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ABSTRACT

The thoughts that teachers have about the content and students they are to teach influences the way in which they will teach. This article briefly discusses the literature on teacher thinking with particular reference to recent work in science education to provide a framework in which to situate the research. The article describes the interview task and the method of analysis for obtaining representations of teachers' conceptions of teaching science that were used in this study. A detailed summary based on an analysis of the conceptions of teaching science held by six experienced high school science teachers is presented. Several features of teachers' conceptions that have emerged from the analysis are discussed. (PR)

CONCEPTIONS OF TEACHING SCIENCE

HELD BY

EXPERIENCED HIGH SCHOOL SCIENCE TEACHERS

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Introduction

The thoughts that teachers have about the content and students they are to teach influences the way in which they will teach. This idea, in accord with common sense and common experience and supported by a growing body of research, underlies the research reported in this article. Our argument is as follows: if we want to improve science teaching (and national reports are calling for just that) and science teaching depends on teacher thinking, then research on experienced science teachers is needed to inform the goals of science teacher certification and professional development programs. The goal of the study reported here represents but one component of such a research program: it is to describe the nature of the conceptions of teaching science held by a sample of experienced high school biology, chemistry, and physics teachers. To address this goal, we identified experienced high school teachers of biology, chemistry, and physics, and interviewed them to determine their conceptions of teaching science (Hewson & Hewson, 1989).

In this article we first briefly consider the literature on teacher thinking with particular reference to recent work in science education to provide a framework in which to situate our research. Next we briefly describe the interview task and the method of analysis for obtaining representations of teachers' conceptions of teaching science. Then, based on this analysis, we provide a detailed summary of the conceptions of teaching science held by six experienced high school science teachers. Finally we discuss several features of teachers' conceptions that have emerged from our analysis.

Literature Review

Teaching is a complex cognitive process in which an individual draws on knowledge from multiple domains in order to teach (Leinhardt and Greeno, 1986). What a teacher needs to know and how that knowledge should be learned and used to teach effectively has been a central theme for many educational researchers and philosophers since the time of John Dewey nearly a century ago.

Constructivism

A way of thinking about teaching that, in our view, readily incorporates these issues of teaching complexity and teacher learning is a variation of a constructivist perspective (Magoon 1977, Resnick 1983, von Glasersfeld 1989, Wheatley 1991). This assumes that humans construct their own knowledge, using their existing knowledge in order to do so. This construction of knowledge takes place within a context of social interaction and agreement. In the process of construction, people develop relatively stable patterns of belief. They construct knowledge in ways that to them are coherent and useful. Since the construction process, however, is influenced by a variety of social experiences, the knowledge constructed by each individual is not normally completely personal and idiosyncratic. Thus, existing knowledge and social agreements about meaning limit not only how new experiences are interpreted, but also determine what is perceived in any situation. In addition, two individuals exposed to the same events may perceive and interpret them in very different ways, depending on their individual underlying knowledge and beliefs.

Research on Teacher Thinking

In recent years there has been a huge upsurge of interest in how teachers think and what they know. A major catalyst of this increased interest was a report of the National Institute of Education that proposed an image of the teacher as a professional whose thought processes were worthy of study (Clark & Peterson, 1986). This has since led to many studies that have illuminated different, frequently overlapping aspects of teacher thinking. Wilson, Shulman, and Richert (1987), for example, have offered a detailed view of what makes up a teacher's knowledge, by presenting a model of the components of the professional knowledge base for teaching. These components are knowledge of subject matter, pedagogical content knowledge, knowledge of other content, knowledge of curriculum, knowledge of learners, knowledge of educational aims, and general pedagogical knowledge. They suggested that these are not isolated blocks of knowledge, but are related to each other in different ways. Further, they sought to describe these ways in a model of pedagogical reasoning that draws at different times and in different ways on these components of a teacher's knowledge. The picture of teacher knowledge, then, that has emerged from this and other studies is a complex one. Some major features of this picture are that teachers' knowledge draws from many different sources, it is used for a variety of purposes, and it is fluid and contextualized.

Different methods have been used to identify and evaluate teacher thinking. In a recent review, Kagan (1990) identified five different types of method. The first was direct and noninferential ways of assessing teacher belief, a common example of this type being the use of Likert-type self-report scales. Second were methods relying on an analysis of teachers' descriptive language that identify, for example, the metaphors embedded in this language. Another type used taxonomies to evaluate teachers' metacognition and self-reflection as provided in a written test, an interview transcript, a reflective journal, etc. A fourth type used multimethod evaluations of teachers' pedagogical content knowledge such as questionnaires, structured interviews, and experimental tasks. The final type involved teachers constructing some form of a concept map of their knowledge.

In science education, different bodies of research have informed the study of the conceptions that science teachers hold about teaching in general, and about aspects of teaching such as science, learning, instruction, and curriculum in particular. One of these is the research on teacher thinking briefly mentioned above. A second has focused on science teachers' beliefs about the nature of science (Lederman, 1992). Hewson and Hewson (1987) considered research on teacher thinking in conjunction with a third body of research: that into students' conceptions of natural phenomena. They presented arguments that led to a definition of the conception of teaching science and the development of the interview task used in the present study to determine conceptions of teaching science (Hewson & Hewson, 1989). They also used an analogy with teaching designed to help students acquire conceptions of natural phenomena, to suggest that certification programs should focus on helping preservice teachers acquire appropriate conceptions of teaching science. The analogy also suggests that both beginning and experienced teachers might hold a variety of different conceptions of teaching science, some of which might result in limited professional knowledge development and ineffective teaching practices.

Evidence to show that teachers hold different conceptions has come from Aguirre, Haggerty and Linder (1990) who used an open-ended questionnaire to elicit preservice science teachers' conceptions of teaching science. They found students entering preservice education programs possessed a variety of views about science, teaching, and learning. For example, almost half of 74 prospective science teachers believed that teaching is a matter of knowledge transfer from teacher "to the 'empty' minds of children" (p.388) in contrast to about a third who believed that "for learning to occur, new information should be related to existing understanding."

Evidence that changes can occur in a science teacher's conception of teaching and learning has been presented by Hollon, Roth and Anderson (1991) in the case of Dave, a preservice teacher. They discussed some of the changes in his conception of teaching science that occurred due, in part, to preservice courses he took. For example, Dave initially expressed a great deal of confidence in his conceptual understanding of subject matter. He viewed biology as "the ideal thing to teach because it's so related to their (students') everyday world and things they might wonder about." (p. 169) At the end of his methods program Dave's expressed confidence was judged to be far more justified because he had developed a set of beliefs and conceptual tools that prepared him to reflect on and learn from his experience as a teacher. Another finding was Dave's new found belief in the importance of students' prior knowledge and the active role this plays in the learning process.

These articles exemplify the findings that teachers do hold different conceptions and that these conceptions can change as a consequence of a teacher education program. The significance of these findings derives from the assumption with which this article began, viz., the thoughts that teachers have about the content and students they are to teach influence the way in which they will teach. Recent studies have sought to test this assumption by combining analyses of teachers' thinking with observations of their classroom practice (e.g., Lederman & Zeidler, 1987; Duschl & Wright, 1989;

Brickhouse, 1990; Gess-Newsome & Lederman 1992). The results reported in this study were obtained as part of a larger research project (Hewson & Hollon, 1989) that has also addressed this assumption (Hollon & Hewson, 1993; Lyons & Freitag, 1993; Freitag, et al., 1993).

Conceptions of Teaching Science

From a constructivist point of view we can argue that teachers build conceptual structures in which they incorporate classroom events, instructional concepts, socially approved behaviors, and explanatory patterns. Following Hewson and Hewson (1989) we refer to a structure such as this as a conception of teaching science:

> the set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature and content of science, and the learners and learning that the teacher uses in making decisions about teaching, both in planning and execution. These include curricular decisions (the nature and form of the content) and instructional decisions (how the content relates to the learners in the instructional setting). The structure of a conception may vary considerably from a relatively amorphous collection of ideas with no strong connections to one which is interrelated and possesses a large measure of internal consistency (p. 194).

The notion of a conception of teaching science has much in common with the picture of teacher knowledge briefly sketched above: it recognizes that the knowledge used in teaching draws from knowledge of the subject, the learner, and instruction; and it is sensitive to the particular context in which a teacher uses it. The method used to elicit teachers' conceptions in this study, the conceptions of teaching science task (Hewson & Hewson, 1989), was included in the group of methods evaluating teachers' pedagogical content knowledge by Kagan (1990, pp.439-41) who commented that the task "yields a purely descriptive measure of a teacher's pedagogical content beliefs and does not address the relative value of those beliefs."

The development of a solid base of knowledge about students' conceptions has been 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 facilitated those changes. While it is clear that researchers have recognized the importance of teachers' underlying conceptions of teaching science, and how these conceptions might influence their teaching practices, a comparable base of knowledge about high school science teachers' knowledge and beliefs does not yet exist. Yet such knowledge is fundamental to efforts to design preservice and inservice models that will be successful in helping individuals acquire more appropriate conceptions of science teaching. Thus the study reported here aims to provide an important link in the chain of knowledge needed to move beyond description of existing practice and toward more effective models of developing effective practitioners by focusing on the description of their conceptions of teaching science.

Design and procedures

The research question addressed in this article is:

What is the nature of the conceptions of teaching science held by a sample of experienced high school biology, chemistry, and physics teachers?

Selection of Teachers

The teachers in the present study were recruited as part of a larger project (Hewson & Hollon 1989). The two criteria for inclusion in the project were that teachers should have a minimum of 5 years teaching experience and a willingness to contribute to the profession. The selection of teachers to participate in the study was accomplished through direct contact with high schools within a radius of about 40 miles of the research site. Meetings were held at more than a dozen interested schools in Fall 1989, at which the goals of the project were outlined, time demands on teachers and students were discussed, questions were answered, and a summary of tasks expected of teachers engaged in the study was handed out. As a result of this process, 4 biology teachers, 5 chemistry teachers, and 5 physics teachers from 10 high schools agreed to participate in the study. Of these one physics and one chemistry teacher were only involved in a pilot study, leaving a total of 12 teachers, 4 in each discipline, in the main study. Three teachers were interviewed using the Conceptions of Teaching

Science Interview in September 1990, and the remaining 11 in May 1991. In this article we report on the results obtained from six of the twelve main study teachers; the analysis of the remaining teachers is in progress.

<u>The CTS Interview and its Analysis</u>

The general conceptions of teaching science held by experienced teachers were determined using an interview task developed by Hewson & Hewson (1989). The task was designed to enable respondents to consider the components of an appropriate conception of teaching science (Hewson & Hewson, 1988), while providing an environment in which a variety of views could be expressed without bias from the task structure. It was developed to allow subjects to respond to particular events while encouraging them to link the events to larger conceptual issues.

Details of the interview and its analysis have been provided elsewhere (Hewson, Kerby, & Cook, 1992). In brief, the interview consists of 10 events that include instances and non-instances of science teaching and learning both in and out of classroom contexts. Each teacher was shown in sequence a written description of each event, asked *whether, in his or her view, there was any science teaching happening there, and invited to give reasons for his or her answer.*

The analysis entailed identifying teacher statements; categorizing them into six categories; writing a summary statement of each relatively homogeneous thought within each category; and identifying any coherent themes linking summary statements in different categories. A theme is the same thought applied in various categories and contexts; it seems to be a characteristic that influences the teacher in responding to different events. The six categories were collapsed into the following four: the nature of science, learning and the learner, instruction and its rationale, and the nature of teaching.

Results

Presentation of Results

The results presented below have two different fields of view. On the one hand, we concentrate on each individual teacher to preserve the integrity of his or her conception of teaching science. On the other hand, we look across individual analyses for points of comparison and contrast. With respect to the first, we present the analysis for each teacher in several different ways. First, we summarize each teacher's set of summary statements (about 15-20 per teacher) and theme statements (about 3-6 per teacher) in a theme analysis grid (or TAG). Second, we present detailed abstracts of each teacher's conception of teaching science that are structured around the themes. Third, for each teacher we comment on different features of the analysis. These comments form the basis for subsequent comparisons and contrasts with other teachers.

Figure 1 contains, as an example, the theme analysis grid (or TAG) of Corrigan, a chemistry teacher. Each of the columns in the TAG represents one of the four collapsed categories: it contains the summary statements within each category, subdivided into different aspects of the category. The rows into which the sub-categories are placed are arbitrary. The themes detailed at the foot of the grid are labeled by symbols (♦, ◘, ▮, etc.) that identify the summary statements defining a theme. For some teachers there are tensions between and within summary statements. These are represented with dotted arrows as follows: <---->.

Figure 1 about here

In the second field of view--presented in both tabular and written forms--we compare and contrast the analyses of different teachers using a number of different criteria. As mentioned above these form the basis for the comments we make in the individual teacher abstracts. The comments for all teachers considered in this article are summarized in Figure 2. The various points of comparison are listed below.

1. Summary: the central features of a teacher's conception of teaching science.

2. Tensions: between and within summary statements.

The remaining three points of comparison arise from the structure of a teacher's TAG and are obtained from inspection of the TAG.

3. Balance: the distribution of summary statements across categories. For example, Corrigan's CTS is well balanced with at least three summary statements in each category.

4. Integration: the links between categories expressed in theme statements. For example, Corrigan's themes link all categories together except Learning and Teaching.

5. Links to Instruction: a subset of point 4. that identifies the links, if any, from Science, Learning, and/or Teaching to Instruction.

These points of comparison allow several issues to be addressed. One is a general concern about the constraints imposed by the interview task: in particular, did the use of the same task restrict the identification of a teacher's uniqueness and individuality? In other words, did teachers come out looking very similar to one another? Another issue is identified by Point 5: the basis on which teachers choose their instructional practices. Are modes of instruction an independent cluster of actions or skills that can be practiced and used by anyone? Or is the choice of modes informed by a view of the context in which they are used, e.g., by the teacher's sense of what it means to teach science?

Figure 2 about here

The comparison summary we present at this point draws from teacher analyses considered later in the article. We preview these results both to illustrate the points of comparison we have used and to provide a structure for assisting the reader in organizing the later analyses.

Mr. Corrigan: Chemistry Teacher

Teaching science for Mr. Corrigan is a complex affair: the analysis of his CTS interview identifies a number of themes that represent different facets of his conception of teaching science. The first two themes outline his two main goals as a chemistry teacher. These are (i) to help students appreciate how the natural world works by using science with its goal of seeking to understand and explain the world; he believes this will help them to be responsible consumers and citizens; and (ii) to prepare students to be successful in college chemistry. Two further themes identify two other aspects of science Corrigan sees as important. The first identifies the processes of science such as observing, analyzing, forming opinions, hypothesizing, predicting, testing; because in his view these require higher level thinking, Corrigan believes it is necessary to present situations to provoke this. The second is based on what he believes is science's essential relationship with the natural world; for him this requires regular hands-on contact in labs and demonstrations. In a final theme Corrigan identifies the need for "field trip" experiences where students are allowed to play, to interact with materials on their own, during which they'll learn unpredictable things. His theme analysis grid (or TAG) is presented in Figure 1.

There are several aspects of Corrigan's themes that seem to be worth noting. The first is that Corrigan contributes in some detail to each of the analysis categories, i.e., the nature of science, learning and the learner, instruction and its rationale, and conception of teaching science. In other words, there are no obvious gaps; his overall conception is well balanced. This can easily be seen in his TAG that contains entries in most cells. In talking about science, he refers to its goal of understanding and explaining the world, he recognizes that it includes many processes (as listed above), he speaks of its essential relationship with the natural world that is explored in the laboratory, and he identifies some of its applications. With respect to learning, he identifies different kinds or levels of learning, he recognizes the possibility of unpredictable outcomes, he is very clear that he regards hands-on experience for students as vital, and he acknowledges the importance of student interest in learning. With regard to instruction, he identifies the importance of having clear learning objectives that match his instructional choices: these include a large component of laboratory work; lectures in which he shares facts, relates insights, and models problem solving; and the use of questions to provoke higher level thinking.

The second aspect to be noted is that the analysis categories are well integrated together within Corrigan's themes. Most of the four categories are linked to each other in at least one theme, as can be seen by inspecting his TAG (Figure 1); the only exception being the absence of a link between learning and teaching. For example, his first theme--to help students appreciate how the natural world works by using science--links his teaching goals to his view of science whose purpose he sees as understanding and explaining the world; i.e., it links teaching and science. His second theme--to prepare students to be successful in college chemistry--links his teaching goals to the instructional necessity he sees of giving lectures that in part model problem solving; i.e., it links teaching and instruction. A special case of linkage worth noting is the extent to which Corrigan's preferred instructional strategies are closely informed by his views of science, learning, and teaching; in other words, Corrigan plans to use particular forms of instruction in an informed and intentional manner.

The third aspect worth noting is that Corrigan's themes are complex. For him, each of the categories has more than one dimension. On occasion this means that they suggest different teaching approaches. The accommodation of these apparent tensions within his overall conception of teaching science is, for us, a significant characteristic. For example, with respect to learning, he differentiates lower and higher levels of thinking, recognizes that both are important, and recognizes that they require different teaching strategies. Also, while at times he talks of an ideal class that is all laboratory or demonstration and he plans for "field trip" experiences with unique and unpredictable student outcomes, he clearly identifies a need for lecturing to present structure, direction, and purpose. In other words, he has different goals: these are informed by the different facets of his understanding of science and learning and result in a reasoned mix of different forms of instruction.

Mr. Jonas: Chemistry Teacher

Science teaching seems, for Mr. Jonas, to involve his meeting the needs of his students by maintaining a balance between organization and structure on the one hand, and wonder and curiosity on the other. His conception of teaching science includes three themes, all of which connect learning and instruction, with some tensions present that reflect competing priorities. His theme analysis grid is shown in Figure 3.

Figure 3 about here

Jonas' first theme--student learning is greatly increased by organization and structure--connects the categories of learning, instruction, and teaching. He refers on a number of occasions to the value of organization. For example, he believes that student learning is greatly increased by organization, structure, and focus in course content, materials, and activities; he recognizes that many activities involve following a recipe; and he holds the view that, when students don't know what's going on, following an algorithm or recipe can give them a sense of the concepts involved. Even when he organizes and focuses materials, though, Jonas sees the need to leave room for spontaneity. This tension is, however, a minor one for him.

The second theme--students' background information and skills are extremely important in learning chemistry--links together the categories of science, learning, and instruction. Jonas sees students' knowledge and skills as essential prerequisites to learning. Since, in his view, the most important of these for studying science are reading and math skills, he would rather students in lower grades worked more on these skills and less on science; he believes with this background they would be better equipped to handle science in high school. He also thinks that, if students have enough background to visualize what's going on, they would learn better from activities that involve following a recipe.

Jonas' third theme--wonder and interest increase students' attention--connects learning, instruction, and teaching, as did his first theme, but with a very different emphasis. For him, demonstrations are the best way to capture students' attention and get them wondering and asking questions. In summary, he believes wonder, interest, and curiosity are important to learning.

A number of comments are worth noting about Jonas' conception of teaching science. The first is that Jonas seeks to meet the needs of his students by maintaining a balance between organization and structure on the one hand and wonder and curiosity on the other. The instructional techniques Jonas talks about would seem to provide him with the means to maintain this balance. He sees the need both to organize and focus the course content, and to allow opportunities for student feedback in order to check that students are paying attention to and becoming curious about content while also coming to understand it. Thus he advocates the use of demonstrations to capture attention, and questions, discussions, and quizzes to provide feedback on student progress. In relation to this it is worth noting that: there is a noticeable tension within Jonas' CTS. Jonas sees a need for organization and structure; he believes that students benefit greatly from it. Even following a recipe or algorithm has value in the proper situations. Yet there is a tension, albeit minor, within this theme because, while he sees a need for structure, he says he does not like to "cookbook" and recognizes a need for students to be spontaneous.

A third comment worthy of note is: Jonas' CTS is well balanced across learning, instruction, and teaching, whereas science is virtually absent. This shows clearly in his TAG: all categories except science contain at least three summary statements. His two summary statements on science are indirect: science is important, and requires reading and math skills. Thus we can infer that the nature of science is something he seems to take for granted. While he recognizes its utility and he is aware of required prerequisites, he makes little comment about science itself, beyond his view that it is organized and that it uses rules, algorithms, and recipes supported by concepts.

A final aspect is: **Jonas' themes are well integrated across analysis categories.** Most of the categories are linked to each other in at least one theme, the exception being the absence of a link between science and teaching. This can clearly be seen in his TAG. A good example of integration is his first theme. It links student learning (increased by organization and structure), instruction (there is value in having student follow a recipe), and teaching (a teacher should organize and focus course content). Together with the other two themes that also include links between learning and instruction (among others), it is possible to see that **Jonas' preferred instructional strategies are informed by his understanding of the factors affecting learning and teaching.**

Ms. Sorenson: Physics Teacher

Ms. Sorenson's view of science teaching is strongly characterized by two major components: the value of hands-on physical experiences and discovery as a major link between science and learning. These are contained within three closely interwoven themes that are centered on her view of learning: how it happens, what it is and how it is used. They are represented in her theme analysis grid contained in Figure 4.

Figure 4 about here

Sorenson's first theme--**science and learning both occur through the process of discovery**--ties science, learning, and instruction together for her. Science, and physics in particular, involves making observations, asking questions, coming up with and testing theories; this for her is the process of discovery. She also sees that these activities are what students do when they learn by discovering things for themselves. In instruction Sorenson uses techniques such as questioning, hands-on activities, and silent demonstrations that involve students actively, because for her they initiate discovery learning.

The second theme--hands-on, concrete manipulations of physical objects are essential to learning science--is, for Sorenson, closely related to the first. In her eyes, science teaching lends itself to hands-on experiments, demonstrations, and manipulating equipment. While these are important in helping students discover things on their own, they are also valuable because, for her, high school students learn better if they do something physical. Sorenson sees that such students, like her, are "pretty much concrete".

The third theme--useful learning involves ingestion--is central to Sorenson's view of how knowledge is acquired and used. For her, when a student "ingests" useful information, he or she takes it in, incorporates it with other information, and makes it so much a part of him/herself that s/he can apply it in different situations. She sees ingestion in contrast to memorization, a poor type of learning which doesn't last long and can't be applied.

Several aspects of Sorenson's conception of teaching science are worthy of note. The first is that, in Sorenson's view of science teaching, there is a strong relationship between learning by discovery, the processes of science, and hands-on concrete experience. This, then, influences her instructional strategies where she sees a need for hands-on, concrete experience to assist the processes of learning.

Sorenson's CTS strongly emphasizes one of the analysis categories: learning.

A point worth noting, however, is the absence of summary statements about her goals, whether these are the goals of science or the goals of teaching, or about subject matter content. This does not, however, suggest she has no teaching goals or no views on subject matter; merely that these seem to be less important to her views on teaching science than her other concerns.

Sorenson's themes are well integrated across analysis categories, with all categories linked to each other.

Sorenson's preferred instructional strategies are informed by her views of science, learning, and teaching.

Last, she sees an important distinction between memorization--a poor, transient form of learning--and ingestion in which things learned are useful, connected, and owned by the learner. There do not appear to be tensions between any two themes.

Mr. Venturi: Biology Teacher

Mr. Venturi's conception of teaching science is strongly oriented to instruction, all four of his themes being linked to his preferred instructional strategies. In contrast, there is an absence in any of his themes of explicit connections to learning. Figure 5 contains Venturi's theme analysis grid (or TAG).

Figure 5 about here

Three of his four themes represent different aspects of the link he sees between science and instruction. First, he wants to get students to ask their own questions and design their own experiments because, in his view, carrying out processes such as this is doing science. He does, however, find that these possibilities are limited because of constraints imposed by laboratory facilities and student numbers. Second, there is a tension for Venturi in his next theme. While he sees the need to consider biological terminology and scientific language in his instruction, these are not, in his view, what is important about biology--this isn't the heart of the subject--and shouldn't be emphasized over conceptual information. Third, Venturi sees that biology is changing, and that topics considered basic today were barely touched on twenty years ago. Thus he doesn't feel that there is a certain amount of subject material he needs to cover each year; instead, he chooses to select and teach biology topics that he considers basic, topics that change as the field changes. Venturi's final theme highlights a link he sees between teaching and instruction. Because he believes that teaching depends on the interaction between teacher and students, he uses discussion as an integral part of his lectures. Thus he regularly plans to pull students in as part of the discussion in the classroom, for example, by redirecting student questions back to the class.

There are several aspects of interest in these themes. The first is that Venturi's themes are not explicitly linked to learning. This clearly shows in his TAG where there is only one unlinked summary statement in the learning category. A closer inspection of summary statements categorized as instruction may raise some questions about this claim: getting students to ask good questions, to answer their own questions, and to design their own hypotheses and experiments all involve active student tasks that we might reasonably infer would lead to learning. Yet all these summary statements are expressed in the first person--these accurately reflect the language Venturi used in his CTS interview--and thus their focus is on the instruction he would carry out. One might infer learning from this, but that is not something Venturi does explicitly. A point that seems less significant, but nevertheless worth mentioning, is the absence of summary statements referring to his goals for science or his goals for teaching; for whatever reason Venturi chose not to mention them in his interview.

In contrast, however, to learning, there are links between other categories, with most of them between science and instruction. For example, Venturi reckons that if students do some of the processes of science, they are doing science. Thus his instruction is designed to get students to do just this. Also, because in Venturi's view the field of biology is changing, he changes the biology topics he chooses to teach. In other words, Venturi's preferred instructional strategies are informed by his views of science, and teaching.

The second aspect of note is that there are some tensions within Venturi's themes. One arises from the practical limitations of lab facilities and student numbers that constrain his students from doing science as he believes it should be done. A second arises from the intrinsic problem of biology's extensive terminology; while Venturi believes this needs to be taught, he also believes that he needs to emphasize conceptual rather than factual information.

Mr. Dodgson: Physics Teacher

Teaching science for Mr. Dodgson is an intentional, purposeful activity that requires explicit student involvement. There are three themes woven into his conception of teaching science; these seem to fit together to provide a relatively coherent whole, without any apparent tensions between them. The first is centered on students, the second on the teacher, and the third on science. Dodgson's theme analysis grid (or TAG) is presented in Figure 6.

Figure 6 about here

Dodgson's first theme--students need to be mentally involved in the task at hand in order to learn--ties together the three categories of learning, instruction, and teaching. He recognizes that he has some responsibility here, since students won't always become mentally involved on their own, and can watch or do something without thinking and learning about it. So he realizes that, in order to get his students involved he needs to interact with them to provide the impetus and direction for them to learn; this he does primarily by asking them questions.

Dodgson's second theme--his need to provide purpose, motivation, direction, structure for all the tasks that he asks his students to do--ties together the same categories of learning, instruction, and teaching that his first theme does. This theme is, however, centered on his role as the teacher. He sees that it is his task to create a proper environment for his students. For example, he models problem solving in which he shows his students how to do and think about the steps, and he asks questions to help his students focus on what's really important in the material. Even rote memorization can be beneficial when practiced under particular circumstances for a specific purpose.

Dodgson's third theme--science is a set of processes that are used for handling data--is largely centered in the nature of science category. He sees these processes including data gathering processes such as observing, measuring, and recording; and data interpretation processes including evaluating, interpreting, and making decisions based on the data. Practicing these processes, such as observing and recording observations, is worthwhile for him even if the outcome isn't correct (though leaving students with false information shouldn't happen). To help students become familiar with these processes, for example, he assigns problems and models problem solving steps.

There are a number of comments that can be made about Dodgson's conception of teaching science. The first is that Dodgson focuses on the need for students to be mentally involved in a task, a problem, a laboratory in order for them to learn. In other words, this is a "minds-on" approach, in contrast to "hands-on" approaches that are more commonly advocated. The emphasis on mental involvement does not necessarily mean that he eschews physical involvement even though he makes little mention of it. This emphasis is, however, consistent with the processes of science he lists: these involve data gathering, but, significantly, also include data analysis and interpretation, i.e., the cognitive, mental components of doing science.

The second aspect of interest is that Dodgson's conception of teaching science appears to be balanced, with a number of summary statements in each category. This can clearly be seen in his TAG: each category contains at least three summary statements. A point worth noting, however, is the absence of summary statements about his goals, whether these are the goals of science or the goals of teaching, or about subject matter content. This does not, however, suggest he has no teaching goals or no views on subject matter; merely that these seem to be less important to his views on teaching science than his other concerns.

A third aspect to note is that Dodgson's themes are well integrated across analysis categories. Most of the four categories are linked to each other in at least one theme, as can be seen by inspecting his TAG (Figure 6); the only exception being the absence of a link between science and teaching. A good example is his first theme that stresses the importance of mental involvement in student learning. This represents a three-way link between learning, instruction, (where he uses questions to get students involved), and teaching (this for him requires interaction with the students). A second example is his third theme, centered on his view of science as a set of processes for handling data; this links science with learning (he sees that practicing the processes of science is a legitimate learning activity) and instruction (he believes in modelling the process of problem solving). These examples also indicate that Dodgson's preferred instruction strategies are informed by his views of science, learning, and teaching.

Mr. Fielder: Chemistry Teacher

Mr. Fielder's conception of teaching science is predominantly student-centered: his main goal is that they should learn how to learn; for him this means being engaged in what they are doing. His CTS includes three themes, two of which are reflected in the prior sentence. The third theme is relatively unconnected to the previous two, as can be seen in his theme analysis grid includeo in Figure 7 .

Figure 7 about here

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teaching students to think critically and learn how to learn

student engagement is the most cetral element in facilitating learning

experimentation and abstract theories are both parts of science

Fielder's main goal is that students should learn how to learn; for him this means being engaged in what they are doing.

Fielder's CTS is well balanced with at least three summary statements in each category.

Fielder's CTS themes are not very well integrated; science is virtually isolated from the other categories

Fielder's preferred instructional strategies are informed by his view of learning and teaching

Comparing and contrasting teachers

A number of results emerge with clarity from the summary table presented in Figure 2. Several of these apply to all the teachers reported in this article. The first is that:

Experienced science teachers' conceptions of teaching science can be represented by a small number of themes.

As used in the analysis of a CTS interview, a theme identifies a single idea that a teacher uses in different categories and contexts. It is thus a concept that identifies integration and organization in a teacher's thoughts. We have found that there is no disagreement over the presence of themes when different analysts work with a teacher's summary statements (Hewson, Kerby, & Cook 1992). When disagreements between analysts have arisen, they have had more to do with the boundaries of the themes than their edges. The presence of themes in a teacher's conception of teaching science indicates to us that the teachers we have studied have sought to find ways of making the task of teaching science more coherent than its inherent complexity might initially suggest.

A second result that applies to all the teachers studied is the following:

Experienced science teachers independently introduced learning into the CTS interview.

The central question of the interview task was: In your view, is there any science teaching going on here? The terms "learn," "learning," and "learner" were purposely not introduced by the interviewer. If, however, one or other was introduced by the teacher being interviewed, the interviewer followed it up, as with other ideas introduced into the conversation. Our experience was that learning was an idea that arose at an early stage in an interview, and that for virtually all teachers, it was central to their understanding of teaching science; the only exception being Venturi, as we discussed above. The ubiquitous presence of learning in teachers' conceptions is a result that is, perhaps, more reassuring than surprising.

Another result that is common across teachers is:

Experienced science teachers' preferred instructional strategies are informed by their views of the nature of science, the nature of learning, and/or the nature of teaching.

This assertion is about the basis on which teachers choose their instructional practices. All the teachers whose analyses are reported in this study have themes that link statements in the preferred instruction category to those in the science, learning, and/or teaching categories. A striking example is Corrigan's link between learning and instruction, i.e., between his belief that students need to get involved in the physical world in order to learn (hands-on is vital) and the extensive amount of time he devotes to lab. Another example is Dodgson's link between teaching and instruction, i.e., he believes that it is his task as the teacher to get students involved in the work of the class: this he does by asking questions In other words, these teachers' modes of instruction are not skills that are independent of context or content. Rather, their choices are related to their understanding of other essential components of the classroom. The instructional decisions they make constrain and are constrained by decisions they make with respect to other aspects of their teaching.

A result that does not appear to apply to all teachers is:

Some experienced science teachers have noticeable tensions within or between themes.

The presence of themes in a teacher's conceptions is understandable since they represent the teacher's attempts to produce a measure of coherency in the tremendous complexity of the classroom. Yet it is also the case that teachers experience competing and at times contradictory demands. If neither can be ignored and one cannot be subordinated to the other, a tension arises between them. As detailed above, examples of this occurred with three of the six teachers considered in this article.

The existence of tensions within and between themes should not be surprising, since there is no a priori requirement that any given grouping of teacher, students, school, and community with all its complexity should form an internally consistent system. We might expect that many teachers would attempt to reduce contradictions, but there is no guarantee that any particular teacher would be successful. As we have seen, some teachers have come to terms with the tensions of necessary compromises.

A final result that arises from a consideration of all teachers, stresses, however, their individuality and uniqueness:

Experienced science teachers' conceptions of teaching science are noticeably different from one another, with respect to both content and structure.

All of the teachers in the study talked about the same general concepts--science, learning, instruction, teaching--in their responses in the interview. Since these are fundamental to the concept of "teaching science" it would indeed be surprising if this were not the case. Nevertheless these six teachers talked about these central concepts in very different ways. The content of their CTSs as indicated in the summary table (Fig. 2) varies considerably. Some teachers reflect tensions in their thinking; others do not; and the basis for these tensions varies. The primary focus of teachers' conceptions is different: some teachers relate to all aspects equally, while others seem to ignore major aspects such as science and learning; thus it isn't surprising that the degree of integration of teachers' conceptions varies considerably. In other words, the analysis of the conceptions of teaching science of this group of six teachers demonstrates that each teacher is a unique individual.

Discussion

Findings

In this article we have reported the results of an analysis of the conceptions of teaching science held by six experienced high school science teachers. We have presented a detailed abstract of each teacher's conception of teaching science, and compared and contrasted the abstracts of different teachers. This process has produced a number of assertions about each teacher, as well as five assertions that relate to the group of teachers studied. These are as follows:

- Experienced science teachers' conceptions of teaching science can be represented by a small number of themes.
- Experienced science teachers independently introduced learning into CTS interview.
- Experienced science teachers' preferred instructional strategies are informed by their views of the nature of science, the nature of learning, and/or the nature of teaching.
- Some experienced science teachers have noticeable tensions within or between themes.

- Experienced science teachers' conceptions of teaching science are noticeably different from one another, with respect to both content and structure.

As we argued at the start of this article, we subscribe to a constructivist perspective that views teachers as building conceptual structures in which they incorporate classroom events, instructional concepts, socially approved behaviors, and explanatory patterns in ways that make sense to them. In our view, the themes identified in this article are consistent with this constructivist perspective.

Implications

When experienced science teachers consider a variety of examples both in and out of the classroom, they bring to bear a structured, relatively coherent body of knowledge. This conclusion has a number of implications for science teacher education.

The first of these is that it helps to explain how a teacher handles complexity. A classroom is a very complex place: science is much like other subjects in this respect. There is a great deal happening in a classroom with a teacher and 30 students working on, perhaps, any of 20 different topics over the course of a school year, within a particular school and community. Any view of teaching must be able to accommodate this degree of complexity. There is an apparent contradiction between the complexity of the classroom and the simplicity of a few relatively coherent, interrelated themes held by a teacher. We would, however, argue that it is only because teachers find ways of reducing the complexity by constructing coherent, integrated ways of handling the complexity that they can cope and even prosper in the unceasing flow of information in the classroom. Their themes, then, serve to turn the information flow into an interpretation of the current state of the classroom that influences what they notice and what they ignore, and forms the basis on which they decide what their next teaching moves will be. When we seek to understand why a teacher's class is as it is, these themes form an important part of the explanation.

A second implication is that the availability of explicit representations of teachers' conceptions of teaching science provides an opportunity for examining the assumption with which we began this article, i.e., that there is a significant link between a teacher's thoughts and actions. As indicated previously, our results were obtained as part of a larger research project that is investigating this assumption (Freitag, et al. 1993). While we expect there to be such a relationship, we do not believe it is simple. We know that teachers do not act in their classes in a mechanically predictable fashion. There are many specific factors in a classroom that a teacher responds to in a range of different ways. This means that the relationship between a teacher's themes and actions cannot be simply one-to-one: it must, in our view, be both complex and structured. It must be complex to accommodate the large number of factors and the huge number of possible teacher actions, and it must be structured for a teacher to use it effectively and quickly. While we expect themes to influence actions, that influence may only be detected over many actions and an extended time rather than being apparent in the detail of a particular instance where the context specifics may seem to be the only important factors.

A third implication is that the outcomes of CTS analyses of teachers can be used to make valuable contributions to science teacher education. The analyses themselves constitute case study materials for use in a teacher education progam. They can be used to bring a variety of perspectives to the attention of pre- and in-service teachers that will stimulate discussion and facilitate their reflection on their own conceptions of teaching science. Allied to this latter point, the availability of a task to identify CTSs means that it becomes more feasible to set, for a teacher education program, the goal of helping teachers change their present conceptions to more appropriate conceptions (Hewson & Hewson 1988). By change we mean that teachers might add to, elaborate upon, reinterpret, and/or replace their current conceptions or parts thereof.

Conclusion

In this article we have identified the conceptions of teaching science of a small number of experienced science teachers who teach in a localized region of this country. We have found that these teachers' conceptions are organized into a few themes that, while having in common their links to the central components of science teaching, contain a wide diversity of emphases: teachers' conceptions are very individual. The major differences between experienced teachers' themes may or may not come as a surprise. On the one hand, we expected and found differences in emphasis on curriculum, on instruction, on classroom management, etc; the inherent complexity of classrooms and schools mentioned above would seem to guarantee this. On the other hand, we expected the experienced teachers in our study to discuss the common elements of teaching: nature of science, of learning, and of instruction; yet surprisingly some made barely a reference to the nature of science while others hardly spoke about learning. Of what significance might this be? We have no means of knowing whether these are in any way representative of the conceptions of other teachers anywhere else in the world: that is for others to decide. Yet to us this finding provides one means of understanding science teaching, and suggests clear directions for science teacher education. As such, we believe it will have a role to play in achieving the critical goal of improving science teaching.

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Figure 1 : THEME ANALYSIS GRID FOR MR CORRIGAN : CHEMISTRY TEACHER

NATURE OF SCIENCE	LEARNING/LEARNER	RATIONALE and INSTRUCTION	TEACHING
GOALS ● Understand, explain world.	**LEARNING IS (IS NOT) -** Different levels: - lower: rote, plug in: - higher: analysis, synthesis, application, etc. ◆ Higher levels for learning science. Lower levels are poor. Not dependent on teaching.	**CURRICULUM/CONTENT** ▌Clear learning objectives. - Focused for lecture. - Broader for lab, inc. unpredictable (field trip exp.)	**GOALS** ● Have students appreciate how natural world works to become responsible citizens. ▣ Prepare for college chemistry.
SCIENCE IS - ◆ Process: includes observing, analyzing, forming opinions, hypothesizing, predicting, testing. ▣ Problem solving.	**LEARNING AS OUTCOME** ▌Ss learn unpredictable things outside T's learning objectives.	**INTERACTION** ◆ Present situations, provoke higher level thinking in students (factor label method is no good).	**DEFINITION, CONDITIONS** Purpose of teaching is learning. There can be good teaching without learning occuring.
SCIENCE REQUIRES -	**COGNITIVE FACTORS INFLUENCING LG** ▾ Hands on: getting involved in physical world.	**ACTIVITIES/TASKS** ▾ Hands on is vital - ideal class all lab, demo. ▣ Lectures used - to share facts, insights, personal experience; - to model p-s. ▣ Lectures necessary to prepare students for college chemistry. ▌Field trip: Ss interact with material on their own.	**TASKS, FACTORS INFLUENCING EFFECTIVENESS**
CONTENT ● Applications: products, technology, science careers.	**AFFECTIVE FACTORS INFLUENCING LG** Interest, question-asking enhance learning.		**OTHER**

THEMES FOR MR CORRIGAN	
THEME 1	● Students should be able to appreciate how the natural world works: science, which seeks to understand and explain the world, and has many applications is the way to do this.
THEME 2	▣ To prepare students for college chemistry it is necessary to give lectures that present facts, insights, personal experiences, etc., and to model problem solving, an essential part of science. In tension with Theme 3 (▾).
THEME 3	▾ Hands-on is vital: this means giving many (all?) classes as laboratories and demonstrations for students to get involved in the physical world. In tension with Theme 2 (▣).
THEME 4	◆ Science includes many processes, e.g., observing, analyzing, forming opinions. Because these require higher levels of thinking, it is necessary to present situations that provoke this.
THEME 5	▌Learning objectives should fit the situation: focussed for lecture, broad for lab or other "field trip" experience where students are allowed to play/interact with material on their own. This experience also furthers goal of students appreciating the world.

Figure 2 : **SUMMARY OF COMPARISONS ACROSS TEACHERS**

Teachers	Summary	Tensions	Balance	Integration	Links to instruction
Corrigan	Sc. Tg. is complex T needs to present chemistry Hands on In. is vital Sc. requires higher level thinking	Lecture-lab Didactic-"field trip"	Well balanced	High Lg.-Tg. absent	Sc., Lg., Tg.
Jonas	Ss need balance between structure & freedom	Structure-freedom	Lg., In., Tg. balanced V. low Sc.	High Sc.-Tg. absent	Lg., Tg.
Sorenson	Discovery links Sc. & Lg. Hands-on In. is important	None	High Lg. Low Sc.	High	Sc., Lg., Tg.
Venturi	Biology includes factual, conceptual information Biology is changing Ss need to design experiments	Practical-desirable Factual-conceptual	High In. Lg. absent	Very low Only I-S, I-T links	Sc., Tg.
Dodgson	Ss need to be mentally involved T needs to provide purpose, structure	None	Well balanced	High Sc.-Tg. absent	Sc., Lg. Tg.
Fielder	Ss need to lean. how to learn S engagement is central to Lg. Classroom is S centered	None	Well balanced	Medium Sc. strong, but isolated	Lg., Tg. Sc. (weak)

Figure 3 : THEME ANALYSIS FOR MR JONAS : CHEMISTRY TEACHER

NATURE OF SCIENCE	LEARNING/LEARNER	RATIONALE and INSTRUCTION	TEACHING
GOALS	**LEARNING IS (IS NOT) -**	**CURRICULUM/CONTENT**	**GOALS**
SCIENCE IS - - important in our everyday lives.	**LEARNING AS OUTCOME**	**INTERACTION** Discussion is best way to teach in some cases. Feedback is crucial to instruction.	**DEFINITION, CONDITIONS** Teacher need not be present.
SCIENCE REQUIRES - ♦ Math and reading skills	**COGNITIVE FACTORS INFLUENCING LG** ▌Ss benefit greatly by organization and structure of materials. ♦ Ss need certain skills, background information.	**ACTIVITIES/TASKS** ◘ Demonstrations are best way to capture Ss' attention, get them wondering. ▌Following algorithms, directions has value if Ss don't know what's going on.	**TASKS, FACTORS INFLUENCING EFFECTIVENESS** ▌Organize, focus material but leave room for spontaneity. ◘ Keep Ss attentive.
CONTENT	**AFFECTIVE FACTORS INFLUENCING LG** ◘ Wonder/interest/curiosity are important to learning.	▌♦ "I don't like to cookbook anything" but following a "recipe" has value if Ss have proper background to think about steps. No memorization work.	**OTHER**

THEMES FOR MR JONAS	
THEME 1	▌Students benefit greatly from organization and structure of material. Even following a recipe or algorithm has value in the proper situations. I don't like to cookbook and I recognize the need for spontaneity. These tensions (<------>) are, however, minor.
THEME 2	♦ Background information and skills are extremely important in learning chemistry.
THEME 3	◘ Wonder and interest increase students' attention.

Figure 4 : **THEME ANALYSIS FOR MS SORENSEN : PHYSICS TEACHER**

NATURE OF SCIENCE	LEARNING/LEARNER	RATIONALE and INSTRUCTION	TEACHING
GOALS	**LEARNING IS (IS NOT) -** ▮ Discovering, going through the processes of science. ♦ Best when students do hands-on experiments. ◘ Is <u>not</u> dealing with information already learned. ◘ Ingestion of useful info: involves incorporating it with other info, making it your own. ◘ Is <u>not</u> memorization, a poor type of learning, only useful for the test.	**CURRICULUM/CONTENT**	**GOALS**
SCIENCE IS - ▮ A process that involves making observations, asking questions, coming up with theories, and testing them.	**LEARNING AS OUTCOME** ◘ Ss must be able to <u>apply</u> what they've learned to other situations.	**INTERACTION** ▮ Questioning leads to S discussion and is key to discovery learning.	**DEFINITION, CONDITIONS** Teaching is contingent on someone learning. A "teacher" need not be present for learning to occur.
SCIENCE REQUIRES -	**COGNITIVE FACTORS INFLUENCING LG** ♦ HS Ss need to deal with things physically, concretely. Material must be at Ss' level.	**ACTIVITIES/TASKS** ▮ ♦ Hands on activities, silent demonstrations, having Ss make observations to initiate discovery learning. No lecture.	**TASKS, FACTORS INFLUENCING EFFECTIVENESS** ▮ ♦ Science teaching lends itself to physical manipulation and to discovery learning.
CONTENT	**AFFECTIVE FACTORS INFLUENCING LG**		**OTHER**

THEMES FOR MS SORENSEN	
THEME 1	▮ Science is a process that is learned by discovery.
THEME 2	♦ Hands-on, concrete manipulations of physical objects are essential to learning science.
THEME 3	◘ Useful learning involves "ingestion": taking information in, incorporating it with other information, being able to apply it; it is NOT dealing with information already learned.

Figure 5 : **THEME ANALYSIS GRID FOR MR VENTURI : BIOLOGY TEACHER**

NATURE OF SCIENCE	LEARNING/LEARNER	RATIONALE and INSTRUCTION	TEACHING
GOALS	**LEARNING IS (IS NOT) -**	**CURRICULUM/CONTENT** ◆ There isn't a set amount to cover. Select topics that are basic; these will charge with field. ▌Teach vocabulary & terms but emphasize conceptual rather than factual information. ◘ Get Ss to ask good questions, & think about/carry out processes of science. Activities done w'thout Ss understanding are a problem.	**GOALS**
SCIENCE IS - ◘ Processes include observing, asking questions, hypothesizing, designing experiments, collecting data, drawing conclusions. Doing a scientific task like problem-solving.	**LEARNING AS OUTCOME**	**INTERACTION** ▸ I use lectures with discussions to pull Ss in.	**DEFINITION, CONDITIONS** ▸ Teaching depends on interaction between T & Ss.
SCIENCE REQUIRES -	**COGNITIVE FACTORS INFLUENCING LG**	**ACTIVITIES/TASKS** Get Ss to answer own questions whenever possible. Fight giving out answers; do so only for sake of expediency.	**TASKS, FACTORS INFLUENCING EFFECTIVENESS**
CONTENT ▌Biology uses scientific language, technical terms (though they aren't "at the heart" of science.) ◆ Topics that are "basic" change with time.	**AFFECTIVE FACTORS INFLUENCING LG** Lg increased by learner interest, inquisitiveness.	◘ Get Ss to design own experiments, come up with own hypotheses within limits of classroom or lab.	**OTHER** T learns while teaching something for first time.

THEMES FOR MR VENTURI	
THEME 1	◘ Students are doing science when they do the processes of science. Thus I get them to ask their own questions and perform their own experiments (within practical, classroom limits.)
THEME 2	▌While biology uses technical terms and scientific language that must be taught, this isn't the heart of the subject and shouldn't be emphasized over conceptual information.
THEME 3	◆ The biology topics I choose to teach, even that which I consider basic, are changing, because the field is changing.
THEME 4	▸ Teaching, for me, depends on the interaction between teacher and students. Thus I use discussion as an integral part of my lectures to include students.

Figure 6 : **THEME ANALYSIS GRID FOR MR DODGSON : PHYSICS TEACHER**

NATURE OF SCIENCE	LEARNING/LEARNER	RATIONALE and INSTRUCTION	TEACHING
GOALS	**LEARNING IS (IS NOT) -** Memorization only learning in particular instances, ◆ for specific reasons. ▮ Students can watch, do things without thinking or learning.	**CURRICULUM/CONTENT**	**GOALS**
SCIENCE IS - ◘ A set of processes involving observing, measuring, recording data; and evaluating, interpreting, making decisions based on data. Decisions influenced by economic, emotional, aesthetic factors.	**LEARNING AS OUTCOME** Incorrect information not valid outcome. ◘ Practicing process of science legitimate outcome.	**INTERACTION** Questions ◆ focus students; ▮ get them involved. ◆ Model problem solving by assigning problems, showing steps, ▮ asking questions to get students involved.	**DEFINITION, CONDITIONS** Teaching is contingent on learning. To be science teaching what is taught must be science. ◆ Teacher must have educational purpose/motive for Ss' activities. ▮ Teacher must be interacting with Ss. Teaching can occur without teache..
SCIENCE REQUIRES -	**COGNITIVE FACTORS INFLUENCING LG** ▮ For Ss to learn, they must be mentally involved. For students to learn, presentation and material must be at their level.	**ACTIVITIES/TASKS** I don't supply questions when Ss watch videos at home.	**TASKS, FACTORS INFLUENCING EFFECTIVENESS** ▮ It is T's task to provide impetus, get Ss involved; ◆ It is T's task to provide direction, create proper environment.
CONTENT Science is separate from technology.	**AFFECTIVE FACTORS INFLUENCING LG** ▮ Students won't get involved in difficult problems on their own.		**OTHER**

THEMES FOR MR DODGSON	
THEME 1	▮ Students must be mentally involved in issue/problem to learn. Since they often won't do this on their own, this task falls to me. I get students involved by student/teacher interactions where I ask questions of the students.
THEME 2	◆ I have an educational purpose or motive for what I ask students to do. Likewise, it is my job to focus students on what's important and provide direction and structure. I do this with questions and modelling.
THEME 3	◘ Science is a set of processes for handling data; practicing it is legitimate but students shouldn't be "left" with false information.

Figure 7 : THEME ANALYSIS FOR MR FIELDER: CHEMISTRY TEACHER

NATURE OF SCIENCE	LEARNING/LEARNER	RATIONALE and INSTRUCTION	TEACHING
GOALS	**LEARNING IS (IS NOT) -** Although memorization is learning, such information is usually acquired as a result of understanding how something works. Therefore, it's not necessary to memorize, nor should memorization be the focus of learning. ♦ Experiments can be good learning situations for students. Students do not learn science by blindly following directions. ♦ A student can learn by listening. ♦ One of the best ways for students to learn is to interact with each other and discuss things. ♦ Student questions present a good opportunity to learn, but whether anything is learned depends on the teacher's response.	**CURRICULUM/CONTENT** ◘ Learning skills (see LNG) are the focus of the activities my students do. To teach hypothesis and observation, I try make laboratory exercise investigative and, at times, open-ended.	**GOALS** ◘ My main goal in science teaching is to teach kids to think critically and become good problem solvers. This is more important than academic knowledge.
SCIENCE IS - ▮ Experimentation is part of science.	**LEARNING AS OUTCOME** ◘ Learning how to learn is the most important skill a student can acquire. Content knowledge, though important, is secondary to the process of learning. Memorization is unnecessary for college prep. students, but might be appropriate for lower ability students.	**INTERACTION** ♦ I respond to student questions with explanations that are geared to the student's theoretical background.	**DEFINITION, CONDITIONS** Whether teaching has occurred depends on whether learning has occurred. Teaching depends on the student being present. Teaching can occur without a "teacher" being present. A student can be taught by himself, another student, or a tv program.

<table>
<tr>
<td>SCIENCE REQUIRES -
▮ Experimentation requires a variety of skills including observation and use of hypothesis.</td>
<td>COGNITIVE FACTORS INFLUENCING LG
◘ Learning to learn requires a variety of skills- reading, analyzing, solving problems, experimentation, organization in terms of taking tests, and listening and taking notes.

◆ A student's knowledge background strongly influences what they can learn.

For the student to learn, the material and presentation must be age appropriate.</td>
<td rowspan="2">ACTIVITIES/TASKS
◆ I model problem solving and get students involved by having them work some problems on the board.

▮ Demos, models, specimens can be used to explain abstract theories</td>
<td>TASKS, FACTORS INFLUENCING EFFECTIVENESS</td>
</tr>
<tr>
<td>CONTENT
▮ Chemistry involves theories, concepts, and ideas, some of which are very abstract.</td>
<td>AFFECTIVE FACTORS INFLUENCING LG
The characteristics and attitude of the individual students greatly influence what they will learn.</td>
<td>OTHER</td>
</tr>
</table>

THEMES FOR MR FIELDER	
THEME 1	◘ My main goal is to teach students to think critically, to solve problems, to learn how to learn, i.e., to acquire skills of reading, listening, analyzing, problem solving, experimenting, test-taking. This is more important than content knowledge.
THEME 2	◆ Student engagement in e.g., experiments, listening, questioning, is the most central element in any attempt to facilitate learning. Students' attitudes and background knowledge, and the teacher's ability to provide feedback appropriate to this background will also influence what they learn.
THEME 3	▮ Experimentation (involving critical thinking skills) and abstract theories, concepts, and ideas (usefully explained by demonstrations, models, and specimens) are part of science.