doing things hands-on to give the experiences students need” (Ginny 1), and to introduce scientific ideas as “an alternative idea after students had a chance to discuss what they think” (Ginny 2). In the meantime, she strongly believed in conceptual change learning. To do so, she needed to “get out what students know from the start” so that she could “know where to start, where knowledge lies currently, and where [she] needs to take them” (Ginny 3 & 4). Regarding conceptual change learning, Ginny viewed students would change their “misconception” if they have “some experience that makes that misconception wrong” as well as a new theory is “plausible enough for them, or intelligible enough for them to use the words from that theory.” Along this line, she expected that her students “are not inactive even when there is a lecture”. She went on to say that “the teacher might model something to the students, but they need to think, do and go through the motions themselves to gain mastery.” In addition, Ginny maintained that students learn by “making connections to things in their own life” (Ginny 2), “finding some more personal information [in some presented materials] that they can come to terms with [and] comparing what they know with what is acceptable” (Ginny 4).
Explainers for Ginny’s Constructivist Profile Changes

Asked to provide the most influential factors in helping her to form beliefs about teaching and learning, Ginny explicated, “the coursework started her out” by giving her basis such as “the conceptual change model” whereas the field experience was where she really came to understand about things that she can and can’t do in a classroom.” She acknowledged her peers were also influential by giving her good ideas. She valued more the field experience over the M.Ed. methods courses because Ginny thought that ultimately “the students define how you are going to be a teacher in that they give you clues on how they learn, and what’s the best” (Ginny 4). She went on to say, “being in the classroom, interacting with other teachers, watching other teachers, and interacting with the students has really kind of laid down where I am and where I think I am going” (Ginny 4).

Asked to reflect on the significant changes in herself as a teacher throughout the M.Ed. program, Ginny commented that she “would try to do more hands-on activities and allow to get the students’ ideas of what things are first” so she would know “where to start, where knowledge lies currently, and where I need to take them.” Had it not been for the M.Ed. program, she “would not have done that before” (Ginny 2). In addition, the M.Ed. program enabled her to “learn about herself and think about what it is [she] wants to do, and where it is I want to go, and what I want to accomplish with my students” let alone “learning theories that [she] did not know about” (Ginny 2). She also acknowledged it could have been better if the M.Ed. program had had “a little more practicality” which could have helped her to understand why she needed to know a specific theory (Ginny 3). She felt that the M.Ed. program “stressed over and over” that the teacher as a guide rather than a pillar of knowledge should use “varied practices, do a lot more activities than [she] thought, and let the students guide [the teacher] what she needs to do to help them” (Ginny 4). In addition, by asking her “to do reflections and to put things in I-statements” a lot of the readings in the M.Ed. program helped her not only “to define what it was that she believed that she was doing when she got in front of a classroom, and what she wanted to do” but also to change her language” (Ginny 4).

Asked to explain apparent beliefs changes in her profiles (ontology, epistemology, and CSTL), she commented that she broadened her views and perspectives as she got “more of the theory and instructional practices.” She offered “the conceptual change” as the most significant factor that “changed in her beliefs and how she will teach.” After examining her profiles, she was satisfied because she had “gotten away from the traditional” category of her CSTL profile (Ginny 4).

Regarding the extent to which she was conscious of the relationship between her ontological/epistemological beliefs and her CSTL, she acknowledged a strong relationship the two in that “how she views the world and how she views science definitely influenced how she presents science to her students”:

I think, how I view the world definitely influences how I view science in that I am showing a view of ontology and that’s showing up again here [epistemology].... And then how I see science is obviously going to affect how I present science to my students. So I think that it kind of follows that I need to define how I see the world, how does that affect how I see science and how I see science is going to affect the explanation I give to my students. The information that I choose to give them, how I guide them, and the direction I guide them is going to be influenced by the other two.

As I have discussed in her ontological and epistemological profile analysis, Ginny was aware of different categories of her ontological and epistemological profiles. As can be seen in the discussion on an incompatibility between her strong Idealist ontology and Piagetian epistemology (scientific realism) in an earlier section, she retreated her stand from Idealist ontology to Realist ontology to compromise with her role as a science teacher and to be able to teach well established scientific knowledge, which is accepted by scientists as true. However, it is important to note that Ginny was aware of different versions of ontologies and epistemologies and was able to “decide where each zone is applicable in an appropriate context,” which in turn resulted in a coexistence of apparently contradictory ontological (as well as epistemological) beliefs in her profiles (Mortimer, 1995, p. 282). As a thinker, who once majored animal behavior and animal psychology, she recognized possible multiple interpretations of reality and denied an absolute standard for judging truth based on a true reality. In the meantime, as a science teacher, she felt that scientific realism would be more useful in teaching science where she tried to acculturize students to the scientific community’s views. During the member check by the end of the fourth interview, she
reconfirmed and settled down her position as Piagetian epistemology where, she thought, “a lot of people probably started because it’s how we are taught and that’s how you see it.”

As far as I could tell, Ginny’s ontological, epistemological beliefs fit well with her CSTL, as she recognized a strong connection between the two belief systems. As time went on, Ginny showed a gradual decrease in the Realist ontological beliefs and, simultaneously, a gradual increase in the Idealist ontological beliefs. On the contrary, her epistemological beliefs moved away from the Relativist beliefs and maintained Piagetian and Fallibilist epistemological beliefs as the backbone in her approach to scientific knowledge. In accordance with her Piagetian position in the epistemological profile, Ginny maintained Piagetian individual constructivist’s CSTL as a backdrop, which was represented as “the conceptual change” learning to her. In the meantime, from the second interview, her profile strongly incorporated the social category in her CSTL profile, whereby Ginny wanted to let her students construct knowledge through communication with themselves. However, this social sector showed a gradual decrease in her profile as Ginny had been frustrated by real classroom situations through her field experience. Ginny “focused on the individual, the conceptual change” aspect during her field experiences, whereas she continued to hope that she “probably look more into the social aspect, find out better for herself” (Ginny 4).

On the other hand, regarding her awareness of the three different versions of educational constructivism, she thought that her “version fell close to the social [constructivist] end because it does take peer interactions and teacher-students interactions to construct their knowledge” (Ginny 2). She also adopted a relativist view of science taken by von Glasersfeld’s radical constructivism that says “there isn’t, can’t even be one true thing or an absolute truth” (Ginny 2).

Len’s Case
Len’s Past Experiences

Len is a white American male in his early thirties, requesting a certification in Earth science for grades 7 to 12. Len remembered that he always “ended up as the instructor or the trainer of whatever it is that we did. I was, even in high school, I was teaching other students things, it’s just something that comes natural to me, even though I have little knowledge of the theories in teaching, I’ve always sort of gravitated towards that position, that as an instructor or enlightener” (personal communication, Len’s Statement of Intent June, 1999). Len also remembered two exemplary teachers who contributed to his self-image as a teacher. He wanted to emulate these teachers’ styles and dispositions believing a teacher should be “very patient, very thorough and always available to students, as well as be more interested in the student as a person and how they developed rather than the information per se that was being laid out” (Len 1). Through his experience as a substitute teacher over the past two years, Len also has “learned that students must be shown respect if the teacher expects respect in return” (personal communication, June, 1999). As a high school science teacher, Len wanted to “educate students of the encompassing relevance that sciences have in each of our lives, and how an understanding of sciences can make life even more exciting and interesting” (personal communication, June, 1999). Having realized his “real passion for instructing others,” Len enrolled in the M.Ed. program after completing an undergraduate degree in psychology, “researching the teaching profession through substitute teaching,” and later additionally taking science content courses (Len 1).

Len’s Ontological Beliefs

Following the first interview, before taking any coursework in the M.Ed. program, Len’s ontological beliefs were firmly grounded in the Realist position (100%), where he believed that objects, including theoretical objects of science, “are real objects whether you can see them or not. They’re still real and if there is no humans here they would still exist, prior to humans” (Len 1). Moreover, “the laws of nature as we found them do not change and have been occurring for a long period of time, so we can use nature as a reference” in our attempt to “understand the processes of nature” (Len 1).
As can be seen in Figure A.4, after the second interview, Len's ontological belief profile was 43% Realist and 53% Radical. The Radical category, the ontological beliefs aligned with and informed by von Glasersfeld's radical constructivism, first emerged in the second interview. During the second interview, Len made a move towards an "antirealism" argument, according to which "a reality is merely an agreement on a particular idea and if people don't agree, then maybe each reality is real to that individual, but you can't say more about it than that" (Len 2). Overall, Len made no assumptions about "the existence of the world behind the subjective realm of experience" (Ernest, 1995, p. 474) and, according to him, each individual "defines his or her own reality" to "represent his or her experience" (Len 2). Accordingly, the truthfulness of constructed reality can be tested according to "how well they fit the world of each individual's experience" (Ernest, 1995, p. 474), or "solely in terms of what each individual has access to, namely his or her own experiences" (Phillips, 1997b, p. 184).

In addition, according to Len, on the one hand, "we as humans many times usually feel that the way we define reality is the way things really are," on the other hand, "everyone's reality can be slightly different if at all different, or can be the same, not everyone's, but yours and mine" (Len 2). Regarding uniformity in what is constructed by each individual or to account for the possibility of individuals' constructing the same understandings, Len explicated: Firstly, "although we construct our own reality and sometimes our reality is based on what other people have told us what their reality is, and so other people's reality or their explanation of their reality influences our reality." Secondly, "since all human beings share the same chromosomes, and we all process things very similarly, that may be the cause of why we all seem to see reality the same way, but we don't know for sure" (Len 2).

Apparently, in Len's ontological profile during the second interview, the Realist category (43%) coexisted with the Radical category (57%). Asked to align his own ontological beliefs with one of the given options during the second interview, Len chose an option representing a Radical ontological position, which states, "there is no rationally accessible, extraexperiential reality" (Matthews, 1994, p. 149). However, in a later part of the second interview, when asked to comment on the relationship between our scientific ideas and the nature behind them, he seemed to assume an observer-independent existence of "the physical world," and "scientific knowledge is discovered through the observation of the physical world as we interact with nature and the world" (Len 2). In other words, Len shifted back and forth between the two incompatible perspectives (the Realist and the Radical ontological beliefs) depending on what he was talking about. In the context of a philosophical debate on the status of an outside world, he contended, "each reality is real to each individual based on his or her own experiential world, but one cannot say more about it than that" (Len 4). On the other hand, as a science teacher, he acknowledged, as a result of "interacting with the real world, we interpret, define, and discover the nature as well as allow the nature to exist descriptively" (Len 2). According to Len's scientific realism, "nature is more the actor or actress
rather than the instructor” and in the process of interacting with nature “we ourselves put constraints upon us” (Len 2).

In the third interview, Len recovered his Realist ontological beliefs with 100% of the text units coded within this category. According to Len’s Realist beliefs, “reality to a scientist is what is observable and what is not observable”; that is, “when the tree falls in the woods, it makes a noise whether there’s anyone there to hear it or not” (Len 2). The role of human minds in this independently existing world is to “interpret nature and define as well as label nature” so that objects can not only “exist physically” but also “exist descriptively” (Len 2). The validity of our interpretation or theories, Len contended, can be judged by consulting how things are in a real world. He went on to explain that as a result of interacting with the real world “we have defined something as being true because we haven’t been able to prove them not to be true, but just because we can’t prove them not to be true doesn’t mean that they are true in the ultimate sense. It’s only true on the level that we haven’t disproved it” (Len 3). In sum, Len’s beliefs fit well with what Harding and Hare (2000) called “open-minded realism” according to which Len accepted “theories as true, surrounded by the particular evidence that supports them, while leaving open the possibility of change (p. 226). This Realist position was completely replaced by the Radical and Idealist positions in the fourth interview, where he argued, “reality doesn’t exist independently of minds, and humans defined reality” (Len 2 & 4).

One of the unique features of Len’s constructivist profile is that in the fourth interview (by the end of the university-based coursework), Len completely shifted away from his initial Realist ontological beliefs to the Radical or Idealist perspective. Some typical statement placed in the radical category for Len included: “only humans are going to define and create what ultimate truth is, and our absolute truth is only based on what we can experience” (Len 4). He went on to explain, “Because there is so much space out there that humans don’t know, so I am not sure that there is an absolute truth or how we will ever find an absolute truth. I guess there could be an absolute truth for the very small space that the earth occupies, or the small space that this galaxy occupies” (Len 4). According to Len, “if there are beings that live in other galaxies or outside of our solar system and are looking down, hypothetically speaking of course, they may see things differently based on what they can experience than the way we see it” (Len 2 & 4). In accordance with his Radical ontological perspective, Len believed “everyone would have their own reality based on what we can experience, and there could be an absolute truth to that individual in his or her own experiential world, for the very small space that he or she occupies” (Len 4). However, “humans could develop certain common perspectives with regard to reality” (Len 4). That is, “to begin with, a reality is merely an agreement on a particular idea and so people don’t agree then maybe each reality is real to that individual, but through expressing an individual’s certain reality to someone else, being able to talk about it, and articulate that to other people, humans can reach an agreement on whether something is real or not” (Len 4).

In the meantime, the Idealist category in Len’s ontological came in to existence when Len contended, “Our reality is defined by humans, so, if all humans agree on something, on one particular thing then that is reality as humans know it. Reality is merely an agreement by humans on whether something is real or not” (Len 4).

I agree with D also. If there is a reality that exists outside of language, there is no way to get to it, because we have to be able to talk about it. Otherwise we are just, everyone would have his or her own reality. I mean if I believe something and I can't articulate that to you, then that's my reality, but it may not go with your reality, but we will never know because I haven't been able to articulate my reality. My final position is probably C [Individuals, in their role as co-participants in socially shared activities, develop certain common perspectives with regard to objects and events in the world].

In sum, in the fourth interview, Len ended up in an ontological position that is informed by radical social constructivism (or social constructionism, as Gergen called it), according to which “the world is open to multiple interpretations and the language members of a particular community agree on what is considered reality” (Prawat, 1996, p. 221).

Summary of Len’s Ontology Profile Changes

Len began with accepting the existence of an external world that constrains “what we can believe about it” (Phillips, 1997, p. 160). After being introduced to the constructivist epistemology and ontology,
Len’s ontological profile showed different interpretations regarding an observer-independent external world as well as the relation between our ideas and the nature behind them. From the second interview, he incorporated the Radical as well as the Idealist ontological perspective into his ontological profile as he acknowledged that everyone would construct his or her own reality on the basis of his or her own subjective experiences (von Glasersfeld, 1995), and that “a particular community determines what sorts of things are regarded as existing using the medium of language” (Phillips, 1997b, p. 188).

Whether he achieved a consciousness of his own profile and was able to decide where each component is applicable in an appropriate context by the end of the interview process will be discussed after reviewing his epistemological profile in the following section. It is important to note that Len drastically reverted to the Realist ontological beliefs (100%) in the third interview, and then retrieved the Radical as well as the Idealist ontological beliefs in the fourth interview. The Explainers for this shift will be also discussed in a later section.

**Len’s Epistemological Beliefs**

Len’s epistemological profiles showed a less drastic variation than his ontological beliefs. Throughout interviews, Len’s epistemological profile consisted of the Piagetian, Fallibilist, and Progressive categories. Aligned with his Realist ontological beliefs, Len’s epistemological belief profile was 80% Piagetian and 20% Fallibilism in the first interview. Len’s epistemological profiles were still governed by the Piagetian category in the second interview with 88% of the text units coded within this category. According to Len’s Piagetian epistemological beliefs, although each individual could construct his or her own reality as well as scientific knowledge out of his or her own experiences with the influence of other surrounding people, the truthfulness of those different theories could be validated by referring to our experience and evidence that are gained through interaction with external nature. On the one hand, although “nature might constrain” what we can construct about it, nature “does not exist descriptively in the absence of humans” (Len 2). That is, Len recognized the role of nature as “more of the actor or the actress than the instructor” and emphasized humans’ active construction of scientific knowledge through “the observation of the physical world, interacting with nature, and defining, as well as interpreting nature” (Len 2).

I think the material world is close to what I believe; however the real world does have to be interpreted by humans for our understanding…. we can observe nature but we have to do the experiments to make sense of what’s happening. Well, I think, the constraints on science is that it is interpreted by humans… science is restricted by human interpretation, using nature as a reference. (Len 1)

![Epistemology Profile (Len)](image)

Figure A.5: Len’s epistemological beliefs profile
Throughout interviews, Len consistently believed, “most scientific knowledge has been produced by doing experiments and studying the behaviors of those things being studied”; however, “we have no way of knowing if it is an ultimate truth. Our truth is defined in what we have been able to prove and explain to the society or the science community” (Len 3). This Piagetian category got further elaborated in the fourth interview as Len contended that nature “is playing a role in constraining or shaping the views we construct about it” (Phillips, 1997b, p. 184), while questioning, “how will we ever find an absolute truth?” (Len 4).

This Piagetian category conceded its first place in Len’s epistemological profile to the Absolutist perspective in the third interview, where Len had 58% Absolutist, 20% Piagetian, and 23% Fallibilism. In the fourth interview, Len’s epistemological profile was 37% Absolutist, 41% Piagetian, and 22% Fallibilism. From his Absolutist position, Len strongly indicated, in some cases such as “the laws of gravity, the shape of earth, and the theory of evolution, we have reached the ultimate truth” with the development of new technology that allowed “scientists to see different creatures that had close similarities through different parts of the earth and to take the picture of the earth from outer space” (Len 3 & 4). As progressive steps toward ultimate scientific truth, “new theories replace old theories” over the course of history, but it gets progressively more difficult to replace old theories because you narrow the possibilities with each new theory that replaces the old” (Len 4). Therefore, in some fields such as the law of gravity, “we are pretty much fixed with that particular law of gravity, at least on this planet. So, until we are able to explore the gravity in new situations, the laws of gravity are not going to change that much” (Len 4). Along this line, Len contended, “we need to learn scientific theories because they give us a starting point for what we are looking deeper into (or for a better understanding), and there is no reason to reinvent the wheel every time we want to look at something” (Len 3). Overall, to an extent, Len believed, “science aims for the truth about the world, and although it does not always succeed, there is progress in approaching truth” (Harding & Hare, 2000, p. 226).

On the other hand, acknowledging, “science is restricted by human interpretation” (Len 1), Len showed his awareness of “the vulnerability of scientific theories to new evidence or interpretation” (Harding & Hare, 2000, p. 231). Len’s Fallibilist category in his epistemological profile maintained as the second largest component throughout interviews: 20% in the first interview, 12% in the second interview, 23% in the third interview, and 22% in the fourth interview. According to Len, all scientific theories are in principle revisable, tentative, and subject to change. Therefore, Len contended, “scientific truths are just things that have not been disproved. So we don’t know if it’s true in the absolute sense, but we do know that it has not been disproved. We haven’t figured out a way to disprove certain scientific theories (Len 3). Len went on to contend, “Statements in science have not been disproved. Theories are merely hypotheses that have stood up over time, but that doesn’t make them true or false” (Len 4). In addition, “we have no way of knowing if it is an ultimate truth in that our truth is defined in what we have been able to prove and explain to the society or the science community” (Len 3). He was not sure “how we will ever find an absolute truth” although we do have a greater understanding than the previous generations (Len 4).

Summary of Len’s Epistemology Profile Changes

In sum, Len’s epistemological profile could be represented as the Piagetian category informed by Piagetian ontological as well as epistemological beliefs, according to which “as a result of interacting with the real world, we only construct scientific theories that are in some logical sense ‘isomorphic with nature’” (Phillips, 1997b, p. 184). This Piagetian category was replaced by the (Progressive) Absolutist category when Len showed faith in current knowledge that moves towards ultimate scientific truth. Overall, Len maintained the Piagetian and the (Progressive) Absolutist categories as backdrop of his epistemological profile, depending on whether he subscribed to the ultimate truth as an attainable goal or not. He was also aware of the fallible and tentative nature of scientific theories in that they are always open to change.

It is important to note that it is rare to locate any Relativist component in Len’s epistemological profile, which would map onto his Radical or Idealist ontological beliefs. Len’s epistemological beliefs fit well with what Harding and Hare (2000) called ‘open-minded scientific realism’. That is, regarding science and scientific knowledge, Len presupposed an observer-independent existence of nature and accepted scientific knowledge as tentatively true, true in a sense reflecting what nature really is, while remaining “open-minded about future change” (p. 226). Therefore, there was incompatibility of Len’s Idealist (or Radical) ontological beliefs with his scientific realism, according to which scientific theories are subjected to natural world for verification. As far as I could tell, this incompatibility did not cause any conflict in Len’s constructivist profile and he was not conscious of this inconsistency. In a following section, how his
ontological and epistemological beliefs mapped onto and reflected in his conceptions of science teaching and learning will be discussed.

Len’s CSTL

Len’s CSTL profile after the first interview had the traditional category as the largest component (41%), along with the Piagetian category (20%) and von Glasersfeld’s radical constructivist category (39%). The initial traditional category of Len’s CSTL profile reflected his beliefs about nature of science teaching based on his own experiences as a student, where he “was absorbing the information that was conveyed by the teacher” (Len 1). Len thought, “if students have no interest in understanding it, they won’t allow the information to be absorbed, they won’t take the necessary steps, they won’t attend to it to the degree that may be necessary.” Aligned with his traditional pedagogical beliefs, Len contended, “the teacher let students know what’s expected of them. The student needs to know what they need to learn because understanding of those is necessary in order to understand the big picture” (Len 1). This traditional category in Len’s CSTL profile was untraceable from the second interview, where he acknowledged, “Yes, before, I would say I would have been more of lecturer, and telling students what it is and having them process that information, and now, I think, I see that it’s very important they need to understand that concept in their own way, and categorize that information so that it makes sense to them” (Len 2).

In the meantime, recalling a lot of previous teachers he was familiar with throughout schooling—“who were just steering or funneling the students towards an accepted interpretation, making some kind of judgment call on the student, and acting as all knowing”—Len contended, “teachers have to have a firm grasp of their ideas and sort of guide students in a direction, but I don’t think you need to be very extremely rigid in the direction that you’re taking them in.” That is, by “not evaluating the students’ contributions with respect to the interpretations of society, teachers could allow the students to come up with new ideas for themselves, which very well may be legitimate” (Len 1). When Len talked about the value of “processing information differently than the majority of society,” his pragmatist (or instrumentalist) views of knowledge were revealed, which is shared by von Glasersfeld’s radical constructivism (Len 1).

Although it has never surfaced as the largest component, Len’s radical category in his CSTL profile appeared consistently whenever Len emphasized individuals’ being able to be different from the majority of people’s way of thinking (14% in the second interview, 6% in the third interview, and 24% in the fourth interview). Overall, according to Len’s Radical position in his CSTL profile, “the ideal role of the teacher is to help the students come up with strategies to solve the problem and to help that student think out those processes and help students stay on track to their final goal of solving the problem” (Len 4). In the meantime, the teachers should “not actually be so directed to tell the students to go through rigid steps or everyone to do the same thing in order to get that answer” because by “letting students come up with their
own method that is easier to understand to them, they may be the next Einstein or they may be the next geniuses of the world" (Len 1). Some typical statements placed in the radical category for Len included:

To a degree, I think, teachers need to direct students in a particular direction, but we can’t restrict a student’s creativity, even though it may not align with society. If it’s not too far out, they may have been able to think of something that none else has yet thought of, or none has articulated it before, so I think teachers need to be careful of the limitations we put on students in their active searching for knowledge. (Len 2)

In other words, as far as students’ constructed ideas and ways of solving problems are useful and viable to them—viable in a sense of giving fruitful results—“teachers need to let students use the method that they understand or use those things that work for them,” even if those methods are not the ones accepted by the majority of society (Len 1). Accordingly, Len went on to say, “I am going to let students explore things in many different ways and try to help them get to the solution to their problem in an efficient manner” (Len 4). Accordingly, Len argued, “the ideal role of the students would be to think about the processes that teachers are talking about and make an effort to draw those parallels between the new knowledge with something that they are already familiar with” (Len 3).

In the first interview, Len also had Piagetian CSTL category recommended by individual constructivism (20%), where the teacher should “guide students knowledge construction so that their knowledge that they're constructing stays within parameters that are acceptable within the science community” (Len 2). This Piagetian category informed by the individual constructivist in Len’s CSTL profile dominated as the largest component from the second interview on (67% of text units in the second interview, 76% in the third interview, and 76% in the fourth interview). Len seemed to assume that students “are capable of generating ideas for themselves” depending on what they already know and what their cognitive capacity is” (Len 1). In the process of students own meaning construction, Len contended, the teacher “can’t expect every student to construct the exact same knowledge, but I can expect them to accept what the scientific community has laid for them” (Len 2). That is, according to Len, one of the primary goals of science teaching is to make “students come to an understanding of what the scientific community has already established, or make students be aware of the conventions of scientific community so that they approach things, experiments, or ideas in a similar way that the rest of scientific community is approaching them, so that when they get to their results, they can be compared with others” (Len 2):

The ideal role of the teacher is to make sure that the student has a clear understanding of the principle set forth by the scientific community.... The students should be aware of what the scientific community has accepted. And so the students will create their own knowledge and should be able to support their findings through experiments and if they can and those things can’t be disproved then they should be accepted. (Len 3)

The learning outcome of science teaching is to help students understand the natural world based on what is already known or thought to be known by the scientific community. (Len 4)

According to Len’s argument, although students are allowed to construct their own meanings, ideas, and knowledge, they are not free to construct anything they please. Len thought, “it is okay for students to construct and to build on the knowledge that they already have as it relates to the scientific community, as long as they come to an understanding of what the scientific community has already established” (Len 2). Moreover, “students are scaffolded or apprenticed as they use information and build upon that information, and hopefully all the students will have constructed similar knowledge to build upon” (Len 4). Therefore, in their meaning construction process, “the students should be kept on track, if they are very far off, I think they need to be helped back into some wide parameters, but kept somewhat in check by teachers” (Len 2). To help students construct their knowledge as close as possible to “what is already known or thought to be known by the scientific community,” the teacher “does need to provide appropriate experimental evidence and a background (Len 3) and needs to direct students in a particular direction that is more acceptable by the scientific community” (Len 4). Len argued, “we are allowing students to construct their own knowledge, where we are not only giving them the resources to do that, but we are also helping them to understand what it is that they are finding through their experiments and investigation” (Len 3).

Furthermore, “constructivism is where we let students construct their own knowledge, but we are pointing
them in a particular direction and this is not a pure exploration” (Len 3). According to Len, the teachers should “make decisions about what could be useful learning activities and interact with pupils to help them interpret those activities appropriately” (Driver, 1989, p. 104) because teachers “have to keep them from wavering too much, from floundering and trying to reinvent the wheel” (Len 3). Len further recognized that there are already “the conventions of scientific community and the accepted scientific knowledge” that students have to internalize (Len 2), and that “students are not going to discover this world, its concepts and their relationships, merely by private inquiry” (Matthews, 1994, p. 155).

In addition, Len believed, “the teacher should encourage students to explain and justify their interpretations, which allows the teacher to better understand the student's thinking. In that way the way the teacher is not in a situation where they have to try and fill in blanks, or guess that what the student is going through their thinking process” (Len 2). Len went on to explain, “as far as being concerned with what goes on in a student's head, I think, teachers need to be aware of possible misconceptions and try to help students to clear up those misconceptions” (Len 4). Len also believed, “if students believe something that is not accepted by the scientific community, they need to be able to justify and prove that position and when they have problems with justifying those positions, I think, you will find that they start to move in a direction that is more acceptable by the scientific community when they find that they cannot justify their conceptions, their misconceptions, or their positions” (Len 4).

Len expected his students to learn by “building on the knowledge that they already have as it relates to the scientific community and the topic that we are discussing” (Len 2) as well as “by drawing parallels to something that they already know or by relating that to something that they are already familiar with” (Len 3). To help students make “the links between their current knowledge schemes and present learning experiences” (Driver, 1989, p. 104), the ideal role of the teacher is to “present an environment for children to learn, and to raise questions to get the students to think and these questions will direct the student's thinking in a particular way that will assist that student in drawing parallels” (Len 3). Students, Len continued to believe, “are supposed to learn the rules that the scientific community has accepted or has put before us, as teachers, to put before the students” because “the accepted scientific knowledge gives us a starting point for what we are looking and there is no reason to reinvent the wheel every time we want to look at something deeper” (Len 3).

Asked to comment on the feasibility of constructivism in the real world after two quarters of his M.Ed. methods courses, Len contended, “Yes, constructivism can be implemented in a classroom because I am actually doing that now in the classroom, in my field experiences. So the only thing I am not sure of is to what degree they are constructing their knowledge or how accurate their knowledge is” (Len 3). On the other hand, considering “time constraints in a classroom and certain objectives that the school district is going to set forth, we cannot just wander aimlessly and teachers have to keep students from wavering too much” (Len 4). Len contended that students by themselves “are not going to discover this world” or construct scientific understanding automatically as they interact with nature; therefore, “scientific understanding and modes of thought require initiation into a scientific tradition, an initiation provided by school science teachers” (Matthews, 1994, p. 161).

The social category in Len’s CSTL profile came into existence from the second interview (19% in the second interview, and 18% in the third interview) where he emphasized, “the importance of individual meanings being compatible with institutionalized knowledge, if not fully consistent with it” (Prawat, 1996, p. 220). This emphasis led him to maintain that one of the main goals of science teaching is enulturating his students into scientific society (Prawat, 1996). Some typical statements placed in the social category for Len included:

Students are capable of generating ideas for themselves, the students need to be aware of the conventions of scientific community so when they approach things, experiments, or ideas, they're approaching them in a similar way that the rest of scientific community is approaching them. When they get to their results, they can be compared with others. (Len 2)

In other words, according to Len, “students should be aware of what the scientific community has accepted” so they can “support their own created knowledge” with regard to the scientific community's convention, including the scientific theory as well as the scientific process (Len 3). In the third interview, asked to choose one of the given preferences that would most align with the way he thought about science
teaching and learning, he chose ways of teaching informed by a social constructivist perspective, according to which "teachers are there to support students as students construct ideas by themselves."

In terms of learning mechanism, Len believed students “learn by relating the knowledge that they already have to the scientific community’s accepted knowledge and the topic that we are discussing” (Len 2). In addition, Len was fascinated by “learning from the apprenticeship” as he had “immersed himself into the process” in his field experiences (Len 3), where his mentor teachers “model the necessary procedures.” (Prawat, 1997, 240) as they engage in a shared teaching activity. Len went on to say, “I think, apprenticeship is a great thing. By just sitting back and observing, we are not going to be able to develop our knowledge as quickly as if we are doing it and most people learn best by teaching someone else how to do it. I think that the apprenticeship could help more students” (Len 3).

Summary of Len’s CSTL Profile Changes

In sum, without having been in the M.Ed. program, Len “would have been more of a lecturer, and telling students what it is and having them process that information, and now I think I see that it’s very important they need to understand that concept in their own way, and categorize that information so that it makes sense to them” (Len 2). Throughout the interviews, Len maintained the Piagetian component as the backbone of his conceptions of science teaching and learning, according to which he wanted to deliberately encourage his students’ learning of “what the scientific community has already established, the conventions of scientific community, and the way that the rest of scientific community is approaching things, experiments, or ideas” (Len 2). He viewed students need to learn the conventions of scientific community as well as ways of doing science in a similar way to that of scientific community in that, based on “an understanding of” these accepted ways of doing science and conventions, students can build on their own knowledge, which should be acceptable to the scientific community (Len 2), clear up their misconceptions by comparing with what is accepted by the scientific community (Len 4), and start to build on a deeper understanding of the world by acting in accordance with “the rules that the scientific community has accepted” (Len 3).

Regarding students’ ways of learning, based on his pragmatist epistemology views of knowledge, Len indicated to let his students “come up with their own methods and strategies to solve the problem in their active searching for knowledge” (Len 2) as long as they “stay on track to their final goal of solving the problem in an efficient manner” (Len 4). Finally, “hopefully, these processes give fruitful results and the right answer,” “right” in a sense that students’ own constructed understandings and solutions are compatible with “what the scientific community has already established” (Len 2).

Throughout the interview, Len was most concerned about the teacher being a link between the students and the scientific community, where the teacher “will direct the student's thinking in a particular way that will assist that student in drawing parallels between their understanding and the scientifically acceptable viewpoint” (Len 3). He also emphasized, “the teacher would have to explain scientific concepts in a number of different ways because each student is going to grasp different concepts in different ways” (Len 2) as well as “the teacher would have to give different types of assessment because different students have different strengths” (Len 3).

Explainers for Len’s Constructivist Profile Changes

Asked to provide the most influential factors in helping him to form beliefs about science teaching and learning, Len offered “probably the field experience and a supervisor that I had” (Len 4). Although “cooperating teachers can be models,” according to Len, “they may be good models or they may be bad models. They may want you to become more like them so anything different than that they would tell you as bad or not good. Some of them are not open to new ways of teaching. I would say that I got less from my mentor teachers or cooperating teachers than I did from my supervisor. Supervisors provide experiences from the teaching classroom but also have a broad base in knowledge of research and instruction” (Len 4).

In addition, Len commented, “the M.Ed. program has given me an avenue to become a teacher. I am taking away from it everything that I possibly can (Len 3); “I think, I have developed a better understanding of how to challenge students, and how to get them to think” throughout the M.Ed. program (Len 4). Had it not been for the M.Ed. program, Len said, “I would have been more of a lecturer, and telling students what it is and having them process that information, and now I think I see that it’s very important that they need to understand that concept in their own way, and categorize that information so that it makes sense to them” (Len 2). By the end of the second interview, Len was “looking forward to getting into the classroom, and putting some of this knowledge to practice. We’ve learned a lot of theory,
and I would like to see how this works in the classroom" (Len 2). However, by the end of third interview, asked to comment about how the field experience of the autumn quarter was similar to what he was taught in the M.Ed. methods courses, Len said:

"We talked about constructivism in the summer and I see a lot of it now. We talked about some of the psychological philosophies and I can see how some of those are supported now. As far as being different, some of the things that they teach us in the program are... they sound really good, but when you try to implement them in the classroom, you can't because as a teacher, you are restricted to a certain amount of time and you have to complete a certain amount of curriculum. I think as a teacher you have to get very creative in how to cover several topics at one time and hopefully do it in a way that students understand all of those." (Len 3)

Asked to explain apparent beliefs changes in his profiles (ontology, epistemology, and CSTL), he commented, "there are so many changes here. I don't know why it changed. I guess if it's changed just because of what I have seen in the classrooms in the field experience; That's where most of my energy has gone" (Len 4). He went on to explain, "I am going to let students explore things in many different ways and try to help them get to the solution to their problem in an efficient manner. There is time constraint in a classroom and we can't just wander aimlessly. I mean, there are certain objectives that the school district is going to set forth, so you have to accomplish those" (Len 4). Len's pragmatist views towards learning to be a teacher and the M.Ed. program were revealed when he indicated, "a person needs to become the best and most effective teacher that they can possibly be" regardless of the different approaches taken by each individual. As discussed in an earlier section, Len's pragmatist orientation was also revealed when he talked about desirable learning outcomes and validating processes of students' own constructed understandings according to what is accepted by the scientific community. That is, although he acknowledged "students will understand matters differently, and will relat the new knowledge to what they had previously known in distinctively different ways" (Phillips, 1997b, p. 181), the teacher deliberately should encourage students to “get to the solution to their problem in an efficient manner and, considering time constraint in a classroom, we can’t just wander aimlessly” (Len 4).

Regarding the extent to which he was conscious of the relationship between his CSTL and his ontological/epistemological beliefs, he acknowledged that a teacher's conceptions of teaching and learning are grounded in one's beliefs about the nature of knowledge, and that a teacher's ways of teaching are intimately related to his or her beliefs about the nature of knowledge. As Len put it:

"Yes, I think, if a teacher believes that there is absolute truth and that scientific theories and laws are fixed, then, I think, they are going to teach in such a way that it leaves for less exploration by the students. It's going to be a much narrower approach to the concepts, I mean the instructor would probably present the information in a very direct manner and would leave no room for error or exploration of any width." (Len 4)

Regarding whether he was conscious of his ontological and epistemological profile and was able to decide where each category is applicable in an appropriate context, Len was aware of different categories of ontological beliefs and he himself showed a drastic transition in terms of his own ontological beliefs. That is, he came in to the M.Ed. program with a strong Realist perspective; however, after being introduced to the constructivist epistemology and ontology, Len's ontology profile incorporated different interpretations about the relation between our ideas and the nature behind them and exchanged his initial Realist beliefs with the Radical (or the Idealist) beliefs.

On the other hand, it is important to note that Len drastically reverted to the Realist ontological beliefs (100% of text units) in the third interview, and then retrieved the Radical (as well as the Idealist) ontological beliefs in the fourth interview. As discussed earlier, Len's epistemological beliefs were firmly grounded in 'open-minded scientific realism' (Harding & Hare, 2000). In other words, Len's newly incorporated Radical or Idealist ontological beliefs in the later interviews did not directly transfer to his beliefs about scientific knowledge and how to validate scientific theories, or to his views of science teaching and learning.

Although there was an apparent incompatibility between Len’s Idealist (or Radical) ontological beliefs with his scientific realistic epistemological beliefs, this incompatibility did not cause any apparent
conflict in Len’s constructivist profile and he was not conscious of this inconsistency, which in turn did not cause any uneasiness when he indicated how his beliefs about the nature of knowledge mapped well onto his conceptions of science teaching and learning in the member check process. As far as I could tell, this inconsistency has not surfaced as a problem in Len’s constructivist profile because, to Len, those two realms—thinking of reality in a philosophical sense, and thinking of reality in a science teaching context or conducting scientific investigation context—are totally independent and belong to different dimensions in his thinking. He seemed to be fully comfortable with this apparent separateness and keeping a boundary between them.

On the other hand, Len’s dominant Piagetian category in his epistemological beliefs reflected onto his CSTL profile, which also consistently maintained the Piagetian individual constructivist position as the largest pedagogical beliefs that he brought with him to the M.Ed. program, Len’s CSTL profile did not show any radical exchange between preexisting beliefs with new ones or incorporation of a new perspective. Len seemed to acknowledge time-honored, established scientific conventions and ways of searching for knowledge and, thus, as a science teacher he wanted to deliberately introduce his students to the scientifically acceptable viewpoint. Another important thing to note in Len’s CSTL profile is that the social category in Len’s profile showed up from the second interview but disappeared in the fourth interview. As a possible reason, Len offered time shortage and the amount of content he felt required to cover as constraints on implementing his ideal CSTL. Therefore, although he acknowledged students’ being capable of generating ideas for themselves and learning through exploring a problem themselves and learning how to do science—or how to be a science teacher—through apprenticeship learning (Len 4), his social category mitigated as he put more emphasis on "the importance of individual meanings being compatible with institutionalized knowledge" (Prawat, 1996, p. 220) and the teacher’s role as introducing what is accepted by the scientific community by “clearing up any misconceptions” (Len 3).

On the other hand, regarding his awareness of the three different versions of educational constructivism (i.e., individual, radical and social), Len seemed not to be aware of different ontological and epistemological commitments of different version of constructivism. According to Len, constructivism was a view of an individual student’s knowing rather than a view of knowledge (or “a model of what it means to know”) (Bettencourt, 1993, p. 39). Len said, “constructivism is building on knowledge, categorizing knowledge in relationship to what you’ve already learned about the topic” (Len 2), which resonates well with the literal interpretation of the metaphor of carpentry or architecture of constructivism. Len continued to believe that constructivism “is where we are allowing students to construct their own knowledge, but we are pointing them in a particular direction, not pure exploration. We are giving them the resources to do that, but we are also helping them to understand what it is that they are finding through their experiments and investigation” (Len 3). Len’s internalized version of constructivism as a way of learning and teaching science was “discovery methods,” contrary to “spoon-feeding” (Len 3). However, “teachers have to have content that goes beyond pure constructivist’s discovery methods” (Len 3) and “students’ knowledge has to be guided by the teacher so that their knowledge that they’re constructing stays within parameters that are acceptable within the science community” (Len 2).

In conclusion, Len was interested in constructivism as a way of learning and teaching science, and he hardly recognized it as an epistemology. In the meantime, according to his vision of what constructivism is, Len was confident with implementing constructivism in a classroom because he was “actually doing that now in the classroom” in his field experiences by “allowing students to explore” (Len 3). According to Len’s interpretation of constructivism, the teacher should act as a link between “what students already know and what is accepted by the scientific community in students’ own knowledge construction to keep them from floundering or wavering too much” (Len 3).

Lynda’s Case

Lynda’s Past Experiences

Lynda is a white American female in her early twenties, requesting a certification in physics for grades 7 to 12. Lynda felt very comfortable with the idea of going into the teaching profession since both of her parents and her grandmother were teachers. Lynda always knew she would continue the long family tradition of becoming a teacher, which is what she grew up with. Although she was fascinated by physics for its own sake and for the complex reasoning involved in research and experimentation, she always knew...
that all she really “did want” was to teach at the high school level, not the collegiate, where she needed to
do “all the research that’s involved.” So after a year in the physic department working towards a Ph.D. in
physics, she decided to pursue what she really wanted, that is, an education certification (Lynda 1).
Throughout her previous teaching experience as a teaching assistant in the physics department, she was
most concerned about “where my students are coming from.” She wanted to teach the student to become
one “who challenges what he or she is told, someone who uses logic and reasoning to discern his or her
thought and the value of what he or she is told.” Moreover, she wanted to become a teacher to “share and
pass along the knowledge of physics which the people of this world have worked so hard to obtain”
(personal communication, Lynda’s Statement of Intent, June, 1999).

Lynda’s Ontological Beliefs

Lynda’s ontological beliefs profile shows that in the first interview she was firmly grounded in the
Realist position. This initial Realist view was consistent and compatible with her physics teaching
background as a graduate teaching assistant and related to several years of work in physics laboratories
where, as Harding and Hare (2000) noted, most scientists held “this nonrelativist (or realist) view” and
“they tend to believe that science aims for the truth about the world, and although it does not always
succeed, there is progress in approaching truth” (p. 226). Harding and Hare go on to say “they [scientists]
could not work in science if they did not have this nonrelativist view (p. 226). In Lynda’s own words, this
Realist ontological view can be summarized as follows:
The material world or objects of knowledge as a real structure exists independently of our
knowledge of their existence. Just because we can’t see, or can’t describe completely all of their
properties, just because I can’t do that for subatomic particles, the experiments that have been made
are enough to convince me that there is an existence of these things. Maybe we’re describing them
slightly wrong, maybe there is some other description for them that we haven’t discovered yet, but I
think they exist. As we learn more about it, as we discover more ... we know better. (Lynda 1)

However, in the second interview, she drastically shifted her ontological position from a Realist view to a
Radical ontological view (81%) as she espoused what “constructivism says” word by word (Lynda 2):

Constructivism says that, the only knowledge we can hold is knowledge and facts, and then
everything [we know is] through our perceptions, meaning we’re never going to reach any sort of
ture, absolute knowledge. If one exists we will never know it because everything we do know is
through our perceptions.... You know, things do exist, but I think things exist only through our
perceptions.... What we perceive would be reality.... I am not sure about that there’s no world
outside of human experiences, I guess I just figure there probably exists something outside of human experiences, but what I am saying is that what we know of is only perceived through our minds. (Lynda 2).

By the end of the second interview, when asked to comment any role change or perspective changes in herself after one quarter in the M.Ed. program, Lynda explicitly expressed her endorsement to the radical constructivist position, which was represented as “the basis of constructivism” to her. This radical ontological position mapped well onto her Fallibilist epistemological portion as can be seen in her epistemological profile in the second interview.

I would say, there’s a bit of change.... the basis of constructivism that the idea of probability. I really thought about it [and it is] so clear that constructivism says that the only knowledge we can hold is knowledge.... through our perceptions, meaning we're never going to reach any sort of true, absolute knowledge. If one exists we will never know it because everything we do know is through our perceptions. I think of that idea as a core, central thing. It has not necessarily changed as much as [it] made me think about it in a different way. (Lynda 2)

This radical shift in her ontological beliefs towards Radical position alleviated in the third interview where she reverted to and recovered her initial Realist ontology category (65%), while she newly incorporated Idealist ontological position (35%). Some typical statements placed in the Realist category for Lynda included:

They [scientific objects] may not exist how we see them now. Yes, I believe something exists that plays the role of an electron, but how it’s described right now may not be so. So we might be wrong a little bit about how it works. In one sense there is some objectivity to science and physical entities.... I guess, our hope is that over time we are more closely coming to what we really observe, making sense of our observations. (Lynda 3)

In the meantime, abandoning an agnostic radical ontological view, she adopted an Idealist ontological view as she acknowledged many possible realities depending on a specific language group, which in turn determines “how to speak” a shared reality.

Some aliens from another planet may look at reality as something different than we do. We only know things in the language that we know how to speak, i.e., [a reality existing outside of language may exist but there is no way to get at it other than through a community’s way of talking about it]. (Lynda 3)

One interesting feature during the third interview was that, Lynda differentiated her ways of interpreting realities into two spectrums: “a smaller—within humans—scale and a larger—beyond humans—scale.” As far as I could tell, Lynda was not conscious of a conflict and incompatibility between the Realist and the Idealist ontological beliefs. When I asked her to choose one of the given preferences that would most align with the way she thought about reality, she picked up two seemingly incompatible—at least to me—preferences at the same time, asking back to me “Is it possible to mix A (Realist preference) and D (Idealist preference)?” (Lynda 3). To compromise an unconscious conflict between the Realist ontology and the Idealist ontology, Lynda seeded to compartmentalize them into two different dimensions. According to Lynda, on the one hand, “on a smaller scale, there is some objectivity to science and physical entities that someone across the world is going to observe and can come to the same conclusion.” On the other hand, she further indicated the possibility that “on a larger scale” there could be different realities if someone or something could take on other-than-human perspectives, or could transgress humans’ language boundary. This Idealist component in the third interview changed into the Radical component in the fourth interview as Lynda replaced possible multiple realities with an inaccessible—although viable—reality. In the fourth interview, Lynda’s ontological profile was 89% Realist and 11% Idealist. As can be seen, Lynda recovered more portions of the Realist ontological beliefs in her last interview up to 89%, where she contended, “I would definitely say, the world is also not just created by that scientific society .... Yes, there is an absolute nature out there independent of humans” (Lynda 4).
By the end of the winter quarter during the fourth interview, although Lynda had the Realist component as a backdrop, she showed her awareness of the possibility of “no extraexperiential reality” (Matthews, 1994, p. 155). That is, other than solely rooting in the realist ontological beliefs, she was conscious of other possible categories of an ontological profile, such as Radical or Idealist. Without giving up her Realist position, she incorporated the other categories as she acknowledged “no direct access to reality other than through our perceptions” (Lynda 3) and the possibility of other realities perceived by other nonhuman beings, for example, aliens. During her member check, she commented:

I would say I am still somewhat of Realist, but yet, maybe I have some gatherings in there [there is a reality but there is no way to directly access that reality]. Yeah, I am probably in here [between Realist and Radical positions]. (Lynda 4)

Summary of Lynda’s Ontology Profile Changes

By the end of the interviews, Lynda identified herself as a Realist, while leaving open the possibility of a coexistence of Realist and Radical ontological beliefs in her ontology profile. Her Radical ontological position also has a potential to further develop into an Idealist ontological position as evidenced in the third interview. Even though I repeated the same question and provided the same preferences in the third and fourth interviews, Lynda chose the Idealist category as her second choice in the third interview and the Radical in the fourth interview. In one sense, she settled down with a Radical position as a minor portion of her ontological beliefs by retreating from an extreme Idealist ontological position—multiple possible realities—to a Radical position—being unable to tell anything beyond one’s perceptions. As will be discussed in a later section, it should be noted that the fluctuations in Lynda’s Realist ontological component in her profile fit well with the pattern of change in her Piagetian epistemological component in her epistemological profile. Attention is focused on reasons for the changes in Lynda’s ontological profile in the explainer section at a later point in Lynda’s case study.

Lynda’s Epistemological Beliefs

Based on the analysis of text units coded for the first interview, Lynda’s epistemological belief profile was 44% Absolutist and 56% Piagetian. When asked to choose from among the epistemologically distinct options A, B, C, or D presented during the first interview, Lynda chose an option representing a Piagetian epistemological position, which was rephrased in Lynda’s own words:

[a] human's role in this world has been to label, and to... I do believe that there is something independent of human mind that we have set out to discover. However, our human mind definitely plays a role in how we interpreted what we've seen. (Lynda 1)
Firmly grounded in her scientific realism, Lynda believed in “an existence of these things [theoretical objects in science] and she also acknowledged a possibility that “maybe we are describing them wrong, [or] maybe there is some other descriptions for them that we haven’t discovered yet.” According to her, another constraint in our knowledge-constructing activities is from “what we can believe” or what we know about the outside natural world:

We’re still constrained to what we can believe.... as the universe seems to expand as we learn more about it [and] as we discover more. Our ideas are more open to what we can believe.... In a sense we’re constrained by our environment. But at the same time, we’re constrained in the time when we thought the earth was flat because we couldn’t see the earth. Now we have the technology and now we can see the earth, so we know better. (Lynda 1)

This quote illustrates the [progressive] Absolutist component of Lynda’s epistemological profile. That is, Lynda viewed that over the course of history, scientific theories approach truth more closely, where these theories are subjected to natural world for verification—the scientific realism of trivial (or Piagetian) constructivism (Ernest, 1995). In other words, “the replacement of old scientific theories by new ones is progressive steps toward ultimate scientific truth” (Ernest, 1998, p. 58). This progressive epistemology thus fit with Lynda’s conceptions of reality, which had an independent existence regardless of our knowledge of its existence. However, as I have discussed in a previous section, Lynda drastically shifted her ontological perspective from a Realist to a Radical in the second interview as she questioned the independent, absolute existence of the reality. Along with this ontological belief shift, in the second interview, her epistemological profile also changed. In the second interview, Lynda’s epistemological profile was 54% Piagetian and 46% Fallibilism. In accordance with her radical ontological beliefs about reality—according to which “there is no rationally accessible, extraexperiential reality,” (Matthews, 1994, p. 149)—Lynda replaced her previous Absolutist perspective with Fallibilist perspective. Lynda acknowledged the fallible and tentative nature of scientific theories, which is caused by humans’ perceptually mediated access to knowing activities:

The only knowledge we can hold is knowledge and facts, and then everything [we know is] through our perceptions, meaning we’re never going to reach any sort of true, absolute knowledge. If one exists we will never know it because everything we do know is through our perceptions. (Lynda 2)

However, as she reverted and recovered the Realist component in her ontological profile in the third and the fourth interviews, this Fallibilist category gradually decreased (30% in the third interview and 19% in the fourth interview). In the mean time, Lynda maintained the Piagetian component as the backbone of her epistemological beliefs throughout the interviews: 56 % of the total text units coded within the epistemology category in the first interview, 54% in the second interview, 41% in the third interview, and 81% in the fourth interview. As far as I could tell, for Lynda’s case, her ontological beliefs thus fit nicely with her epistemological beliefs. That is, there were correspondences between her Realist ontological beliefs and the Piagetian epistemological beliefs, as well as her Radical ontological beliefs and the Fallibilist epistemology in light of patterns of occupation in Lynda’s profiles. The progressive Absolutist epistemological perspective came into existence whenever Lynda amplified her strong beliefs in gradual access to the ultimate truth; so did the fallibilist epistemological perspective when she took a highly skeptical stand about inaccessible—therefore deniable—existence of the external world. During her member check where she read and saw her own ontological and epistemological profiles resulting from the first three interviews, she reassured her epistemological position as “somewhere around these two [Piagetian and Fallibilism positions]” (Lynda 4).

Summary of Lynda’s Epistemology Profile Changes
As she acknowledged in her member check, Lynda “came in as a Realist” which aligned with Piagetian and Absolutist epistemological perspective, and strongly advocated the radical constructivist’s ontological and epistemological perspective as she read and learned about various versions of constructivism, among which only von Glasersfeld’s radical version left a deep impact on her. However, as time went on in the M.Ed. program, with a little bit of fluctuation in her epistemological profile, she settled down with the Piagetian epistemological perspective, with a minor portion of Fallibilist perspective.
Whether Lynda achieved a consciousness of her own profile at the end of the interview process, and was able to decide where each component was applicable in an appropriate context will be discussed in the final section of Lynda’s case study when I examine the relationship between her ontological and epistemological beliefs about the nature of science and her beliefs about science teaching and learning.

Lynda’s CSTL

In the first interview, Lynda’s CSTL profile was 72% Individual and 28% Traditional. Lynda’s initial Individual constructivist’s position resonated well with Driver’s views on science learning, that is, learning is “essentially a process of acculturation into the ideas and models of conventional science” (Driver, 1989, p. 103). According to Driver (1989), the teacher needs to lead students towards the theoretical ideas of the science community because “there are things which children cannot be expected to ‘discover’ for themselves... Moreover, if given the opportunities, children will make discoveries but these will not necessarily be what was intended” (p. 102). Lynda explicated her own position:

But the teacher doesn’t just put these ideas in students’ minds.... There’s more information and more discovery in this world than ever. How can all the scientific ideas be grappled with? At least for the classroom, some of these ideas can be given to the students, and then the student on his own time, on his own pace can grapple with them. So it’s like teaching students how to grapple with ideas, and yet, still presenting ideas that they wouldn’t necessarily grapple with at that moment. (Lynda 1)

This quote illustrates that Lynda was also aware of the fact that “even when pupils are told something they still have to makes sense of it for themselves” (Driver, 1989, p. 103). Lynda contended that teachers should not only teach to “pass on information we have already discovered,” but also teach to “help students develop minds and logic” (Lynda 1), which reminds Piaget’s development of mind.

As can be seen in Figure A.9, this Individual category of Lynda’s CSTL was maintained as the largest component throughout the interviews: 75% in the second interview, 67% in the third interview and 76% in the fourth interview. Accordingly, Lynda strongly advocated a conceptual change model whereby she wanted to exchange the misconception with “the right idea” (Lynda 2). On the other hand, she acknowledged, “eventually the student has to take his or her meaning on things” and that only the student can make the links between “various experiences that are set up to teach them” and “their conceptions that they come in with” (Lynda 3). To Lynda, constructivist approaches for teaching were represented as conceptual change and conceptual development. Some typical statements placed in the Individual category for Lynda included:

Figure A.9: Lynda’s CSTL profile

As can be seen in Figure A.9, this Individual category of Lynda’s CSTL was maintained as the largest component throughout the interviews: 75% in the second interview, 67% in the third interview and 76% in the fourth interview. Accordingly, Lynda strongly advocated a conceptual change model whereby she wanted to exchange the misconception with “the right idea” (Lynda 2). On the other hand, she acknowledged, “eventually the student has to take his or her meaning on things” and that only the student can make the links between “various experiences that are set up to teach them” and “their conceptions that they come in with” (Lynda 3). To Lynda, constructivist approaches for teaching were represented as conceptual change and conceptual development. Some typical statements placed in the Individual category for Lynda included:
Science learning I would say takes on probably the constructivist and the conceptual change kind of views where, first of all, students who don’t have any knowledge at all of a subject would then build upon what they do know… Then if they have a concept that will be considered a misconception then, I think, the only way they're going to learn the right way would be to change the misconception in order to provide the right idea. (Lynda 2)

We [teachers] would like to bring the individuals toward the accepted scientific knowledge…. and sometimes also individuals have building blocks and they are able to piece everything together and come up with the current scientific knowledge on their own. Eventually the student has to make his or her own meaning on things…. [since] students already come in with their conceptions, especially in high school, I think that a conceptual change might be an important way to go about things. (Lynda 3)

I hope to implement a conceptual change strategy…. I do think that the teacher should present what is currently held as scientific knowledge in the scientific community, and also take into account what the students think right now. I think that's important…. I think it's good to let the kids come up with their own ideas, but I don't think it's okay to let them have misconceptions…. I think you can take their ideas and try to hit their ideas and try to teach it yet another way, by providing more manipulatives, more demonstrations or whatever the case will be, so that they eventually say, [well, maybe I was wrong, or maybe this is more acceptable]. (Lynda 4)

The traditional component of Lynda’s CSTL profile showed up when she emphasized the rationale of science teaching is to “pass on information we have already discovered” and the role of the teacher is to “just present from information” (Lynda 1). This traditional sector resurfaced in her CSTL profile in the third interview with 21% of the text units. Acknowledging time constraints in knowledge acquisition through each student’s direct experience of the world, Lynda expected her students “to expand his or her understanding through the expert’s [teacher’s] accounts” (Lynda 3). The reason she reverted to the traditional position can be found in her comment about the autumn quarter field experiences:

My cooperating teacher’s view of teaching is somewhat traditional. She teaches sixth grade and she, I think, looks at learning from the, [I need to give students this information] position…. We can learn all about constructivism, and we can even learn examples, [okay, this is an example of how you can teach constructivism], but in reality, you are talking everyday continuous lessons. How can we link all of that together and still make sure that the students come out with something; because I don’t know how to do that. I can have constructivist activities for the students, but …. we need to take all these things and say, we can do this even though the students have to take proficiency exams in the end. We can do this even though there are certain expected outcomes. (Lynda 3)

This quote illustrates Lynda’s frustration upon meeting the need to cover content required in real classroom settings. She was also frustrated with missing connections between theory and practice. By the end of the autumn quarter, she compromised her beliefs about teaching and learning by reverting to and re-incorporating the traditional component into her CSTL profile. As can be seen in the next part of her profile analysis, this traditional category disappeared again when Lynda met “a positive role model by all means” during her winter quarter field experiences.

Another feature of Lynda’s CSTL profile was that from the second interview on she consistently maintained the social category as a minor position: 14% in the second interview, 13% in the third interview, and 16% in the fourth interview. When asked to choose one of the pedagogically distinct options presented during the interviews, Lynda sometimes chose an option representing the social constructivist’s views as her second choice. Accordingly, she contended, “I hope to take the approach that we [the teacher and the students] are all learning this together and have the students discuss and come up with their own equations, come up with their own relationships as much as possible” (Lynda 2).

However, although she recognized, “students themselves as a community come up with their own thought, … share that [thought],” she as the teacher always wanted her students to leave her class with “the crucial concepts and information that should have been learned and discussed” (Lynda 2). She described what she would be in her classroom “as some sort of facilitator or leader“:

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I think it's important to ask students where they are now if we start other things, and then have students come up with their own thought from their own observations, on their experiments afterwards and have students share that. And I guess, your hopes are that the students are going to discover, and figure out exactly what they should in the first place, and if not, I think it is important that I, the teacher does point out any of the crucial concepts and information that should have been learned and discussed. I do believe that teachers should make available what the science community says. (Lynda 2)

On the other hand, Von Glasersfeld's radical category in Lynda's CSTL profile appeared when Lynda substituted “the crucial concepts and information of the science community” with “viable knowledge structures” that are compatible with learners' experiences:

Basically I would be with C's idea of working to change the students' conceptual structures, taking what the students already know so that students can learn what the current society regards as having greatest viability at that particular time. (Lynda 4)

Summary of Lynda's CSTL Profile Changes

In sum, Lynda’s conceptions of science teaching and learning centered on a model of learning as conceptual change. Accordingly, her role as the teacher was to diagnose “where the student is coming from” (Lynda 3) and to make sure “students can learn what is currently held as scientific knowledge of the scientific community” (Lynda 4). With her love of physics and research, Lynda was most concerned about the scientifically acceptable viewpoint. According to her, “it’s good to let the kids come up with their own ideas” but she did not think, “it’s okay to let them have it [kids’ own alternative ideas that are incompatible with the accepted viewpoint]” (Lynda 4). Lynda’s perceived ideal role as a science teacher is to “bring the individuals toward the accepted scientific knowledge” (Lynda 3).

In terms of how to help learners achieve this goal and how to design teaching approaches to promote conceptual change in learners, she wanted to “give them various experiences that are set up and designed to teach them certain things.” In particular, to change students’ misconceptions, she would “take their ideas and try to hit their ideas and try to teach it yet another way, by providing more manipulatives, more demonstrations or whatever the case will be, so that they eventually say, [well, maybe I was wrong, or maybe this is more acceptable].” (Lynda 4). As far as I could tell, Lynda was very convinced that with various experiences and “demonstrations where that theory that you [teachers] are trying to get across is demonstrated in these” she could easily change students' misconceptions. Accordingly, Lynda argued, one of the important roles of the teacher is to make decisions about what could be useful learning activities or experiences, and what should be learned:

I see the teacher mostly as the facilitator, who brings together these experiences for the students. As being an initiator of the class, saying okay this is where we need to start then letting the students take over... and then maybe at the end just bring together whatever the students said. (Lynda 4)

Along this line, Lynda contended that learners learn by ‘discovery of ideas themselves’ (Lynda 1 & 2), “building upon what they do know” (Lynda 2), “changing the misconception with the right idea” (Lynda 2), and “piecing everything [building blocks] together and coming up with the current scientific knowledge on their own” (Lynda 3). In the fourth interview, she summarized the process of students’ learning, identifying it with the process of conceptual change:

The learner must first start out by realizing what they already know. Once the learner has taken a stand and says ‘this is what I know and I don't know the next step’. Then the learner can have some sort of experience or observation or something to say okay, now I might not agree with what I knew before, or I might want to change that or add to it. Finally the learner has to take these new observations and new ideas and somehow put them back into their old idea. (Lynda 4)

Explainers for Lynda’s Constructivist Profile Changes

Asked to provide the most influential factors in helping her to form beliefs about teaching and learning, she offered the M.Ed. theoretical coursework as the most influential, which "showed me lots of
articles and theories on different educational theories, and this is important because some of them I have never heard before" (Lynda 4). The second most important factor in her beliefs formation was the field experience where she could not only observe her mentor teacher's teaching style, but also "do your experimenting and your testing based on some of the coursework" (Lynda 4). Lynda also mentioned that she valued the field experience—or being in a classroom—because when combined with the coursework she had it provide the groundwork for translating theory into practice.

And I don't think field experience without methods courses isn't helpful. I think what's been most beneficial for me is going to see so many different teachers.... After observing teachers' practices, we should also relate back to what we have learned in methods courses. So I think that will be important too, to make a link between practice and theory such as constructivism and conceptual change theory. (Lynda 3)

I would say, with the field experience was the most influential and that was because of my mentor and her experiences and her style of teaching.... My mentor teacher was a positive role model by all means, very positive. She has taken the conceptual change theory and implemented it into her classroom, almost completely. So I was able to watch as she used the conceptual change theory in practical ways. For the two lessons that I saw, it did work. It took a long time, though. And it wasn't an absolute conceptual change theory as in the Sister Gertrude study, but she definitely modeled the basic four components. (Lynda 4)

To Lynda, her mentor teacher during her winter quarter field experience was very influential, who showed her the feasibility of conceptual change model in real classrooms and "helped [her] out either give [her] the encouragement or support or the criticism that [she] needed." Without her mentor teacher, Lynda "doesn't think [she] would have come this far" (Lynda 4). On the other hand, she compared the difference between the M.Ed. theoretical coursework and the field experiences:

My field experience is just ultra-practical, and those methods classes are ultra-not [laughter]. I think the methods courses were fantastic for me just to keep in mind, and to kind of, say 'okay, there is a different way and there could be a better way to teach', but in the end, at least in my field experience, I couldn't make a 180 degree turn and try taking some complete constructivist view, so perhaps when I have my own classroom, methods classes might be more useful. (Lynda 3)

This quote indicates that the academic elements of preservice teacher education could have an impact on teachers with a possible lag time (Richardson, 1994). Several teachers indicated that when they have full control over his or her own classroom they want to implement what they learned in the M.Ed. program, which will be extremely hard in the beginning of their career, not to mention in the field experiences and in others' classrooms. For Lynda, what she has learned best throughout the M.Ed. coursework was "the basis of constructivism" including constructivist epistemology such as "no truly absolute knowledge" and a perception-bounded reality, conceptual change, and "the constructivist approach" that includes group works and alternative assessments.

I definitely learned a lot about the conceptual change theory and that is definitely going to influence me as a teacher, as well as nontraditional ways of teaching, and various pedagogies with group work. These showed teachers not as someone who has to be up at the board, teaching and writing on the board and being the only person talking in the classroom. All of that definitely will influence me as a teacher, as well as different instructional practices.... when I came in here, I thought I can teach physics because I was thinking along the line of everyone thinks like me and everyone is coming from the same point of reasoning as I am, but I have learned that they are not. I see such a great need now and I don't think I did before to find out where the students are coming from and help them without just telling or without just showing. (Lynda 4)

On the other hand, she was very impressed by M.Ed. program professors who taught preservice teachers "as they wanted preservice teachers to teach" (Lynda 2):
He has really challenged me in this area; maybe teaching and learning is not at all that I came in thinking it was. And he put some of his theories and ideas into practice and it works in the classroom. He used all sorts of different ways of teaching and he actually incorporated those ways of teaching into his classroom.... he has provided so many different methods and ideas... that he has used and he will use it with us. He will be an example of what he is teaching. And so far, he has been the main one who was an example when he starts teaching. (Lynda 4)

Regarding her awareness of her ontological and epistemological profile, she confirmed through member check that she was not aware of any of her beliefs changes. Asked to explain apparent beliefs changes in her profiles, she offered, “reading real literatures” throughout the M.Ed. program as a possible reason. During the member check, she reconfirmed her position as “some gathering in Realist and Radical ontological sectors” and “somewhere around Piagetian and Fallibilism sectors” (Lynda 4). Regarding the relationship between her ontological/epistemological beliefs and beliefs of science teaching and learning, although “those are all connected,” she was hardly convinced that “there has to be absolute” correspondence. That is, Lynda denied any absolute links between a teacher’s beliefs about science knowledge and her way of teaching.

In the mean time, when asked about her awareness of the three different versions of educational constructivism (i.e., individual, radical and social) during the second interview, she did not use the specific terms and offered two different dimensions of “knowledge construction” (Lynda 2). Lynda only remembered “the basis of constructivism” and incorporated the core epistemology of constructivism as “the idea of probability” towards any knowledge claim and knowledge—or reality—modification based on “our perceptions” (Lynda 2).

As far as I could tell, Lynda’s ontological, epistemological beliefs fit well with her conceptions of science teaching and learning, although she refused any direct link between those. Throughout the interviews, she maintained Realist ontological beliefs, Piagetian epistemological beliefs (the scientific realism of the individual constructivism), and Piaget’s individual category of pedagogical beliefs as the largest component, with the exception of the second interview. Other than the second interview, her overall belief system might map well onto that of Piaget’s individual constructivism version.

Since Lynda was firmly grounded in the realist ontology, she was convinced that people “across the world could come to the same conclusion” by consulting with the natural world (Lynda 3). Her beliefs about the nature of knowledge thus fit well with her beliefs about science teaching and learning in terms of what to teach and how to teach. Lynda contended, “the teacher should present what is currently held as scientific knowledge of the scientific community.” Moreover, if the student had an incompatible idea (or misconception) the teacher should “find out where students are coming from... implement a conceptual change strategy... [and finally] help students learn what is accepted.”

On the other hand, in the second interview, right after having been introduced to constructivism during the summer quarter, she strongly subscribed to the radical constructivist’s epistemology that aligned with the Fallibilist perspective. This shift in her ontological and epistemological beliefs were also reflected in her beliefs about science teaching and learning where she insisted that teaching be hit-or-miss affair without the teacher’s knowing of where the students were coming from and what was going on in their heads.

During the member check, Lynda commented, in the process of “solidifying her thoughts” ‘conceptual change learning and teaching’ was a driving force in her profile configuration changes. Even though there were some shifts in her profiles (ontological, epistemological, and CSTL profiles), she firmly believed in conceptual change learning, whose feasibility or practicability was reassured through her exemplary mentor teacher’s implementation. The social constructivist category of Lynda’s CSTL profile was maintained as a minor component since the second interview on as Lynda acknowledged students’ own shared meaning construction among one another and honored the students’ group as a community, where a teacher is part of the community members. However, this social component has never dominated her profile because she always wanted to introduce “more acceptable knowledge [or] what they should come up with [through consensus building]” at the end of students’ meaning construction activities (Lynda 4). Lynda did not think, “it is okay to let students have what[ever] they come up with” (Lynda 4).
APPENDIX F

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

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

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

Major points of preservice teachers' CSTL informed by von Glasersfeld's Radical constructivism:

Participants' CSTL quotes regarding how to be a Radical constructivist teacher

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

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1 What follows is a compilation of the participants' ideas about how to implement conceptual change learning, many of which were suggested by all of them.
Accordingly, a Radical constructivist teacher should:

- Assess the context of the students and then he kind of can organize, transform the content knowledge into various forms that the learner can take it into himself to construct his own knowledge. (Ben 4, Rob 3, Rob 4)
- Have an adequate model of the thought process of the students and how they make sense things in their heads. (Ginny 3, Young 2, Rob 4)
- Deliberately encourage students to learn the scientifically acceptable viewpoint because it is students’ benefit and helpful in empowering underprivileged students to know what is accepted by a scientific community, which could change in the future. (Ellen 4, Young 2, Rob 4)
- Need to be careful of the limitations they put on students in their active searching for knowledge so that they do not restrict a student’s creativity in problem solving situations, even though it may not align with what is accepted by the majority of society. (Len 4)

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

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


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