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Exploring the dimensions of personal epistemology in differing classroom contexts: Student interpretations during the first year of college[☆]

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Abstract

The study of personal epistemology has typically addressed the theories and beliefs that individuals hold about knowledge and knowing, and the way in which such epistemological perspectives are related to academic learning. This qualitative, exploratory case study focuses on the epistemology of instructional practices as interpreted by students in two versions of introductory-level college chemistry, each with different underlying epistemological assumptions. Classroom observations and interviews of 25 first-year students provide a contextualized perspective on the dimensionality of beliefs as identified in the literature: *certainty of knowledge*, *simplicity of knowledge*, *source of knowledge*, and *justification for knowing*. This research suggests that students' perceptions of instructional practices are interpreted through the lens of their epistemological assumptions, but that such perspectives are evolving and instructors may influence them in multiple ways.

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1. Introduction

Basic questions such as "How do I know what I know?" have occupied philosophers for centuries, but only in recent decades have psychologists begun to explore how the answers to such questions take shape in the human mind and how this is transformed over time (Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; Hofer & Pintrich, 1997, 2002; King & Kitchener, 1994; Kuhn, 1991; Perry, 1970; Schommer, 1990). The beliefs and theories that individuals come to hold about knowledge and knowing have been of particular interest to psychologists concerned with education and instruction. This "personal epistemology" of individuals has been linked to academic learning through such constructs as cognitive processing (Kardash & Howell, 2000), conceptual change learning (Andre & Windschitl, 2003; Mason, 2003; Qian, 2000), and strategy use (Hofer, 1999; Schommer, Crouse, & Rhodes, 1992).

Although general evidence exists for the effects of a college education on epistemological development (Baxter Magolda, 1992, 2001; Perry, 1970, 1981), what recent studies suggest is the need for a better understanding of how educational practices are interpreted by students and how these interpretations interact with and influence the development of epistemological beliefs and theories. The purpose of this paper is to extend a theoretical model of the dimensions of personal epistemology as developed through a review of the extant literature (Hofer & Pintrich, 1997), exploring how epistemological beliefs and theories develop within different classroom contexts. This exploratory case study combines the use of classroom observations and interviews, following students who were each enrolled in a general introductory psychology course and in one of two versions of college chemistry, each with different implicit epistemologies. As an embedded case study, this approach focuses on an examination of the epistemological perspectives of individuals within two distinct "case" approaches to science instruction.

2. Dimensions of personal epistemology

A review of existing models of personal epistemology suggests that individual theories about knowledge and knowing are comprised of multiple dimensions that can each be expressed as a continuum (Hofer & Pintrich, 1997). Many of the existing schemes are developmental in nature (Baxter Magolda, 1992; Belenky et al., 1986; King & Kitchener, 1994, 2002; Kuhn, 1991; Kuhn, Cheney, & Weinstock, 2000; Perry, 1970), implying a hierarchically integrated sequence of meaning. By contrast, Schommer-Aikins' (2002) model of epistemological beliefs is based on the assumption that these dimensions may be more or less independent, but can each be represented along a continuum from less sophisticated to more sophisticated. The dimensions of personal epistemology that appear in both types of models are relatively consistent, however. Although some of the models contain beliefs about learning and education, all include reference to dimensions that can be clustered into two central areas: the *nature of knowledge* (what one believes knowledge is) and the *nature or process of knowing* (how one comes to know). Within *nature of knowledge* are the dimensions *certainty of knowledge* and *simplicity of knowledge*, and within the area of *nature of knowing* are the dimensions *source of knowledge* and *justification for knowing*. These four dimensions can be described as follows:

Certainty of knowledge. The degree to which one views knowledge as certain is an aspect of personal epistemology across multiple schemes. The continuum of development has been described as moving from a fixed to a more fluid view (King & Kitchener, 1994; Kuhn, 1991), a progression from believing that absolute truth exists with certainty to the position that knowledge is tentative and evolving (Schommer, 1990).

Simplicity of knowledge. At lower levels, knowledge is viewed as discrete, knowable facts, and at higher levels, individuals see knowledge as relative, contingent, and contextual. Schommer (1990, 1994) describes a range of beliefs that move from viewing knowledge as an accumulation of facts to seeing knowledge as highly interrelated concepts.

Source of knowledge. An aspect of the *nature of knowing*, this dimension refers to the locus of knowledge, perceived as originating outside the self and residing in external authority (from whom it may be transmitted) or, on the other extreme, as actively constructed by individuals in interaction with the environment and others (Baxter Magolda, 1992; Belenky et al., 1986).

Justification for knowing. This dimension involves how individuals justify what they know and how they evaluate their own knowledge and that of others. Individuals may justify beliefs through observation or authority or on the basis of what feels right, or through the evaluation of evidence, expertise and authority, and the assessment and integration of the views of experts (King & Kitchener, 1994).

As argued elsewhere (Hofer & Pintrich, 1997), these four dimensions comprise the core of what have been called *epistemological theories*, an integrated, relatively coherent structuring of related beliefs. These personally held theories are part of an individual's "folk epistemology" (Burr & Hofer, 2002; Kitchener, 2002) and are activated metacognitively. In a recent study (Hofer, 2000) these four dimensions were empirically tested in two domains with a discipline-focused instrument. Factor analysis of this instrument supported the existence of a multi-dimensional model of epistemology across disciplines, but the *certainty* and *simplicity of knowledge* did not emerge as separate factors. This parallels the empirical work of Qian and Alvermann (1995), who factor analyzed a revised version of Schommer's Epistemological Belief Questionnaire and identified one factor that merged certainty and simplicity of knowledge. To a limited extent, this study of dimensionality (Hofer, 2000) provided some evidence for the existence of the hypothesized dimensions, but none of the factors was as multi-faceted as suggested in the literature. Although survey instruments play an important role in epistemological research, making it possible to identify relations among various academic learning constructs (epistemological beliefs, motivation, conceptual change, learning strategies, achievement, etc.), they need considerable development in order to capture the complexity of a particular construct, and have been particularly problematic in the study of epistemological development (Wood, Kitchener, & Jensen, 2002). Thus more qualitative work may be needed to further explore the understanding of dimensionality, which may prove useful in refining instrumentation for investigating personal epistemology.

The study reported here provides a means of addressing these issues through a qualitative approach to identification of the four dimensions, as addressed in classroom context. Rather than a decontextualized survey approach, this research endeavor incorporates both interviews and observations to integrate evidence of these dimensions in context. This also provides a means for further understanding how instructional practices are interpreted epistemologically.

3. Instructional practices and personal epistemology

Limited empirical evidence exists that explains what fosters epistemological development or the alteration of epistemological beliefs, although several lines of inquiry provide some suggestions for instructional practice (Hofer, 2001). Developmental models typically assume that disequilibration fosters a movement from one level to the next; thus suggested educational practices are to provide challenging ideas in a supportive context in order to stimulate cognitive conflict and subsequent reorganization. Others have proposed that epistemic doubt is a precursor to change, and that it is also linked to identity (Boyes & Chandler, 1992) and affect (Bendixen, 2002), raising implications about the influence on motivation at different phases in the process and how instructors might support students through epistemic change (Bendixen, 2002). Belief change may also resemble conceptual change (Hofer & Pintrich, 1997) and need similar conditions: a dissatisfaction with existing beliefs, an acceptance that the alternatives are intelligible and useful, and a means of connecting new beliefs to earlier conceptions (Pintrich, Marx, & Boyle, 1993), thus suggesting how instructors could facilitate the process. Newer models of belief and knowledge change drawn from social psychological literature (Dole & Sinatra, 1998) may help further the understanding of epistemological change and related educational practices.

Part of the press to understand the nature and power of epistemological beliefs came from those such as Perry (1981) who reported their frustration at the range of interpretations of educational practices among students. It seems plausible that there is an interaction between the implied message of those practices and the current beliefs of the student. Furthermore, it is possible that instructors are not necessarily explicit in their communication about epistemology, nor sensitive to the developmental level of their students. Recent research on the epistemological world views of teachers (Schraw & Olafson, 2002) provides an important step toward addressing teachers' beliefs as an under-investigated component of epistemological understanding. Teachers' practices, however, may contradict their own beliefs (Hofer, 2002; Schoenfeld, 1985).

We need to know more about how students make sense of the epistemological aspects of their instructional environments, what practices are most salient, and how they are interpreted through the lens of existing beliefs and knowledge, which are also being altered in the process. Addressing how individuals view knowledge and knowing obviously requires much more than direct instruction, as belief change is clearly more than a simple process of transmission. Beliefs are situated in a sociocultural context and we need to know more about contextual influences, instructional practices, and how students interpret them epistemologically as they acculturate to new educational settings. This study explores students' epistemological understanding as it evolves in the context of first-year science classes in a university setting.

3.1. Instructional practices

As noted, the various instructional elements that carry epistemological impact need further investigation. One broad framework for thinking about what occurs in educational settings is provided by Schwab (1978), who describes four "commonplaces": the learner, the teacher, the milieus in which learning take place, and the subject matter, each viewed as of equal rank and as essential to educational thought and practice. Although numerous frameworks exist for identifying elements of educational settings, this model was selected for its simplicity and applicability to a case study of educational contexts and practices, permitting a focus on aspects common across disciplinary boundaries.

Each of the four commonplaces is addressed in this study, but narrowed to address the topic under investigation. More specifically, reference to the learner includes both the background of the student participants and an exploration of their individual epistemological views. The teachers of concern in this study are those teaching the courses identified as the setting for this study, and the milieu in which learning takes place is the particular chemistry courses in which these students are enrolled during the time of this study. Although milieu in Schwab's terms could be more broadly conceived to include family, community, and class and ethnic background, this study limits the focus to the more immediate learning environment. Finally, the subject matter of concern is that of chemistry.

As conceptualized in this study, the area of instructional practices combines aspects of both the teacher and the milieu. Elements expected to have epistemological significance were identified both by a review of the literature on academic work and tasks (Blumenfeld, 1992; Doyle, 1983) and by pilot observations in college classes. Instructional practices expected to have epistemological significance include the nature of academic tasks both in and out of class, testing and other evaluation practices, patterns of teacher and student talk, classroom structure, the physical arrangement of the classroom, reward systems, and textbook organization and language. Although observations suggest that each of these might carry epistemological meaning, we do not know how students make such interpretations, which suggests the need for a study that explores these perspectives in context.

Doyle (1983) claims that academic tasks are "defined by the answers students are required to produce and the routes that can be used to obtain these answers." Tasks have been demonstrated to influence how learners direct their attention and thus process information (Doyle, 1983). For example, some types of tasks require memory and others require comprehension. One important arena in the study of epistemological beliefs is how students make such distinctions and how student beliefs interact with the dictates of task. For example, tasks that suggest memorization as an appropriate strategy may reinforce views of knowledge as discrete bits of information.

Testing and other evaluation practices have been shown to have a powerful impact, both direct and indirect, on student learning strategies, motivation, and achievement (Crooks, 1988). Many students select an approach to studying that is likely to ensure success on examinations, though students may differ in their ability to accurately assess such situations. Nor are all students able to make adaptive choices; those accustomed to a more surface approach to studying have the greatest difficulty when testing calls for deeper studying strategies (Crooks, 1988). It would seem that another intervening variable is individual epistemological theories. Students who believe knowledge is simple would be less likely to comprehend the more complex cognitive demands of some tests and thus might select strategies that convey a belief of knowledge as discrete facts. Accordingly, beliefs about knowledge may help define individual goals for learning and studying as well as their general perception and attitude toward types of testing. For example, students with simplistic beliefs about knowledge may view multiple choice testing differently than those with more sophisticated beliefs and approach the studying process differently.

In summary, there is considerable impetus for understanding how personal epistemology is influenced by—and how it interacts with—instructional practice, as well as for refining our understanding of the dimensional nature of personal epistemology in context. Specifically, this study addresses the following questions: (1) how are the four hypothesized dimensions represented in context? and (2) how do individuals interpret instructional practices epistemologically?

4. Methods

This qualitative case study focused on the experience, perceptions, and meaning making of undergraduate students enrolled in both science and social science classes during their first semester of college at a large research university. The study combined observations of classes and interviews with students in order to provide multiple sources of evidence and contribute to triangulation of the data (Denzin, 1989; Fielding & Fielding, 1986).

4.1. Methodological framework: The case study approach

The framework for this research is that of a case study (Stake, 1995; Yin, 1989). As Yin (1989) notes, case studies are advantageous approaches to research projects that address explanatory and/or descriptive questions in a real-life context, and are particularly appropriate in a setting in which the researcher has no control over events. The goal of a case study is not to provide results that are generalizable to a broader population, but to expand and generalize theories. Case studies typically make use of multiple sources of evidence; this case study draws on interviews, observations, and pedagogical artifacts.

Although Yin (1989) describes causal explanation as a possible outcome of a case study, Stake (1995) distinguishes between explanation and interpretation as epistemological distinctions between quantitative researchers—who seek explanation and control—and qualitative researchers, who press for understanding complex interrelationships. One intent of this particular study is to develop an interpretative understanding of the relation between classroom practices and student beliefs.

Furthermore, an important aspect of the design of case studies is in determining the central focus of analysis. This particular case study can best be understood as an embedded case study (Yin, 1989), in that the focus of analysis is the evolving epistemological perspective of students enrolled in two particular "cases" of chemistry instruction, experienced within the context of the first semester of college at a large research university. Examining embedded levels of context in educational research is important in order to understand the influence of larger contexts and to obtain more holistic representations of events (Evertson & Green, 1986).

4.2. Participants

Of the 25 students who participated in the study, all were in their first semester of college at a large research university, which they had entered directly from high school. There were 12 females and 13 males in the study, with an average age of 18. The ethnic background of the students represented a cross-section of the university, with one Hispanic student, two African-Americans, and five Asian-Americans of diverse regional origin; the remainder were white. Students were selected based on their enrollment in both introductory psychology and in one of two introductory chemistry classes. All were enrolled in the same introductory psychology course; 13 were enrolled in a general chemistry course and 12 in a more advanced organic chemistry course. They each earned credit in their introductory psychology course for participating in the study.

4.3. Observations

During the semester of this research study, I observed the psychology and chemistry courses in which these students were enrolled, observing at least weekly in the psychology course and at least weekly in one of the chemistry courses, and more often at critical periods, such as the first few weeks of class, prior to exam periods, and at the end of the term. For purposes of this paper, the primary focus is directed toward the two chemistry classes, which provided high contrast in terms of underlying epistemological assumptions. Observations were centered on the large lectures for these courses (although students also attended laboratory sections), as the lectures were the experiences common to the students interviewed and were conducted by the faculty members responsible for the courses.

An observational study is shaped by a particular purpose, which guides what is obtained and how such information is used (Evertson & Green, 1986). My primary goal in these observations was to examine how beliefs about knowledge and knowing are communicated in the classroom and how they are situated in classroom interaction. The observations offered a richer understanding of the classroom environment so that interview questions could be contextualized within the common classroom experiences of the students, providing specific critical incidents for discussion in the interviews, and allowing for an understanding of implicit epistemological foundations for the two courses. These observations also provide the "thick description"(Geertz, 1973) that may help convey both the participants' experiences and the interpretations that follow.

The focus of the observations was on instructor material and presentation, classroom interaction, tasks, and assessment practices. Notes from the observations were recorded in writing as running field notes. In addition, pedagogical artifacts such as texts, syllabi, and exams were collected. The written field notes were interpreted in accordance with the dimensions of epistemology identified in an earlier literature review (Hofer & Pintrich, 1997). This was done by identifying examples of practices and incidents that might be classified as indicative of *simple knowledge*, *certain knowledge*, the *source of knowledge*, or *justification for knowing*. A select number of these were transformed into interview questions. For example, students' views about differing testing practices and the relative merits of certain types of questions seemed to suggest views about the simplicity or relative complexity of knowledge within the domain. Engaging students in a discussion of such situated practices provided for the possibility of a contextualized, phenomenological understanding of students' personal epistemology.

4.4. Interviews

Students were interviewed at two points in the term: toward the end of the first month of the semester and during the final month. The interviews were guided by an interest in hearing individuals "use their own words to express their personal perspectives"(Patton, 1990, p. 277), using open-ended questions that provided a framework for such expression. The interviews were semi-structured; the primary questions were pre-planned and standardized in order to minimize interviewer effects (Patton, 1990), and presented in the same general sequence, but the course of the interviews varied slightly depending on student responses, as the did the follow-up probes.

The interview protocols included questions that explored personal epistemology on a general level, by adapting questions from existing interview protocols that tapped the range of the four dimensions suggested in the literature (Baxter Magolda, 1992; King & Kitchener, 1994; Kuhn, 1991), as well as questions pertinent to instructional practices as experienced by the students in their immediate academic setting. Course-specific questions were developed based on observations of classes, identifying commonplace practices within the framework of the four dimensions, and critical incidents from classes or quotes from lectures (e.g., an instructor's comment in lecture about the importance of reproducibility in science). Interviews were audio-taped, transcribed, and entered into HyperResearch, a qualitative data analysis software program.

4.5. The analytical process

The process of analyzing the data consisted of multiple, overlapping phases. Early analysis of the observational notes was necessary in order to select incidents and topics for questioning for the two interviews; accordingly, observations were read for suggested evidence of the four hypothesized dimensions of personal epistemology. Analysis of the interviews was an ongoing, iterative process, facilitated by note-taking at several points. Interviews were scheduled with 1 h free immediately afterwards so that notes could be made about each interview, including comments about students' nonverbal responses and ideas that triggered other questions that might be asked; this and other aspects of a "memoing" process also provided for conceptual theorizing in the early stages of analysis (Miles & Huberman, 1994).

After all the interviews had been concluded, I listened to each tape and made analytic notes, looking for patterns in the data and registering particular comments of interest; I later repeated this process with each of the written transcripts. Entering the data into HyperResearch facilitated further data management and analysis. For example, all the answers to a particular question could be read together, in order to discern patterns of responses, prior to conducting various levels of coding. To begin the coding process I tentatively coded each question on the two interview protocols for the dimension(s) that guided the writing of the question. For example, a question about what a student might do if the instructor and book disagreed was hypothetically coded as "source of knowledge." This permitted another reading of the responses, with all those expected to provide evidence of a particular dimension read together. In many cases, questions elicited responses indicative of more than one dimension.

This reading led to a resorting of the data, organized by each of the dimensions actually represented by students' responses. I read through one cluster at a time for all evidence of that particular dimension, progressively moving through the data, identifying various points on the continuum of beliefs suggested by the literature review. For example, the existing literature suggests that simplicity of knowledge ranges in a continuum from a view of knowledge as discrete bits of information to a view that knowledge is complex and integrated. Was there evidence that students actually view it as such in context? Moreover, what in the educational environment elicited these beliefs?

In summary, these multiple readings of the data allowed me to identify evidence for dimensionality in personal epistemology, representations of a continuum of beliefs, and linkages between beliefs and instructional practices. I wanted to know how students expressed these concepts in their own words in the context of educational experiences common to these first-year college students.

The final methodological step was to consider issues of verification. I employed "member checking" (Creswell, 1998; Stake, 1995), an accepted means of establishing credibility in a qualitative study, by providing an early draft of this paper to the instructors whose courses were observed. I met with them individually to discuss their perspectives of the accuracy and fairness of my representation and the veracity of my interpretation. The instructors also provided written summaries of their comments, and as best as possible, I have incorporated their suggestions into the final paper. In regard to interview interpretations, two psychologists with expertise in personal epistemology also read early drafts and discussed claims and interpretations, in order to provide a form of verification through "peer reviewing" (Creswell, 1998).

The study also includes the triangulation of data through multiple sources to provide corroborating evidence. Seeking convergence of outcomes in this way is a central aspect of a case study (Stake, 1995).

5. Underlying epistemological assumptions: A tale of two courses

As described above, the methodological framework for this research is that of an embedded case study, with individuals in the study enrolled in similar courses within the same large research university. Thus it is necessary to provide some descriptive detail of these wider contexts, or in Schwab's terms, the milieus in which their learning takes places. In the broad picture, these students are part of an entering class of 5000 at an institution internationally known for the caliber of its graduate programs. Most introductory courses for first-year students are conducted as large lectures, although about half the students interviewed were also enrolled in one small seminar course. Students are expected to live on campus during their first year and many find themselves in daily contact and conversation with individuals unlike anyone in their previous personal experience. When asked "what stands out for you about the year so far?" more than half the students commented on the novelty of dormitory living or simply meeting and interacting with so many new people. These and other extracurricular aspects of college also influence and challenge ways of knowing and beliefs about knowledge, as has been demonstrated by Baxter Magolda (1992); this study, however, focused on instructional practices.

As noted earlier, students in this study were divided between two chemistry courses, with 13 in organic chemistry and 12 in general chemistry. As is customary in this institution, students were tested during orientation for their placement into these courses, with prior knowledge determining the entry-level course for first-year students. Both courses were structured with large lectures three times weekly, supplemented by a weekly lab and discussion session, led by graduate student instructors.

The two chemistry courses both met in the same room, a large auditorium with approximately 500 fixed seats, all facing forward. Rows are curved, with aisles throughout, and the space is dramatically tiered, with a stage for the instructor at the bottom center behind a large white counter with sinks and faucets, suggesting the aura of a laboratory and the potential for in-class demonstrations. Behind the instructor are triple blackboards that layer with the push of a button, flanked by huge screens for overhead projection. Most notable in the room is the periodic table, inlaid in large tiles on both sides of the auditorium, knowledge literally chiseled in stone.

Although taught in this same setting—an imposing environment with implicit messages about the source and certainty of knowledge and the role of authority, the two versions of the chemistry courses offered dramatic differences in pedagogical style as well as implicit messages about the meaning of knowledge and knowing in chemistry. Examples from sample observations are provided as illustrative of this experience.

The first day of class served as a useful exemplar for the organic chemistry course. The professor arrived as students were talking and began by writing his name, preceded by the title "Dr.," in a very deliberate manner in large bold letters visible from the rear of the room, along with the course number and title. The room fell immediately silent. He continued to write details about the course and they quickly began to copy. He began speaking by pronouncing his name as deliberately as he wrote it, followed by "And if you get the pronunciation wrong, you get an F." He smiled as he said this, but the students on both sides of me sucked in their breath and hunched over their notebooks a bit more. He then proceeded to describe the multiple components of the course, including the fact that it is a nearly paperless course and that they would find everything they need to know on the course web site. He then told them about his approach to the course:

> Instructors each have our own personal version of working our way through the subject matter and each person organizes this differently. What you'll get is *my* representations, *my* style, *my* personal approach... Hearing me talk about chemistry, hearing how I think about chemistry is a reason to come to class—this is value added—these little 50 minute gatherings three times a week.

Following this enticement, he discouraged them from purchasing course notes from an unauthorized but popular note-taking service and explained why he also did not plan to provide his own notes to them, speaking explicitly of the value he placed on students constructing their own knowledge. This "higher-order" view of both knowledge and knowing suggested that students would be expected to construct an individual understanding that reconciles and integrates previous knowledge, the authority of former instructors with the current one, and the knowledge represented in the textbook.

The first day in this class, as in most courses, was also a time to address grading procedures and testing practices. The professor described the exam process for this class:

> It will require more than filling in bubbles. Exams are a combination of drawing pictures and diagrams and writing, and they won't be problems that have appeared in class... You take on the teacher role in exams. I come and ask *you* the questions and we reverse roles. A person wouldn't just want the answer—they would want to know how you got it... The solution is the most incidental part, an outcome of the most important part. So you need practice in those skills, in thinking aloud, which is what you will get in this class. You wouldn't want to practice this skill in a high stress situation.

He explained the role of study groups in the course and why it would be important to practice working problems aloud with others. "The true assignment of this course is learning how to learn, and learning how to express yourself in a new and unfamiliar area, an important skill even if you never do chemistry again." Again, he emphasized the constructivist nature of learning he expected, explaining that he would provide sample exam problems in the coursepack, but there would be no answers there, since he expected them to derive them collaboratively. Students were referred to the course web site for further explication on using these problems as a learning tool. In bold print, the web site also stated:

> There are no answer keys for this coursepack for a good reason. If you had answers you would: 1. Use them too early: 2. Be less inclined to work with your peers. This second point is critical: year after year, some students begin the term complaining there is not an answer key. Then, an amazing thing happens, they learn the intended lesson: working with others

> gives you the single best opportunity you'll ever have for learning—you will talk about your ideas with others. Don't just think about it—do it!

Making this explicit both in class and in the written materials that appear on the course web site (and alluding to student complaints) suggests that this approach may differ from students' expectations and previous experience.

As is common on a first day of class, the instructor also described how students would be graded, a system that differed from most large lecture classes at the institution:

> We don't grade this course using a normative standard. That would be unrealistic if you want people to work together. We use an absolute standard. And if all 1000 students got 80% or above, we would be happy to give you all some version of an A or above. We would think we had done a good job.

On the first day students were also given a preview of the professor's discourse strategy: "The subject matter is one big story. The course is one big long narrative. If you're not used to this, it will feel strange." From the surprised looks of students and the hushed whispers, it was clear that this is novel indeed, and not how most had learned chemistry in high school. In the remainder of this first class period he discussed the differences between "information" and "meaning," how meaning is constructed, and how interpretation is based on prior experience and context. The final part of the class focused on the subject of the course in more detail. The professor wrote on the board and then turned and read aloud as a pronouncement: "Chemistry answers questions about the material world." He then described the parameters of the subject.

Classes observed during the remainder of the term followed what had been promised on day one, with a narrative story line about chemistry unfolding through particular problems of real-world application, and with continued reference to the meaning of signs and symbols and their origins. Observations throughout the term indicated that attendance for the class remained high, students appeared attentively focused throughout, and seldom did students arrive late, leave early, or engage in conversation during class. The instructor frequently asked questions during class and expected students to call out answers, which often came from several dozen students simultaneously.

The other course, general chemistry, was taught with an emphasis on mathematical processing and measurement as the focus of the knowledge base, a purposive attempt on the part of the instructor to integrate measurements and mathematical processing as an important aspect of the physical sciences. This class typically followed a different format from organic chemistry and appeared to embody alternative epistemological assumptions about knowledge and knowing. Nearly all classes observed consisted of the professor working mathematical problems on the board, observed and copied by students, who sometimes asked questions or called out brief answers in response to questions about the formulas and the appropriate information needed to work them. Tests consisted of open-ended problems, except for the final, which was multiple choice format. Previews of the open-ended problems did not appear in advance in the coursepack. Grading for the course was normative, or "curved," and this process was not explained to the students.

Observations of general chemistry classes showed a routine pattern to the classroom discourse. For example, the professor opened a class as follows:

> I asked you to read sections 1 and 2 for today and I'm going to act as if you did. Wednesday we'll go over topics in section 5 and 6 and Friday we'll finish up the chapter and perhaps get started for the review on Monday. I'll hand out some problems we'll go over on Monday. Ok, chemical equilibrium. This may be a bad thing to do today when you've come back from the weekend, but we need to go over some of the formulas for chemical equilibrium. (He turns to the board and begins writing as he continues to speak.)... So this is described by a constant, capital K, and for this general reaction we will write this constant... then we'll use algebra to describe the equilibrium...

He continued in this manner for several minutes, a cordless microphone making his voice audible throughout the room, even during long sessions facing the board. He referred students to the textbook for the formula and noted that "I've used the numbers in the textbook so you can check them." At one point he summarized his instructional strategy and the pedagogical goals for this lesson:

> So today I'll try to go over the elements of the formula and use them in calculation and once you understand that you'll know what you need to know.

In direct contrast to the expressed goals for learning in organic chemistry, the goals for this class, as presented by the instructor, are to know the formulas, when to use them, and how to use them. This suggests a different view of knowledge altogether and a different focus of attention in the learning of chemistry. This formulaic, mathematical approach is a deliberate one on the part of this instructor, though it may have unintended consequences. A sample observation included repeated phrases such as "n over v is equal to t over rp" and little other spoken detail, other than numbers that were to be plugged into such formulas. Knowledge in this class involved repetition and replication, and little direct engagement or individual construction of understanding or meaning. Many students arrived late and/or left early, and it was common to see students sleeping or in conversation. None of the students who were interviewed dropped organic chemistry, but four of the twelve enrolled in general chemistry had dropped the course before the second interview, consistent with overall course patterns.

I observed the last day of class in both courses, held back to back in the same room, with approximately the same number of students (approximately 350). In general chemistry (the course just described) students continued to wander in late and to chat with neighbors, as the instructor began class with a short introduction to the exam process and a brief review of the course:

> Ok, I gave you an overview of the main topics for review and we'll work our way through these topics. Let me address the exam first. It begins at 8 a.m. next Monday and you should bring two number 2 pencils that are reasonably sharp. It's hard to find pencil sharpeners here. You should have your calculator. And there will be a data sheet similar to the second exam. For the final exam there will be 52 multiple choice questions.
>
> All right, let's review the main themes of this course. We started off looking at measurement. Then we laid the groundwork for chemical systems. Then we started with building blocks and atoms and then we went to molecules. Then we looked at interactions among ions, molecules, etc. Then we finished with equilibrium. And that's the course. Ok, let's review problems.

As he worked final problems on the board he also provided test-taking cues appropriate to the multiple choice format of the final exam:

> So if you are rushed for time on this kind of problem, there are several things you could do... You want to be able to reject the wrong answers quickly, so in this case if you looked at the magnitude of the answers, you'd come down to these two. And if you were rushed for time and couldn't do the calculation, then you could just pick between these two. However you get the answer is ok.

As the end of the hour approached, students began to pack up noisily, and many stood and began to walk up the aisle to the doors at the back of the hall. "One more comment," he says loudly.

> I really think there have been some major changes—learning—that have taken place in this class. That's my perception. And I want you to show it a week from today on the final exam.

Students continued to head to the doors.

By contrast, the final class in organic chemistry began quite differently. The room was silent as the instructor began speaking with animation and energy, focused on the audience, scanning the students visually.

> I want to end up with a story on oxidation in order to serve as a reminder on the last day of class that the goal in any subject is to make sense of what the world is making sense of.

> I'm not recommending everyone go out and become organic chemists... When I took organic chemistry I felt I was being exposed to what looked like the state of the art in the field... If you saunter through the library and pick up the *Journal of Organic Chemistry* you can understand it after just one course. This would not be the case with the *Journal of Physics*, for example, after one physics course. It's easier to get the state of the art in this field than in any other area... And that's why we test you the way we do, giving you real problems...

Such a conclusion acknowledges students' induction into an academic community, as individuals who have learned enough to be literate about organic chemistry, no small accomplishment. He then began to weave a story about chemistry, tacitly conveying his expectations that they can now follow such a narrative. He talked about amines and nitrates, their presence in food products, how nitrates are used as fertilizers but also added in curative action, "so meat looks redder," then discussed what happens in the frying of bacon in a pan or entering a smoky bar, leading to the issue of contact carcinogens, laboratory experiments with rats, work with analogous compounds. Students seemed riveted and engaged and asked questions throughout.

The final exam in this class, as was the case with earlier exams, consisted of authentic problems culled from recent chemistry journals. In this last class he stated "I want to walk you through some of these and the kinds of problems we've been dealing with." He asked questions throughout, such as "Now which step has the highest activation energy?" and when he got a range of answers, probed the reasoning of several students, commenting "Be careful how you say that!" He patiently helped a student with a rephrasing, reminding them that he was interested in their reasoning, not just the answer. As the end of the hour approached, he was still talking and the only other sound was the hourly chimes from students' watches around the room. In this course, no one moved until he signaled the end of class, saying that "the course isn't really over yet"—there would be help sessions all week and a review session he would conduct on Sunday, the night before the exam.

Thus students interviewed in this study, divided among these two courses with such widely differing approaches to the instruction of chemistry, experienced dramatically different inductions into the scientific world of chemistry as taught at the college level. Moreover, these approaches convey differing underlying assumptions about knowledge in general and knowledge within the discipline. One course offered the view that students are cognitive apprentices who can rise to the challenge of constructing knowledge much as scientists do, within a discipline in which knowledge continues to evolve. The other presents a view that knowledge in chemistry consists of facts and formulas and that knowing chemistry means remembering and applying these formulas and recognizing appropriate contexts for their particular use.

6. Dimensionality and the epistemological interpretations of instructional practice

This analysis was conducted in a multi-layered, multi-stage process, through reading and sorting students' responses to epistemological questions, both general in nature and specific to the courses that had been observed, as explained earlier. The analyses below are organized by epistemological dimension (simplicity, certainty, source, and justification). Within each dimension, the responses to questions regarding instructional practices are presented. The intent of this analysis is to expand the theoretical understanding of the dimensions of personal epistemology and the continuum of beliefs, as expressed in context. Illustrative quotes have been selected as representative of the range of beliefs along the continuum. Quotes are followed by a participant identification number and either the letter "a," indicating that the quote was excerpted from the first interview, or the letter "b," indicating an excerpt from the second interview.

6.1. Simplicity of knowledge

In the existing literature on personal epistemology, *simplicity of knowledge* is viewed as operating on a continuum that ranges from viewing knowledge as an accumulation of discrete, concrete, knowable facts to viewing it as an interrelated network of concepts that are relative, contingent, and contextual. In the case of this dimension of simplicity of knowledge, there were no general questions from previous epistemological interviews that tapped this particular dimension. Thus all questions that students were asked in order to elicit beliefs about this dimension were related specifically to classroom practices.

6.2. Instructional practices

Key areas that appeared to provide opportunities for students to make inferences about the simplicity or complexity of knowledge included testing practices and exam review sessions. Students were also interviewed about particular instructor comments that seemed pertinent to beliefs about the relative simplicity of knowledge.

6.2.1. Testing practices

Both interview periods coincided with exam periods, so students were seen when testing practices were particularly salient, and when it was possible to gain naturalistic evidence for how students approached their preparation for tests in both subject areas. In both chemistry courses, the tests were largely open-ended problems, with the exception of the final exam in general chemistry, as described earlier. Students were asked what they thought of this, and why they imagined the instructors might test in such a way.

For some students, these questions elicited complaining about the open-ended nature of the tests and a preference for a multiple choice format. These students liked what they perceived as the simple, concrete nature of multiple choice questions and found the open-ended format of the chemistry exam problematic and unfamiliar relative to their high school science tests. One student commented that

> At my high school we had a note card and it had all the formulas... and she would give us questions but they were things we had seen before. So the stuff she went over in class was on the test, not the exact questions, but the same idea. And what was so different about *this* test was that these were things people had never seen before and that really threw us! (17a)

Such students wanted the familiar replication of discrete facts, and the safety of knowing that the essential knowledge of a field could be contained in formulas that fit on a note card. Not surprisingly, given these views of knowledge, when these students were asked how they studied for their exams, they described memorization as the primary mode of study. Such strategies had low value in preparing for tests with open-ended problems, but were reported as somewhat more useful in studying for multiple choice tests in other courses, such as the introductory psychology class. Also not surprisingly, but disturbingly, three of the four who reported having dropped general chemistry by the time of the second interview were among those with the most simplistic view of knowledge. The type of preparation with which they were familiar, the beliefs they held about knowledge, and the formulaic mode of instruction made it very difficult for them to perform well on exams that were a novelty and that required more than formula recognition and calculation.

There were other students who seemed to have a window on why instructors might want to assess more complex thought processes during the chemistry exam, for example, although they did not express comfort with the method. One student, when interviewed early in the term, lamented the loss of the straightforward tests of high school and anguished over a more open-ended approach. He described a typical high school tests as "Find the molecular weight, find this, find that." The new exams presented a dramatic contrast: "But here it's like 'In a factory this acid is being produced...' and they work it into a whole story problem! That's what gets me!"(20a) Interviewed in November, after the second exam, he still talked about the differences in testing practices, but his understanding of the rationale for this approach was clearly growing.

> In high school the wording of the exam is so straightforward. 'This means A, B, C, or D.' And in college it's like 'If you have this and you take away this, and then you have the inverse'—you know, it's weird! They could say it so much simpler. The hardest thing is finding out what they're asking... But it's just about thought processes. They want you to think more about it instead of just plug and chug. Like in chem—before you just plugged the numbers into the equation and worked it out. Now you have to find out what equation to use and what numbers to use (20b).

This student—and several others like him—seemed in transition between two sets of beliefs. Exposure to new practices caused him to reconsider a previous view of knowledge that had been reinforced by high school testing practices and to evaluate the intent and meaning of such practices. Knowledge as "plug and chug" had begun to fall away.

Toward the more sophisticated end of the continuum of beliefs about the simplicity of knowledge, there was an easy acceptance of a mode of testing where problems are open-ended and situated, and this was often accompanied by an awareness of study strategies appropriate to the task. One student, enrolled in organic chemistry, noted that such testing involves creativity and that the need to assess this is purposeful on the part of the instructor:

> There are multiple things that can happen in each problem and they want you to think creatively... It separates people basically—those that can think creatively, because that's what an engineer does, or in chemistry or physics or whatever. They want people who can think creatively and problem solve (7a).

For these students, moving beyond a simple view of knowledge is valued and seems to be an assumed part of college. Several students recalled the organic chemistry professor's rationale for a more open-ended approach and affirmed it.

> I remember what he said about the test in the coursepack: 'Now you're the teacher and I'm asking the questions.' That wouldn't really apply if it was multiple choice. Multiple choice would be easier, but you wouldn't learn as much... And you wouldn't study as hard (1a).

6.2.2. Review sessions

Further messages about the relative simplicity of knowledge are communicated by faculty members as they assist students in preparing for testing. As described earlier in the observations of the last day of class in chemistry, instructors give messages either directly or indirectly about the view of knowledge in the course as they lead students through the review process. In addition to the final exam, students were tested at several points during the term in each of these classes and scheduled review sessions were held for each of the three tests in both chemistry classes.

In general chemistry, the course instructor set aside one class period prior to the exam for a general review and distributed a set of practice problems in advance. A typical review consisted of students calling out problem numbers, which the instructor then worked on the board. Such problems consisted largely of applied mathematical work. This method seemed to suggest a particular approach to the material: the need to know how to recognize a certain type of problem, recall the appropriate formula, and perform the calculations required. The actual tests, as noted earlier, required more synthesis and integration.

In organic chemistry, a review session was scheduled in the evening a few days prior to each exam. Students were given practice tests in their coursepacks, which they had been encouraged to review early in the course, working with others to develop answers. At each review session, the professor began by explicitly stating what he called ground rules: "I want no questions of the format 'Can you work the problem on page 36?'" He did not suggest an acceptable alternative and left this for students to determine, but it was clear that he was not interested in conducting the type of review session most students had come to expect in math and science courses, largely spent observing the instructor work problems.

Given the contrast between this review session and the one observed in general chemistry, presumably more familiar from high school classes, I chose to use this incident as a platform for discussion during interviews to assess how students interpreted this and to see what it might elicit about their beliefs about knowledge.

Queried about this toward the end of the term, only a few students seemed exasperated by this tactic. One student, although acknowledging the educational value of the process, described her view of knowledge in regard to chemistry, a perspective that appeared relatively simplistic, but evolving:

> I didn't like it. I kind of wanted to go over the coursepack and I didn't like that he only wanted general questions, although it turned out to be helpful in the end. I think chemistry is more like set rules—you just have to know how to do certain types of problems... And I wanted to know how to do that process and we couldn't ask questions like that. (And why do you think he doesn't allow that?) He probably wants us to think more and not just do what I'm trying to do, but to actually know the chemistry back and forth. (And what do you think of this?) I'd think it's a good idea if my grade wasn't so highly dependent on these exams (6b).

Several students talked about the review process as a means of encouraging broader application of knowledge:

> I think that's good, because it forces us to come up with a question that's going to apply to many other questions, so you'll be able to apply it to the exam, and not just the particular problem in the book, so it keeps us from thinking that this is how you do this one and only this one. You can apply it to many (2b).

They also described it as a way to enable students to "try to understand the concept instead of just the problem."(3b) As one student noted, "Working a problem, once you get the algorithm down, that's nothing. And what he wants is more the thinking process."

By the end of the term in this particular class, all but three of the students enrolled in organic chemistry seemed accepting of this mode of review and were able to describe their responses in terms that indicated an approach to knowledge that acknowledged complexity and interrelationships among ideas. The response among students in the general chemistry class was largely exasperation and frustration over the incongruence between their preparation for the test, based on strategies suggested by the type of problems in the review sessions, and what the tests actually seemed to require.

6.3. Instructor talk: Critical incidents from classroom observations

On the first day of class in organic chemistry, as noted earlier, the instructor discussed the role of ideas and symbols in chemistry and the difference between meaning and interpretation. In the interview, students were given a particular example he had offered and asked what that had meant to them. The following three responses indicate varying levels of views about the simplicity of knowledge. On a relatively concrete plane, one student interpreted this as follows:

> He was just trying to get us to look at stuff for what they are. I think when we get into more hardcore chemistry stuff he wants us not to forget what the basic things really are, not just what they stand for, but what they are and what they're made of, like seeing the tree instead of the forest.

A second student was somewhat mystified by it but seemed to recognize that the challenge for her was to begin to connect with this way of thinking:

> I was a little annoyed because it didn't really help me at all with the work we were supposed to be doing... I was just laughing the first couple days. I was like "this guy's really cool, but I don't know how I'm going to get my mind to work with his!" (she laughs) (why do you think he teaches this way?) I think he wants people (not to) just think the first thing that comes into your mind, but to think about things more. I think that's interesting, but it's a little bit rough in chemistry! (13a)

A third student was typical of those who could see what the process required of them and who could accept both a more complex view of knowledge as well as a means of knowing that required "critical thinking":

> It's a totally different way of looking at chemistry. (And why do you think he does that?) To make people learn how to critically think. This seems to be a big thing in all our classes, the critical thinking. In the beginning of all our classes that's what's being discussed—that you're analyzing what you're learning and picking it apart (9a).

The emphasis on critical thinking was raised by several students at repeated times during the interviews. As an explicit goal of some of the first-year classes (e.g., it is directly addressed in the introductory psychology class as a necessary approach for evaluating social science research) and an implicit agenda of the college curriculum, critical thinking seems to require a particular level of epistemological development, as others have noted (Belenky et al., 1986). A problematic issue from a developmental perspective is how this approach is interpreted by those at lower levels of epistemological understanding and what additional support might be needed for developing these skills.

6.4. Certainty of knowledge

The dimension of *certainty of knowledge* concerns the degree to which one sees knowledge as fixed or more fluid. At lower levels, absolute truth exists with certainty. At higher levels, knowledge is tentative, evolving, and modified in genuine interchange with others. Student beliefs about the certainty of knowledge were assessed with both general questions and those specific to incidents in their classes.

Asked "How would you define truth?" students gave a range of answers that display the continuum expected. As found by King and Kitchener (1994), none of these first-year college students described all knowledge as certain, although there were several students who give answers that conveyed a belief in a considerable amount of certainty of knowledge. Several examples follow:

> I guess I'd just define it as something that's real and can't be proven wrong and is always going to be there, always going to be what it is. Like I'm a male and you're a female, something like that (1b).
>
> Something that is known with absolute certainty. And something that is believed to be true, that is 100% true. Like mathematics concepts (6b).

As students begin to make the transition away from such firm beliefs about the certainty of knowledge, opinions take center stage:

> I'm not really sure there is an absolute truth. Because everybody has a personal truth, and I think that's the best definition of truth, what you think is true, what your set of beliefs are (4b).
>
> Truth is different for everyone. You can believe something and it will be true to you but for the other person it's completely different. It's all about opinions... Truth to you is your particular view (16b).

For some students this transition is quite difficult to discuss, perhaps something fairly new that they have yet to think aloud about. Asked how she would define truth, one student responded:

> It's like you don't know what's for real... I guess it's just the right thing, but you don't know what the right thing is, so it's what you believe true. But it's so hard because you usually follow what people tell you and you never have to know the truth yourself, it's always out there. Well, not always. But it's out there for you in certain situations, so you know what the truth is. (What do you mean 'out there'?) Ok, not everything has a truth, and you don't know answers for everything, but say you were talking about science. Of course there is probably going to be a right answer to a problem. That's the truth (15b).

A consensus view of reality was described as truth by some:

> It can be anything from a scientifically proven fact that smoking causes cancer or, looking at anthropology, an accepted norm across cultures. One norm is that if you marry outside the family, every culture accepts that as right, that's one thing every culture believes in. (And that's truth, if all cultures believe in it?) I think so. It's a fundamental thing that everyone believes in (12b).

And another struggled with accepting a view of knowledge as constructed:

> I think truth is still kind of theory. There are a lot of things you don't know for sure. I'm sure there are facts—like you can touch this (she laughs as she touches the desk) but I think—I know that in science that theories are truths. No, forget that. (pause) I think that everything has a gray area and it's not black or white and people thought of these truths and rationalized things and came up with names and ways to explain things, so I think there's no real definite truth. (In any area at all?) I don't know if I'm looking at it too deep, but everything, I think, the way we talk about things, is constructed. We call a tree a tree because someone made that term up (10b).

Another grappled with the changes in his beliefs, speaking first of a position in which all beliefs are relative, and then moving to a position where evidence plays a role:

> It's in the eyes of the beholder. It's one's personal beliefs. There's no one set true thing. Who's to say what's what? I could call this a cow (points to a chair) and someone else could call it a chair. (So it's completely relative, and one person's version is as meaningful as someone else's?) Yeah. Hmm. Well—not always. How much you can back it up is how valid it is. With what evidence you can back it up. (Did you always think this?) Not always. I remember when something was either true or not true. I read about people like that in my psychology book and I though "that's exactly how I was!" (8b)

This ability to reflect back on a previous position was reported on by several students. Two students in particular described evolving views of knowledge that enabled them to see knowledge as less certain, more tentative, and more open to re-evaluation.

> I'm not sure there's truth. I think there's a lot of different ways of looking at things and there's degrees of truth. I'm not sure you could ever prove anything definitely. You kind of have to be willing to accept that there's different explanations and some are going to be more plausible than the others and there's always an exception. (Did you always think this?) No. I think before I thought there were absolute truths and there were some things you absolutely accepted and they were right no matter what and you came to believe it. One thing would be completely right and the other would be completely wrong. Now I'm much more open-minded. (When do you think that changed?) I can remember when the whole process started, but I've changed my mind about a larger number of things just since I've gotten here. Because there are so many people that have really interesting and new ideas when you talk to them—you open your mind to ideas you were previously closed to... My life is completely different here than it was before. I've had to change, to adapt... to become more open-minded (13b).

> I think there are many elements that go into truth. I don't think there's one thing you could say is the truth. You have to look out when someone says 'this is the truth' because there's always new experiments going on, there's always new findings, so you have to be able to accept those and not be rigid and not think 'this is the truth, I can't deviate from it.' You have to be more open I think. (Do you think you always thought that?) No, I think before, more like early high school, I didn't think. More as I got into advanced placement classes in later high school years, and now that I came here, I think. I've developed more critical thinking and more openness to other perspectives and other findings, to be able to say 'I'm not as rigid, I can look at other people's argument and see what their side of the story is.' (2b)

6.5. Instructor talk: Critical incidents from classroom observations

During the early weeks of the psychology class, in which all of the participants were also enrolled, the instructor talked about psychology's origins and its ties to both philosophical inquiry and the scientific method. The instructor also made explicit attempts to distinguish pop psychology from scientific psychology and discussed the use of evidence to validate claims in psychology. During that lecture he said:

> In science we have explanations and theories and they must be regarded as tentative. We're never satisfied that it's the final explanation.

Because this was applicable as well to their beliefs about chemistry, during the first interview this was repeated to students as a statement the instructor had made in their psychology class and then they were asked to comment on it. This seemed to provide a way to gauge their understanding both of the concept and their sense of certainty of knowledge.

None of the 25 students interviewed questioned this statement, and all seemed to accept that there is a tentativeness to explanations and theories in science, but some were quick to restrict and qualify this and others saw it as a widespread phenomenon. Their beliefs about the reasons for the tentative nature of knowledge in science varied. Highly affected by the "information explosion," many of these students viewed the tentative nature of science as a necessary position in a world where the knowledge base continues to change rapidly.

> New things can be found every day and maybe you might learn something and you believe it is best but then five years from now they discover another part of the brain that controls something. (3a).
>
> I think he means that you can always keep testing something, and I guess maybe he means that nothing is ever absolute. Something can always change. Like 50 years from now something we believe to be true now we can learn that it's not—I know it's happened before (1a).

Others saw this as a matter of the changing technological climate, that it had recently become possible to challenge previous knowledge through methodological advances:

> Different things are happening now and a lot of technology is advancing, and we're going to discover more things, so some things are going to have to be tentative. But I think some things that have been around a while are concrete (20a).

Some students expressed a general openness about the tentative nature of knowledge:

> There's always new things we're finding out, so nothing can be final, it can always be some new perspective that comes into play, where you have to examine it from a different angle (2a).

And for some this had a personal cast, as they reflected not so much on whether they saw knowledge itself as certain or evolving, but whether they were able to approach knowledge with any personal sense of certainty. For example, one stated:

> There's just so many theories so you don't know which one is the exact right one. And I guess that keeps things open. You can lean towards one but as long as your mind is till open, then you're not so adamant about it (9a).

By contrast, another student spoke of her need for certainty:

> I think it's true, but I like to have answers, so it frustrates me. Like I don't know if I could live with a career that involved that, because I really like to feel like after I've done something that I have a definitive answer I've gotten out of it. Like I've really accomplished something finite. But it's interesting (13a).

Finally, some described a quest for new knowledge:

> I think that's true in science—that scientists are never satisfied with the results—or they'd lose the passion for it (5a).

6.6. Source of knowledge

At lower levels of most of the models of personal epistemology, knowledge is viewed as originating outside the self and residing in external authority, from whom it may be transmitted. The evolving conception of self as knower, with the ability to construct knowledge in interaction with others, is a developmental turning point of most models. Perry (1970) described this awareness as one of the shifts in his model of intellectual development, when "the person, previously a holder of meaning, becomes a maker of meaning"(p. 87). Similarly, both King and Kitchener (1994) and Belenky et al. (1986) describe a shift in the action of knowing in the higher stages of epistemological development, with the knower moving from spectator or passive listener to an active constructor of meaning.

In order to assess general views about the role of authority in knowing, students were asked several questions about the nature of expertise and their reliance on expert authority. One such question, adapted from Belenky et al. (1986) was: "In learning something you really want to know, can you rely on experts?" At one end of the continuum, students seemed to express confidence in expertise, a view that also reflected their sense of certainty of knowledge:

> Yes. I guess if I wanted to know something about chemistry, to give me the right answer, I guess I could rely on my professor to tell me the right answer and how to get it (14a).

Those with a slightly less certain view of knowledge suggested that this might not always be reliable:

> Sometimes. You can't always assume they'll be right. In the case of science, experts said the earth was flat and it turned out to be wrong. So, sometimes you can and sometimes you can't (6a).

Others assumed that experts would be acceptable up to a point, but that "of course they are going to have their own biases." (7a). Along this continuum, parallel to what has been sketched out by King and Kitchener (1994), there were those who described a more questioning attitude toward expertise. For example,

> I think it depends on who the experts are... I think if there are unbiased experts, it's ok, but you have to look at where they're from and what their motives would be for reporting this (21a).

> I still think you have to think about it critically. You can't just rely on experts because you don't know all the facts under which their tests were run. You have to ask what were the variables—and are they telling you everything that happened? (2a)

Others spoke of the role that firsthand experience plays in knowing:

> I don't know if I'd rely on them solely, but I think if I wanted to learn something, I'd consult experts in that field and maybe read some of their literature. But I think I'd want to experience something firsthand, definitely. The experience is more valuable than reading a textbook or even talking to someone who has the experience (5a).

A more constructivist view was evident in several students' responses about expertise:

> An expert can tell you all he knows, but you have to be able to do it in a way that can get into your mind so that you know it. (25b).

> To a point. I mean, you have to think about it yourself—people can only give you so much. There can only be so much input, then the information has to be assimilated and put together and made into what you know (11a).

To further investigate students' views of external authority, students were also asked "How do you know when someone is an expert?" At one end of the continuum, their definitions reflected a view of expertise as synonymous with a quantifiable body of knowledge and an extensive amount of training. Students described experts as those who "had been to all the classes and really know what they're doing," who have "studied for a really long, long time," or who have "more knowledge in the field than the average person." Such experts are "certified at something" and "are supposed to know every little detail about certain things." One student noted that experts "don't need to look anything up." This view embodies a view of knowledge as certain and simplistic, as suggested by this student's response: "Credentials. Facts they've found that have been proved. If you know they've done a lot of good things and what they've done is true." (15a)

Another view included the assumption that training and education are a valued aspect of expertise, but extends this to include other criteria such as "someone at the cutting edge of what they're doing, continually trying to bring more information into their field" or "they have their own original ideas and ways of doing certain things." In this discussion several talked about the value of being able to integrate ideas, the need to continue to learn within a field, and the ability to effectively communicate. One student described signs of expertise as "how well they understand things, how well they can tie them in with other things, how well they can get something across to someone." Such views suggest an interrelationship among the four dimensions of personal epistemology, as this also represents a more complex view of knowledge.

6.7. Instructional practices

Within the structure of these large classes, students face multiple possibilities for determining the source of knowledge. The instructor at center stage in the front of the room would be an obvious source for many, as would the text and other supporting materials. Students are also encouraged to learn from others, and this is formalized both through discussion sections and organized study groups. Such participatory experiences also give them opportunities for constructing their own ideas and expressing them aloud, perhaps validating their own knowing. Laboratory experiences provide opportunities for direct engagement in learning, as do research experiences. Outside the structure of the courses, there are other sources of knowledge, including peers, parents, former teachers, other printed resources, and various other forms of media.

6.8. Conflicting sources of knowledge

In the first interview, students were asked a series of questions about what they might do when various sources of knowledge conflicted. Several spoke of conflicts between personal experience and the text and how they resolved this. Students also recalled experiences when the text differed from what their teachers or professors had said in class, and their interpretations revealed what they judged to be the more credible and trustworthy source. For some students, the fact that a teacher could question the authority of a text was baffling. One such student described a set of conflicts between the lectures of his high school world history teacher and the textbook for the course, and the ambiguity this created for students, particularly when they inquired about preparing for an exam:

> We'd say 'which do you want us to use, the lecture or the book?' ... And he said this quote I'll remember till the day I die. He said 'Books lie.' (pause) That's what he told us! We didn't know what to do, it was so tough. (And what did he mean, 'books lie'?) I have no idea! He was a really weird man. And no one wanted to argue with him, because he was the authority (20a).

Texts had been a paramount authority to this student, and reconciling this with the teacher's judgment had been insurmountable for him at the time.

In most of the cases cited from high school experiences, students were overwhelmingly in favor of the book as the higher authority over their high school teachers. One commented on a discrepancy about the scientist who discovered DNA: "Basically, I remember the book, because I didn't trust the teacher. I would just think the people writing the book would know more what they were talking about. They would know more about the field." (6a) Others offered similar views.

Although it might be expected that students would see college professors as perhaps more authoritative sources of information than their high school teachers, given the relative preparation involved and the difference in roles, such changes do not occur immediately, and these students, interviewed during their first semester of college, were still likely to suggest that the textbook would be a more reputable and trustworthy source. They were pragmatic about this, of course, distinguishing between what they would give as a test answer and what they might actually believe. For example, one student commented that the psychology professor had alerted the students that a particular explanation during the lecture differed from that of the text:

> He obviously believes he was right and the book was wrong. And so he just told us to listen to him—for the test. But when it came down to it, I think if I were to go back a few years from now, I'd look in the book... Maybe he's an expert in his field, but the person who wrote the book was also an expert in psychology or otherwise he wouldn't have used that book, so I think I would trust the book a lot... Other professors are going to find that same book to teach psychology from, so it's him going against 100 different psychology professors... (17a)

Students who could not give specific examples were asked what they would do if such an occasion should arise and how they would resolve it. Some who argued for the book were very matter of fact about it, assuming that books are right, e.g., "I would just tell myself that this guy doesn't know what he's talking about." Others who said they would be more likely to accept the information in the book presented the position that texts represent the views of multiple sources, validated in the publishing process, and seemed confident that this would carry more weight.

> Books have normally been reviewed by many people or written by many people, so you know it's the opinion of more than one person. What the teacher is saying could just be their own opinion (8a).