CONCEPTUALIZATIONS OF EFFECTIVE CHEMICAL DEMONSTRATION TEACHING AMONG EXPERIENCED AND NOVICE CHEMICAL DEMONSTRATORS AND THE INFLUENCE OF INTENSIVE INSERVICING

by

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ABSTRACT

Title of Dissertation: CONCEPTUALIZATIONS OF EFFECTIVE CHEMICAL DEMONSTRATION TEACHING AMONG EXPERIENCED AND NOVICE CHEMICAL DEMONSTRATORS AND THE INFLUENCE OF INTENSIVE INSERVICING

Christian Peter Clermont, Doctor of Philosophy, 1989

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This study examined the pedagogical content knowledge (PCK) of two groups of physical science teachers identified as experienced and novice chemical demonstrators. Science teachers, as do other teachers, use their pedagogical content knowledge to make decisions on how to teach very specific subject matter topics to students of various ages and abilities. Given the importance of this knowledge system for effective science teaching, this study also examined the influence of an intensive chemical demonstration workshop (a NSF summer institute program) on fostering pedagogical content knowledge growth among a group of eight novice chemical demonstrators.

A clinical interview, consisting of a critical-stop task and a semi-structured interview, served to probe the experienced and novice chemical demonstrators’ PCK. The critical-stop task required subjects to view videotaped chemical demonstrations and stop and discuss the tape at segments they perceived contributed to effective or ineffective chemical demonstrating. The clinical interview focused on teachers’ pedagogical knowledge of demonstrating density and air pressure.
Domain, taxonomic, componential, and theme analyses and several quantitative content analyses were conducted on the verbal data. The data indicated that experienced chemical demonstrators possess quantitatively greater and qualitatively richer pedagogical content knowledge for demonstrating basic chemical concepts than novice chemical demonstrators. Experienced demonstrators, unlike novices, possess a large body of knowledge about chemical demonstrations, chemical demonstration variations, and accompanying inquiry strategies for presenting subject-matter topics to middle school students.

The study further showed that the two-week chemical demonstration workshop produced an increase in the number of chemical demonstrations and demonstration variations novice chemical demonstrators could discuss on the targeted concepts, density and air pressure. The novice demonstrators also became more cognizant of the complexity of several chemical demonstrations, how these complexities could interfere with learning, and how simplified variations of these chemical demonstrations could promote science concept learning. After the workshop, novices' verbalizations also contained fewer references to pedagogically unsound chemical demonstrations on the targeted concepts. Many of these changes brought novices closer to the characteristics of experienced chemical demonstrators' PCK.
DEDICATION

To Brenda, Mom, and Dad.
ACKNOWLEDGEMENTS

A doctoral dissertation study is an undertaking that is completed only through the supportive help of a number of caring people. I would like to acknowledge several of the key players in making this study possible.

First, I would like to thank Dr. Joseph Krajcik, my research advisor, for his tremendous encouragement and support in helping me begin, conduct, and complete this study. Without his energetic enthusiasm and insightful guidance, this study would not have been possible. Dr. Krajcik has become a well-respected friend and professional colleague during the dissertation phase of my graduate program at the University of Maryland.

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**Exploring Teachers' Cognitions Through Expert-Novice Studies**

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"How should I teach it?" This simple question fills the mind of many beginning science teachers on almost a daily basis. Many reflective science teachers also ask themselves this question in an effort to improve the quality of their science teaching. This question emerges whenever science teachers plan lessons on science concepts that students find difficult to learn. Thinking through this planning question provides a major challenge to both beginning and experienced science teachers whose professional responsibility includes the goal of taking their comprehension of a science discipline and making it comprehensible to learners.

According to Shulman (1986, 1987), one of the characteristics of teachers that distinguishes them from content specialists is their knowledge of teaching, called pedagogical content knowledge. This body of knowledge represents an integration of content and pedagogy that provides teachers with an understanding of how particular subject matter topics, problems, and issues are organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction. This body of knowledge plays a vital role in teacher planning of specific topics in a discipline.

Most research on teachers' pedagogical content knowledge has been conducted in the context of how beginning teachers learn to transform their knowledge of subject matter into a form suitable for teaching (Shulman 1986, 1987; Wilson & Gudmundsdottir, 1986; Wilson, Shulman, & Richert, 1987). These studies have focused on how classroom teaching experiences and the process of pedagogical reasoning promote
pedagogical content knowledge growth. Current findings seem to indicate that pedagogical content knowledge growth is slow and largely dependent on the motivation, creativity, and reflective thinking skills of the beginning teacher. This study examined pedagogical content knowledge growth resulting from an intensive two-week inservice intervention designed to help teachers develop their chemical demonstration teaching skills. The findings of this study may help determine whether knowledge growth in teaching can be accelerated through highly-focused, intensive inservice efforts. To help establish a frame of reference, the pedagogical content knowledge growth of novice chemical demonstrators was contrasted with the pedagogical content knowledge of experienced chemical demonstrators.

The inservice program of interest to the present study is the Institute for Chemical Education (ICE) Workshop B: Chemistry Supplements for Pre-High School Classes. This NSF-sponsored program provided two weeks of intensive training in chemical demonstrating. The central goal of the inservice workshop was to increase elementary, middle, and high school science teachers' use of chemical demonstrations (Bell, 1987).

Two cognitive research methods were used to probe demonstrators' pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK) of effective chemical demonstration teaching. These methods included a think-aloud task and a semi-structured interview. Such methods have been effectively used in other cognitive studies probing teachers' thoughts and knowledge structures (Berliner, 1987a; Borko & Livingston, 1988; Elbaz, 1981; Peterson & Comeaux, 1987; Yinger & Clark, 1982).
Purpose

This study had a two-fold purpose. First, this study explored the nature of science teachers' pedagogical content knowledge and general pedagogical knowledge (Shulman, 1986, 1987) as it relates to effective demonstration teaching. It specifically compared experienced and novice chemical demonstrators' knowledge of how to demonstrate basic chemical concepts at the middle school level. The chemical concepts examined were density and air pressure.

Second, this study investigated the effects of a two-week intensive chemical demonstration workshop on novice demonstrators' pedagogical knowledge growth. This growth was gauged by comparing novice demonstrators' pre- and post-workshop clinical interview responses. Changes in their response, together with a comparison of experienced demonstrators' clinical interview responses, helped determine whether pedagogical content knowledge and general pedagogical knowledge growth can be accelerated among elementary and secondary school science teachers participating in an intensive, skills-oriented inservice workshop.

Research Questions

Three major research questions are addressed in this study:

1. What are the domains of knowledge that characterize experienced and novice chemical demonstrators' pedagogical discourses on effective chemical demonstration teaching?

2. What are the commonalities and distinguishing characteristics of experienced and novice chemical demonstrators' discourses
on effective chemical demonstration teaching in the identified domains?

3. How does an intensive (two-week), skills-oriented (chemical demonstration) teacher workshop alter novice chemical demonstrators' evaluative judgments and knowledge of effective chemical demonstration teaching of targeted chemical concepts?

Rationale for the Study

A Theory-Based Rationale for Examining Teachers' Pedagogical Knowledge

Why examine teachers' pedagogical knowledge (i.e., their PCK and GPK)? Over the past decade, researchers have given greater attention to teachers' thought processes and knowledge structures as part of a broader effort to understand the process of teaching. This research has been guided by the premise that what teachers do is influenced by what they know and how they think about teaching. Several reviews on teacher effectiveness, for example, have stressed the importance of linking teachers' actions and teachers' cognition (Clark & Peterson, 1986; Gleissman & Pugh, 1981; MacLeod, 1977; Sacerdoti, 1977; Shulman, 1986). Such an integrated view of teaching coincides with schema theory in cognitive psychology, which suggests that teachers' mental processes and associated knowledge systems strongly influence behavior in successfully performing complex tasks. Research conducted by Leinhardt and Greeno (1986) and Shulman (1987) suggests that effective teaching is a complex cognitive skill involving numerous thought processes that interact with various knowledge systems.

Teachers frequently rely on a form of knowledge called pedagogical content knowledge. According to Shulman (1986, 1987)
pedagogical content knowledge refers to a unique body of knowledge that teachers possess that allows them to make subject matter content comprehensible to students of various ages and abilities. This knowledge system grows gradually as a result of classroom teaching experiences and the process of pedagogical reasoning. It plays a vital role in teachers' pre-active and interactive teaching. Although some research exists on the pedagogical content knowledge of beginning teachers in English and social studies, a paucity of research currently exists regarding the nature and growth of this knowledge system among science teachers. This study examines science teachers' pedagogical content knowledge and the influence of an intensive, inservice chemical demonstration workshop on fostering PCK growth among novice chemical demonstrators.

Rationale for Examining Experienced and Novice Science Teachers

Studies that attempt to understand the cognitive processes and relevant knowledge systems associated with performance on complex tasks frequently examine expert-novice differences. Comparisons of this nature have been effective in identifying the particular thought processes and knowledge structures associated with competent performance in a variety of disciplines; e.g., math, science, engineering, and chess (Bloom, 1986; Chi, Glaser, & Rees, 1981; Gick, 1986; Larkin, McDermott, Simon, & Simon, 1980).

Studies that have probed the cognitive aspects of teaching have also examined expert/novice teacher differences, particularly with respect to teachers' thinking about students, lesson structure, and classroom events (Berliner, 1986; Calderhead, 1983; Housner & Griffey, 1985; Huberman, 1985; Leinhardt & Greeno, 1986). These studies have
provided detailed accounts of the routine behaviors and knowledge systems characteristic of expert teachers. The rich descriptions generated by these expert/novice teacher studies make it possible to infer the knowledge structures, or schemata, that are unique to highly skilled and master teachers (Berliner, 1986, 1987a; Leinhardt & Greeno, 1986). In addition, these studies generate hypotheses about the mental processes and knowledge systems that provide a basis for effective teaching (Borko & Shavelson, in press; Clark & Peterson, 1986; Fogarty et al., 1982; Peterson & Comeaux, 1987).

By probing experienced and novice teachers' thinking and the various components of their professional knowledge base, it is possible to identify a set of cognitive characteristics unique to experienced and novice teachers. In keeping with this goal, this study sought to examine the nature of experienced and novice chemical demonstrators' pedagogical content knowledge and general pedagogical knowledge (Shulman, 1986, 1987; Wilson, Shulman, & Richert, 1987) needed to demonstrate basic chemical concepts. The differences that emerge could provide a set of "neutral data" or standards that Yarger and Galluzzo (1983) and Joyce and Showers (1980) indicate are needed to evaluate the level of impact of teacher education programs. The data obtained may also help identify some of the substantive needs among practicing science teachers, which together with the assessment of teachers' perceived needs, provide two important strategies in the development of effective inservice programs (Evans, 1987; Jones & Hayes, 1980; Yarger & Galluzzo, 1983).

Finally, if Shulman's (1987) suggestion for the professional testing of teachers include less emphasis on the generic aspects of
teaching and greater emphasis on the teaching of specific subject matter topics, then a thorough analysis of what experienced and novice teachers actually know about teaching specific science concepts is warranted.

**Rationale for Examining Science Inservice Workshops**

The 1980's has seen a remarkable interest in science teacher inservice education. This interest comes from leaders in education as well as those in political circles seeking to improve science education across America (Evans, 1987). This interest has been tied to several factors, including reported declines in student achievement and interest in science (Rakow, Welch, & Hueftle, 1984; Yager & Penick, 1984) and a growing shortage of qualified science teachers in this country (Bethel, 1985; National Science Board, 1983; Yankwich, 1984).

Educators generally agree that students' science achievement scores and attitudes towards science will not improve much if the quality of teaching does not improve substantially (DeRose, Lockard, & Paldy, 1978; Medley, 1982), and that science teaching will not improve much without dramatic improvements in teacher education (Lanier, 1986). At the present time, federal support exists for the inservice training of science teachers (Evans, 1987) as evidenced by the revitalization of NSF summer institutes (Bell, 1987; Lippincott, 1985; O'Brien, 1987). These programs reflect the convictions of leaders in both education and government that the quality of science teaching can be rapidly improved by concentrating on inservice teacher training.

Amid the numerous benefits cited for having federally-funded inservice programs, research continues to fall short in providing
conclusive evidence for the effectiveness of these programs on improving teacher performance (Joyce & Showers, 1980; Wade, 1984-1985; Yarger & Galluzzo, 1983). This situation exists, in part, because of the difficulty in conducting sound experimental studies in inservice teacher education and also because of the difficulty in finding acceptable standards and procedures for comparing the diversity of inservice studies found in the literature (Yarger & Galluzzo, 1983). Joyce and Showers (1980) have noted that many inservice research studies do not meet acceptable standards of evaluation, such as the collection of pretraining observations of teaching to determine entry level skills. A majority of the evaluations use client perceptions of a variety of inservice activities for evaluation purposes. Few studies provide concrete evidence of workshop effects on teachers' pedagogical knowledge gains. Most inservice evaluations simply represent statements of participant satisfaction, which the evaluators use to determine the success of the program (Wade, 1984-1985). Such studies do little in the way of directly assessing knowledge growth in teaching (Shulman, 1986) or improvements in the use of complex teaching skills (Yarger & Galluzzo, 1983). This study specifically examined science teachers' pedagogical content knowledge growth resulting from participation in an intensive chemical demonstration workshop. Growth was gauged using cognitive research methods which, in turn, became the means of evaluating the inservice workshop. This study may therefore suggest the usefulness of cognitive research methods for a more objective assessment of workshop success.

Examining the influence of an intensive (two-week), skills-oriented (chemical demonstration) workshop may also provide educators
with evidence that inservice summer institutes with certain design
characteristics can stimulate pedagogical content knowledge growth
among practicing science teachers. Shulman’s model of learning to
teach, which addresses pedagogical content knowledge growth, was born
out of numerous case studies of beginning teachers learning to teach
specific subject-matter content to their students (Shulman, 1986,
1987; Wilson, Shulman, & Richert, 1987). The study conducted by this
researcher may show that Shulman’s model of learning to teach may also
be applicable in the context of science teacher inservice education.

Rationale for Examining Science Demonstration Teaching

National studies of science teaching at the precollege level have
documented the central role of the textbook and the lecture-discussion
teaching strategy as predominant features of science teaching in U.S.
schools, with hands-on inquiry-oriented labs and activities receiving
less attention (Harms & Yager, 1981). An overreliance on teacher­
centered approaches, however, keeps students from going beyond the
mastery of a series of facts (Yager & Lunetta, 1984) and may
contribute to students’ less than positive attitudes toward science
(Hurd, 1982; Yager & Penick, 1984). Research suggests that skillfully
presented science demonstrations might be as effective as laboratory
approaches in promoting student cognitive growth because of its
potential to be delivered as a guided discovery teaching strategy that
increases pupil attention and task involvement (Beasley, 1982; Garrett
& Roberts, 1982). It is, therefore, important to provide science
teachers with opportunities to acquire these skills and to increase
their use in the science classroom.
Rationale for Examining the Target Concepts, Density and Air Pressure

Teachers' pedagogical knowledge was examined with respect to the demonstration teaching of two basic chemical concepts, density and air pressure. These concepts were selected because of their frequent inclusion in the elementary/secondary school science curriculum, their association with other fundamental concepts in chemistry, their abstract nature (Hewson & Hewson, 1983; Swamy, 1986), and the variety of chemical demonstrations available for illustrating these concepts. Hewson and Hewson (1983) have shown that middle and secondary school students often hold alternative conceptions of density that are at variance with the scientifically acceptable conceptions, equating density and relative density with terms such as mass, weight, or denseness (crowdedness). Students also possess several misconceptions regarding the behavior of gases (Swamy, 1986). These alternative conceptions may be confronted through conceptual change strategies that include the use of chemical demonstrations.

Significance of the Study

This study was designed to contribute to an understanding of science teachers' pedagogical content knowledge and factors that contribute to its growth. By documenting substantive differences between experienced and novice science teachers' pedagogical content knowledge and the influence of intensive inservice training on pedagogical content knowledge growth, this study may be useful in several ways.

First, this study may demonstrate the applicability of Shulman's (1986, 1987) model of teaching to science education. It may provide evidence that science teachers possess a body of professional knowledge, called
pedagogical content knowledge, and that the breadth and depth of this knowledge system is related to their experience in teaching science and to their knowledge of science. By highlighting the similarities and differences between experienced and novice chemical demonstrators' knowledge of chemical demonstration teaching, this study may contribute to the process of validating Shulman's model of teaching (e.g., the components of teachers' pedagogical content knowledge system and the factors that contribute to its growth). Such findings would contribute to a better understanding of the professional knowledge base of experienced science teachers (Valli & Tom, 1988).

Second, such a study may also contribute to the body of literature examining cognitive differences between experts and novices in various disciplines (Bloom, 1985; Gick, 1986; Chi, Glaser, & Rees, 1981; Larkin, McDermott, Simon, & Simon, 1980), including education (Berliner, 1986, 1988; Borko & Livingston, 1988; Leinhardt, 1983). Documenting cognitive differences between experienced and novice chemical demonstrators, for example, may lend support to Leinhardt and Greeno's (1986) assertion that effective teaching involves complex cognitive skills and knowledge structures that are ill formed in novice teachers and well developed in expert teachers.

Third, this study may identify some of the cognitive outcomes of an intensive, skills-oriented inservice workshop for science teachers. In the context of chemistry teaching, this study may help determine the nature of pedagogical content knowledge growth as it occurs during two weeks of chemical demonstration training. Knowledge growth would be reflected in novice demonstrators' think-aloud discourses and interview responses to probes of effective chemical demonstration...
teaching.

Fourth, this study may provide support for the usefulness of cognitive approaches (e.g., think-aloud tasks and semi-structured interviews), for evaluating skills-oriented workshops. In the past, these approaches have been used as tools in educational research, not inservice program evaluation. Therefore, this study may suggest the utility of cognitive research methods for evaluating skills-oriented workshops. This information would be useful to inservice program implementors seeking to use more direct methods for evaluating teachers and the success of their programs.

Last, by documenting pedagogical content knowledge growth in an inservice context, this study may help provide funding agencies and decision makers with data on the importance of supporting discipline-specific (e.g., biology, chemistry, physics) inservice workshops that focus on teachers' instructional skills.

Beyond these theoretical, methodological, and policy-making contributions, the most important beneficiaries of science teachers' pedagogical content knowledge growth are the students themselves. As science teachers learn how to better teach complex science concepts, students ultimately benefit by having a greater understanding of science and the world in which they live.

Assumptions

This study makes several theoretical and methodological assumptions:
1. Shulman's (1986, 1987) model of teaching (Wilson, Shulman, & Richert, 1987) provides an adequate model for describing the
various components of teachers' pedagogical content knowledge system (see p. 28), and knowledge acquired in at least one of the components of the model reflects meaningful PCK growth.

2. The nature of experienced and novice chemical demonstrators' pedagogical content knowledge can be reasonably inferred from the verbal statements they elicited during the clinical interview.

3. Teachers evaluated the videotaped chemical demonstrations with candor and professional integrity; therefore, the think-aloud discourses represent a reasonably accurate reflection of teachers' knowledge and judgments of effective chemical demonstration teaching.

4. The semi-structured interview contains questions that are sufficiently non-directive and do not distort teachers' reporting of their pedagogical knowledge, judgments, and science concept understanding.

5. The experienced and novice chemical demonstrators selected for this study are representative of the two populations under investigation. Furthermore, the verbalizations obtained from the experienced and novice demonstrators in this study are assumed to be comparable to those that would be obtained from other chemical demonstrators possessing similar levels of demonstration experienced and content knowledge.

Scope and Limitations

The number of chemical demonstrators available to this researcher and the time available to conduct the clinical interviews delimited the scope of this study. A few conceptual and methodological
shortcomings also existed that placed restraints on what could be known about the population under investigation and about the impact of the inservice workshop. These limitations could not be overcome during the course of this investigation.

The limitations and delimitations of this study included the following:

1. Experienced and novice chemical demonstrators' analysis of the videotaped chemical demonstrations and their response to the follow-up interview may not fully tap teachers' pedagogical knowledge (i.e., their PCK and GPK) about how to demonstrate the targeted chemical concepts: density and air pressure.

2. Descriptions of experienced and novice chemical demonstrators' pedagogical knowledge of how to demonstrate the concepts, density and air pressure, to students at the middle school level do not necessarily reflect the nature of their pedagogical knowledge in other chemistry content areas.

3. The generalizability of the findings is somewhat limited by the small number of experienced and novice demonstrators examined and the possible nonrepresentativeness of the voluntary populations.

4. The experienced and novice chemical demonstrators examined in this study differed not only in their experience in conducting chemical demonstrations (i.e., confidence and weekly use in conducting chemical demonstrations), but also in their chemistry content knowledge. This difference in content knowledge undoubtedly contributed to some of the observed differences in experienced and novice chemical demonstrators' clinical interview verbalizations.
Definition of Terms

The following theoretical and operational definitions apply to this study.

Chemical Demonstration - "a type of interactive teaching strategy where the teacher presents and manipulates a real chemical system or a model thereof to introduce, illustrate in concrete form, and/or challenge students' understanding of a particular principle or concept by engaging them in observing, questioning, and reasoning. As such, the demonstration includes both the advanced preparation and follow-up activities." (O'Brien, 1987)

Critical Feature - a teaching behavior that is discussed by a chemical demonstrator during the critical-stop task. This behavior, as displayed by a videotaped teacher performing a chemical demonstration, is judged by the viewer as contributing to or hindering effective chemical demonstrating.

Critical Incident - the occurrence of a critical feature. The emphasis is on the time and place a critical feature or teaching behavior was manifested. Occasionally, the terms "critical incident" and "critical feature" are used interchangeably to describe the videotaped teachers' demonstration skills.

Experienced Chemical Demonstrator, (E) - an experienced chemistry or physical science teacher who regularly incorporates chemical demonstrations into his/her teaching and who has conducted teacher training workshops and outreach programs using the chemical demonstration teaching strategy.

General Pedagogical Knowledge, (GPK) - knowledge of generic teaching skills. This knowledge includes principles or methods of classroom
organization and management as well as knowledge of the learner and their backgrounds (i.e., individual differences among students) (Shulman, 1986).

ICE Workshop B - an intensive two-week chemical demonstration workshop sponsored by the Institute for Chemical Education and held at the University of Maryland, College Park, during the summer of 1987. In this workshop, participating teachers observed chemical demonstrations being modeled and discussed by the workshop staff. As part of the workshop, teachers also practiced and presented chemical demonstrations before peers, middle school students, and ICE workshop staff.

Institute for Chemical Education (ICE) - "an institute centered at the University of Wisconsin-Madison whose objective is to promote scientific literacy and chemical education at all levels, from elementary through advanced university studies. ICE activities include sponsoring a variety of teacher workshops and programs at various sites around the country." (O'Brien, 1987)

Novice Chemical Demonstrator, (N) - an elementary, middle school, or high school science teacher who has had at least one year of chemistry or physical science teaching experience, who possesses minimal competency in demonstration teaching as suggested by his/her low self-reported confidence in chemical demonstration teaching, and who incorporates few chemical demonstrations into his/her own teaching (frequency of one or less per week).

Pedagogical Content Knowledge, (PCK) - "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" of how to
teach specific subject-matter topics (e.g., density) to students of various ages and abilities. "It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are (i) organized, (ii) represented, and (iii) adapted to the diverse interests and abilities of learners, and (iv) presented for instruction." (Shulman, 1987, p. 8). It includes (i) how to present the idea, (ii) what materials to use, (iii) how to sequence those materials, and (iv) what misconceptions the students have about the topics of interest (Wilson & Gudmundsdottir, 1986). In this study, these definitions of PCK apply exclusively to science teachers and to their knowledge of how to perform effective chemical demonstrations on the concepts density and air pressure at the middle school level.

**Pedagogical Knowledge** - the body of knowledge that includes pedagogical content knowledge and general pedagogical knowledge (knowledge of generic teaching skills).

**Teacher’s Evaluative Judgments** - one form of mental processing of classroom teaching information performed by teachers. In this study, this cognitive activity permits teachers to provide critical analysis of an observed chemical demonstration teaching episode as being ineffective, effective, or neutral. It reflects both subjective and objective aspects of teachers’ pedagogical knowledge of effective chemical demonstration teaching.

**Chapter Summary**

This chapter provided a brief overview of the study. It presented a case for examining science teachers’ pedagogical content
knowledge and its growth during intensive inservice training, assumptions and limitations in conducting such a study, and the potential contribution this study makes to the field of science education. Chapter 2, which follows, presents a review of the literature with respect to the theoretical and methodological underpinnings of this study.
CHAPTER 2
REVIEW OF THE LITERATURE

The following review of the literature examines the professional development of practicing science teachers. The review begins by examining research on teachers' thinking, with particular emphasis on teachers' pedagogical knowledge. This is followed by a discussion of qualitative methods used to explore teachers' knowledge of teaching and the techniques used to analyze verbal data derived from these methods. The review culminates with an examination of the impact of inservice programs on fostering teachers' professional development with special consideration given to the impact of past National Science Foundation inservice programs on promoting science teachers' teaching skills.

Research on Teachers' Thinking

Teaching is a complex process. To explore this complexity, behavioral studies on teaching are increasingly being complemented by studies examining teaching from a cognitive perspective. Because of this trend, research on teachers' cognition has grown into a highly visible body of research called research on teachers' thinking. This body of research has a common concern with the ways in which knowledge is actively acquired and used by teachers and the circumstances that affect its acquisition and employment (Calderhead, 1987).

Research on teachers' thinking consists of three broad areas of investigation. One area probes the source of teachers' understandings, contrasting knowledge gained from classroom experience
with knowledge acquired through more formal modes of teacher preparation (Pigge & Reed, 1985; Queen & Grete, 1982). The second area of research deals with teachers' decision-making and problem-solving activity during pre-active and interactive teaching, (Clark & Peterson, 1986; Shavelson & Stern, 1981). And the third area of research involves studying the content and structure of teachers' professional knowledge base (Shulman, 1986, 1987; Berliner, 1987a). Because this study is concerned with science teachers' pedagogical knowledge of demonstrating basic chemical concepts, the literature review that follows will focus primarily on this third area of teachers' thinking. The review will give particular emphasis to the nature of teachers' pedagogical knowledge, the influences on its formation, how it is applied to the analysis of teaching situations, and how it becomes embedded in teachers' actions.

Teachers' Professional Knowledge Base

Researchers have begun to make concerted efforts at understanding the professional knowledge base of teaching. Much of this research has been prompted by the recognition that teachers possess extensive and specialized knowledge about children, curricula, classroom organization, and methods of instruction. This knowledge helps them relate to children, manage classrooms, decide how to teach a particular topic, maintain children's interest, and instruct them. Teachers use their specialized knowledge to guide their actions and cope with a constant barrage of complex situations while teaching. This knowledge also influences the development of teachers' classroom routines and responses to classroom events (Calderhead, 1987).
A Theoretical Model

A theoretical model has recently been proposed by Wilson, Shulman, and Richert (1987) to describe the structural components of the professional knowledge base of teaching. This model is referred to as a "logical model" derived largely from the general educational literature but also from a series of studies conducted at Stanford University seeking to understand knowledge growth in teaching. The Stanford studies indicate that beginning and experienced teachers draw upon many different knowledge systems as they make decisions about the content of the courses they teach. The model proposed by Wilson, Shulman, and Richert (1987) that describes the professional knowledge base of teaching includes the following components: (1) knowledge of subject matter, (2) knowledge of other content, (3) knowledge of learners, (4) knowledge of curriculum, (5) knowledge of educational aims, (6) knowledge of educational contexts, (7) general pedagogical knowledge (GPK), and (8) pedagogical content knowledge (PCK).

As teachers make pedagogical decisions they must draw upon their content knowledge, i.e., their knowledge of subject matter. Within this particular knowledge system teachers must understand numerous facts and concepts in the discipline they teach. They must also have knowledge of the substantive structure of the discipline (Schwab, 1964), that is, how the fundamental principles of the discipline are organized and related to one another. In addition, teachers must possess knowledge of the syntactic structure of the discipline which provides the rules that guide inquiry in the discipline and help establish evidence and proof.
Teachers also draw upon their knowledge of other content that is not within the scope of the discipline they are teaching. Examples of this knowledge include knowledge derived from other disciplines, current events, popular television programs, or even personal experiences that could be introduced into a lesson and linked to a specific discipline topic. Teachers also have knowledge of learners that includes a knowledge of student characteristics and cognitions as well as knowledge of motivational and developmental aspects of how students learn (Wilson, Shulman, & Richert, 1987).

Teachers frequently use their curricular knowledge to make pedagogical decisions. This body of knowledge consists of an understanding of the programs and materials available for teaching particular topics and subjects at a given level. In addition, teachers have knowledge of educational aims, goals, and purposes that enter into their teaching and planning decisions.

Shulman (1987) also discusses the importance of yet another category of teachers' professional knowledge base, namely, knowledge of educational contexts. It refers to knowledge ranging from the workings of student groups and classrooms, to the governance and financing of school districts, to the character of communities and cultures. Each of these factors enter into teachers' pedagogical decisions which, in turn, influences the kind of instruction that occurs in the classroom.

Teachers regularly make use of their general pedagogical knowledge during pre-active and interactive teaching. This knowledge consists of pedagogical principles and techniques that are not bound by topic or subject matter, techniques that have been the focus of
much research on teaching (Shulman, 1986). It includes knowledge of (i) verbal and nonverbal communication skills, (ii) techniques for presenting information such as using advanced organizers and determining prior knowledge, and (iii) questioning skills such as using different levels of difficulty in questioning, different types of questions, wait time, and providing feedback (Arends, 1988). Teachers' general pedagogical knowledge also includes an understanding of generic principles or methods of classroom organization and management such as (i) maintaining order, (ii) maintaining equity in the distribution of teacher time among students, (iii) determining the number of students who can work together on a given task, (iv) regulating the amount of student-student interaction, and (v) gauging timeliness in teacher-student interactions (Cohen, Intili, & Robbins, 1979). It also includes knowledge of procedures for (i) controlling student movement and student talk, (ii) ensuring smoothness and momentum during instruction, (iii) cuing and signaling, (iv) managing inappropriate and disruptive behavior, (v) using rewards and punishment, and (vi) establishing rapport with students (Arends, 1988).

The preliminary findings of Shulman and his colleagues suggest that teachers also possess another type of subject matter knowledge that is enriched and enhanced by teachers' various knowledge systems and is called pedagogical content knowledge. It is a form of content knowledge that:

... embodies the aspects of content most germane to its teachability. Within the category of pedagogical content knowledge I include, for the most regularly taught topics

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in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others... [It] also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning. (Shulman, 1986, p. 9)

[It is] that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding. ... It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction. (Shulman, 1987, p. 8).

Pedagogical content knowledge refers to a knowledge of how to teach the subject matter. It includes how to present the idea, what materials to use, how to sequence those materials, and what misconceptions the students have about the topics of interest (Shulman 1986, 1987). This form of content knowledge is discussed below in greater detail because of its central importance to this researcher's study.

Case Studies of Teachers' Pedagogical Content Knowledge

The research literature provides several examples of the various facets of the term pedagogical content knowledge. These examples are taken from a growing body of casework based on experienced and novice secondary school teachers planning and teaching specific topics in English and history. Most of the reported examples are taken from studies conducted by researchers at Stanford who are giving special attention to knowledge growth in teaching.

Two case studies are briefly examined to illustrate the construct 'pedagogical content knowledge.' Wilson, Shulman, and Richert (1987)
have conducted numerous interviews on teachers preparing to teach a specific topic. One case study reported on an English teacher, who was required to teach Shakespeare's *Julius Caesar* to a class of ninth graders towards the end of the school year. In an attempt to introduce the play in a meaningful way, one that would take into account their interests and their level of intellectual sophistication, the teacher presents his students with a popular television program (*Star Trek*) and a scenario of how the students would confront the central character (Captain Kirk) whose adventurous campaigns are needlessly risking the lives of others (the crew).

The analogy presented to the students illustrates one teachers' favored representation of the idea of moral conflict. It further represents this teachers' transformation of the subject matter for teaching that is likely to initiate understanding on the parts of students. Wilson, Shulman, and Richert (1987) maintain that as beginning teachers experience pedagogical content knowledge growth they develop multiple representations of the subject matter they teach, and thus build upon their schema for teaching a given concept. Work based on the Stanford studies has fostered the idea that beginning teachers should develop a 'representational repertoire' for the subject matter they teach because a multiplicity of connections renders understanding more durable and rich. The possession of variations of representations also permits instruction to be tailored and adapted to the various types of learners teachers confront.

Another case study (Wilson, Shulman, & Richert, 1987) exemplifies a teachers' efforts at transforming subject-matter for the purposes of teaching and provides information on the nature of
pedagogical content knowledge growth in teaching. The case is taken from another secondary school English teacher who was going to teach the concept of 'theme' for the first time. When this teacher was asked during a pre-instruction interview how he would introduce this concept to his class of tenth grade boys, this teacher had several ideas, one of which included tracing a theme for his students after they have read a short story. In addition to exemplifying this term for students, the teacher also planned to use a metaphor he created (a baseball game) to help him communicate his tacit knowledge of theme and thematic analysis to students.

After teaching the concept of theme to his students, he was asked during a post-instruction interview what he knew about the concept of theme after having the experience of teaching it. It became apparent to him that his students had difficulty understanding how the concept of theme was related to patterns observed in a baseball game. In addition, they still did not understand how to find a theme in a text, the teachers’ major lesson objective.

Wilson, Shulman, and Richert’s (1987) case study further documented how this beginning English teacher, though frustrated, searched for a better metaphor to help his students trace and understand theme. The teacher transformed the content again, this time focusing on the trail of a wounded animal. Through the process of planning, teaching, adapting the instruction, and reflecting on the instructional experience, this English teacher slowly added a new representation to his teaching repertoire, making his pedagogical content knowledge richer and fuller. For this English teacher, the representation is a more refined understanding of the use of analogies.
for instruction. The new knowledge acquired also included an understanding of some of the difficulties students have with understanding the concept of theme.¹

As novice teachers begin to transform their content knowledge for instruction suitable for a particular level of student, they engage in and develop their pedagogical content knowledge. Wilson, Shulman, and Richert (1987) indicate, however, that pedagogical content knowledge is not simply a repertoire of multiple representations of the subject matter. It is also characterized by a way of thinking called pedagogical reasoning. This type of reasoning facilitates the generation of subject matter transformations into teachable forms. It plays a pivotal role in fostering pedagogical content knowledge growth.

In this study, the representations that experienced and novice chemical demonstrators have for the demonstration teaching of density and air pressure provide a perspective of these science teachers’ pedagogical content knowledge.

A Model of Pedagogical Reasoning

Based on numerous interviews with novice teachers Wilson, Shulman, and Richert (1987) developed a model for the process of pedagogical reasoning, a model which attempts to account for growth in teachers’ pedagogical content knowledge base. This model is depicted in Figure 1.

¹ Precisely how this English teacher came up with the hunter metaphor is not stated in Wilson, Shulman, and Richert’s (1987) article. One is left with the impression it was an act of creative thinking associated with reflection and lesson planning.
The process of pedagogical reasoning consists of six aspects related to the act of teaching: comprehension, transformation, instruction, evaluation, reflection, and new comprehension. The pedagogical reasoning process begins with comprehension. This requires a teacher to critically understand the substantive and syntactic structure of the content to be taught. In addition, it refers to an understanding of how the content is related to ideas in other domains.
The transformation process, the central component of the pedagogical reasoning model, occurs next. It describes the thought processes that enter into the lesson planning task. It involves the following five cognitive subprocesses: critical interpretation, representation, instructional selection, adaptation, and tailoring. These five subprocesses contribute vitally to the growth of teachers’ pedagogical content knowledge system.

The first of these subprocesses, critical interpretation, involves reviewing instructional materials in light of one’s own understanding of the subject matter, including the identification of errors in a text as well as changes in understanding of a particular construct since the text’s publication date. Once the instructional materials have been critically examined, teachers often consider alternative ways of representing the subject matter to students, the second step in the transformation process (see Figure 1). This may include the development of analogies and metaphors, or numerous other forms of representation to help convey to students particular subject-matter concepts or problem-solving strategies. Ideally, teachers should possess a representational repertoire that consists of metaphors, analogies, illustrations, activities, assignments, examples, and other forms of representation that teachers could use to transform the content for instruction (Wilson, Shulman, & Richert, 1987).

A third aspect of the transformation process, instructional selection, refers to the embodiment of representations in an instructional form or method (Shulman, 1987). This process requires teachers to draw upon a repertoire of instructional strategies of
teaching to present the chosen representation. This repertoire includes a wide variety of teaching strategies such as lecture, recitation, seatwork, cooperative learning, reciprocal teaching, inquiry methods, student projects, and several other instructional approaches.

Adaptation, the fourth aspect of the transformation process, refers to the process of fitting the subject matter representation to the characteristics of students in general. If students possess particular misconceptions about light that would interfere with learning, a teacher might present or introduce an activity about light in such a way as to clear up the misconception or in a way that would avoid reinforcing the misconception. Tailoring, the last process, involves adapting the materials and representations to specific students in one class rather than to the student population in general. Together, the four mental processes of interpretation, representation, adaptation, and tailoring produce a plan, a set of strategies for teaching a lesson, a unit, or a course.

Instruction refers to the observable performance of the teacher during teaching. It includes all the teacher behaviors related to effective instruction in areas such as management, grouping, pacing, coordination of learning activities, explanation, questioning, and discussion.

Evaluation is the teacher's efforts at checking for understanding in their students during and after instruction. Teachers use two modes of evaluation: formal modes and informal modes. Formal modes of evaluation include the use of unit tests and quizzes; informal modes include strategies such as questioning during interactive teaching.
Checking for student understanding and misunderstanding is usually tied to specific school subjects and to individual topics within a subject. Shulman (1987), therefore, indicates that evaluation represents an important way in which pedagogical content knowledge is used.

Teachers also engage in an evaluation of their own teaching through a process of reflection. Reflection refers to the process of learning from experience. It involves a mental recollection of the teaching and learning that has occurred over a given span of time, highlighting the accomplishments and shortcomings that have occurred along the way. The final phase of the pedagogical reasoning cycle is a new comprehension of the purposes of instruction, the subject matter, the students, and the instructional strategies.

Findings from the Stanford studies have shown that new comprehension, the last phase in the pedagogical reasoning model, is not always discernible after each unit of teaching (Wilson, Shulman, & Richert, 1987). In some instances, enriched understanding in teaching of a specific topic grows slowly by accretion, whereas in other instances a single experience promotes a significant leap in new comprehension. In many cases, teachers showed no changes for long periods of time. An understanding of the factors influencing these various growth patterns awaits further research.

The two models presented above (the components of the professional knowledge base of teaching and the model of pedagogical reasoning, Figure 1) provide a theoretical base for research on knowledge growth in teaching. Although these models have empirical support and are logically based, it is also clear that more detailed
conceptualization and testing of these models are still needed (Wilson, Shulman, & Richert, 1987). Such efforts would help contribute to a clearer understanding of how teachers perform the crucial task of transforming their content knowledge for the purposes of teaching and the factors that contribute to pedagogical content knowledge growth.

Studies on Teachers' Professional Knowledge Base

This section reviews several studies that have examined the nature of teachers' professional knowledge and influences upon it. The review will focus primarily on four knowledge systems comprising teachers' professional knowledge base, namely, their subject-matter knowledge, pedagogical content knowledge, general pedagogical knowledge, and knowledge of students. Attention is first given to recent studies on teachers' pedagogical content knowledge and how it is used during planning and interactive teaching. This is followed by a review of expert/novice teacher studies examining the other three knowledge systems that teachers frequently use in their teaching.

Factors Influencing Teachers' Pedagogical Content Knowledge

One question of particular interest is the role that teachers' subject-matter knowledge plays in instruction. It can be stated as follows: "How do teachers use their knowledge of content for teaching?" A study by Hashweh (1987) examined this question by investigating the influence of teachers' subject-matter knowledge on their transformation of the content into a form suitable for instruction. The study compared two groups of science teachers who
differed in subject-matter knowledge as they prepared to teach identical material. The two groups of teachers were asked to teach two lessons, one involving content that they knew intimately, and one involving content they had never encountered. This situation was created by having a group of three biology teachers and three physics teachers each plan a biology and a physics lesson using selected chapters out of a popular biology and physics textbook during think-aloud interview sessions.

Hashweh (1987) observed that prior subject-matter knowledge affected the transformation of chapter organization. In situations where science teachers were presented with a chapter in which the theme was meaningless or unsound from a disciplinary perspective, only the knowledgeable teachers rejected the chapter structure and established their own organizing scheme. Unknowledgeable teachers closely followed the chapter structure. Knowledgeable teachers were also more prone to make additions that were consistent with their organizing theme for the chapter and deletions that were not essential for developing the theme. Hashweh attributed these planning behaviors to the rich knowledge schema the knowledgeable teachers possessed with respect to the targeted science concepts (subject-matter knowledge) and related science activities (pedagogical content knowledge). His findings suggest that the organizational and adaptation aspects of science teachers' pedagogical content knowledge depended greatly on teachers' subject-matter knowledge.

Teachers possessing a good understanding of the substantive and syntactic structures of a particular sub-discipline of social studies showed similar patterns in their cognitive abilities to transform the
subject matter into a teachable form (Wilson & Gudmundsdottir, 1986). Among beginning social studies teachers, subject-matter restructuring was limited to the content they knew, with very little emphasis on the restructuring of the content to include an interdisciplinary perspective (Gudmundsdottir, 1987). Although these beginning teachers possessed a novitiate form of pedagogical content knowledge, their experiences during the first year of teaching reportedly provided these teachers with some measure of pedagogical content knowledge growth. The most striking shifts in content presentations reflected a change in instructional selection. The lecture method gave way to story-telling encounters that included methods and activities for getting students engaged in learning by having them take on the interviewing role of cultural anthropologists.

Most studies reported in the literature have examined how teachers' pedagogical content knowledge grows as a result of classroom experience. Little is known about how this knowledge system differs between experienced and novice science teachers and how it is effected by intensive inservicing; hence, a need for studies in these areas exists. This review continues by examining what is known about experienced and novice teachers' thinking in those areas of teachers' professional knowledge base that have received recent research attention.

Exploring Teachers' Cognitions Through Expert-Novice Teacher Studies

Researchers have recently begun to use the theories and methods from cognitive psychology to study the nature of pedagogical expertise. These studies tend to focus on the thought processes and knowledge structures of experienced or expert teachers and those of
minimally experienced or novice teachers. Studies involving experienced teachers typically examine individuals who have completed four or more years of elementary or secondary school teaching (Housner & Griffey, 1985; Yinger & Clark, 1982). Studies involving expert teachers typically involve those who have had several years of teaching experience and have a reputation of teaching excellence that has been recognized by colleagues or school administrators. Identifying expert teachers may also include the use of student standardized test scores and validated observational measures used by independent observers (Berliner, 1986). Each of these measures, however, has its limitations as an indicator of pedagogical expertise. Consequently, the distinction between 'experienced' and 'expert' teachers is not always straightforward, and as a result, the two terms are often used interchangeably (Berliner, 1986; Peterson & Comeaux, 1987). In the review that follows, an attempt is made to use the terms following the criteria discussed above.

In a study of experienced and inexperienced (novice) social study teachers, Peterson and Comeaux (1987) examined teachers' thinking during classroom instruction in terms of their recall, representation, and analysis of problem events during interactive teaching. The three cognitive abilities were probed by presenting teachers with videotaped recordings of problem events associated with handing back tests, a class discussion, and cheating. Structured interviews that followed the videotaped viewings revealed that experienced teachers showed greater recall of classroom events, relied more on procedural knowledge and principles in analyzing the problem episodes, and gave more justifications for their decisions and comments. Novices tended
to recall more of the surface or literal characteristics of classroom events and their solutions to classroom problems tended to be more simplistic and specific, conveying fewer underlying pedagogical principles. From these findings, it was suggested that experienced teachers have better developed knowledge structures or "schemata" for phenomena related to classroom teaching and learning than novice teachers.

In a related study, Carter, Cushing, Sabers, Stein, and Berliner (1988) noticed distinct qualitative differences between expert and novice math and science teachers in terms of their ability to process visual information of math and science classrooms. When these teachers were presented with a series of slides taken from an actual math or chemistry class, experts appeared better able to (1) perceive and interpret the importance of one piece of visual information against another, (2) form connections among pieces of information, (3) make sound inferences of classroom events, and (4) represent management and instructional situations in terms of meaningful problem units. The findings indicated that expert teachers possess a rich store of classroom knowledge about students and events, and that they use that knowledge to understand and explain classroom phenomenon. These findings suggest that expert teachers possess comparatively richer schemata than novices for ascribing meaning to visual classroom information.

Studies of experienced and novice teachers engaged in actual, rather than simulated, lesson planning and interactive teaching tasks showed other interesting cognitive differences. Housner and Griffey (1985), for example, conducted an analysis of expertise as it
pertained to the planning and interactive decision making of experienced and inexperienced (or novice) physical education teachers. An analysis of teachers' think-aloud verbalizations showed that the experienced teachers were better able to anticipate possible teaching situations and generate appropriate contingency plans to meet the demands of these situations than novice teachers, e.g., what to do if students showed high ability or if there was extra time. The experienced teachers, thus, had a larger number of alternative instructional strategies and adaptations stored in clinical memory than did inexperienced teachers. The experienced teachers also made over twice as many instructional strategy decisions than novices during their lesson planning task. In this regard, they gave considerably more attention to the establishment of rules and routines for managing student activities and to giving students feedback that would facilitate skill acquisition. During interactive instruction, the experienced physical education teachers' attended more to cues related to individual student performance, while novices attended more to cues related to student interest and overall class behavior. These differences in experienced and inexperienced teachers' general pedagogical knowledge, their thinking about instruction, and their processing of classroom information further reflects the enhanced cognitive abilities that experienced teachers have over their novice counterparts.

Leinhardt and Greeno (1986) examined teachers' cognitions by looking at the activity structures by which certain teaching plans (e.g., opening homework review, guided practice, transitions) were carried out among expert and novice mathematics teachers. The study
focused on routines embedded in relatively common teaching activities. A micro-analysis of the opening homework review activity, for example, showed that the expert teachers performed this activity in one-third less time than novices, and in the process were much more thorough in picking up information about student attendance, homework completion, and who would need help later in the lesson. For experts, these routines are virtually automated pieces of action that allow students and teachers to devote their attention to other, perhaps more important matters in the lesson. For novices, these activity structures were largely absent or they showed day-to-day changes in the way an activity, such as opening homework review, were performed. These patterns reflected the hypothesized presence of ill-formed action schemata characteristic of less expert teachers.

Borko and Livingston (1988) examined the planning, teaching, and post-lesson reflections of three expert and three novice math teachers. Their study showed that novices showed more time-consuming, less efficient planning behaviors for presenting lesson content. They also made less selective use of information during planning, showed limited ability to see relationships across the curriculum, and revealed less ability to anticipate student problems. During interactive teaching, novices made less use of instructional and management routines, and appeared to be more distracted by student responses that diverged from scripted lesson plans. Novices also reported more varied, less selective post-lesson reflections than experts. Their post-lesson reflections showed a lack of consistent focus, with thoughts ranging from concerns about their effectiveness as teachers, to student understanding concerns, to concerns regarding
the overall lesson structure. These researchers' findings suggested fundamental differences in expert and novice teachers' cognitive schemata. In contrast with experts, novices appeared to possess less-developed propositional structures for pedagogical content knowledge and limited inter-connections among their cognitive structures for content knowledge, pedagogical content knowledge, and knowledge of students.

Other studies involving experienced and novice teachers' cognition include those examining teachers' knowledge of students. Calderhead's (1983) study, for example, showed that experienced teachers have amassed a large quantity of information about students and, in a sense, "they seemed to 'know' their students before they met them (p.5)." Novices did not show as well-developed student schemata.

In a related study, Carter, Sabers, Cushing, Pinnegar, and Berliner (1987) examined differences between expert and novice math and science teachers with respect to the way they processed and used information about students in simulated teaching tasks. These researchers identified nine propositions that distinguished expert and novice teachers in their thinking about students. These differences included the importance teachers' attributed to available student information before taking over a math or science class, their inclination to accept as valid the information provided by the previous teacher, the way they talk and think about individual students, the kinds and quality of solution strategies they proposed for classroom problems, the strategies for taking over a new class, routines for getting to know students and for assessing what the students have learned, the types and amount of information they
remembered about students, the attention given to student test and homework information, and the amount of time allocated for planning instruction based on available student information. These researchers concluded that, "expert teachers, like other experts, appear to bring rich schemata to the interpretation of phenomena, and these schemata appear to provide them with a framework for meaningfully interpreting information (p. 156)."

Most of the studies reviewed above compared experienced and novice teachers in terms of their skill in planning instruction, processing information derived from student performance, and the adherence to interactive teaching routines. Berliner (1988) recently proposed a model suggesting that the development of expertise in pedagogy consists of 5 stages of skill development and that most expert-novice teacher studies only examine the extremes in teacher performance and cognition. Berliner suggests that there are several stages teachers move through in the development of pedagogical expertise. He identifies these stages as follows:

Let us view the development of expertise in pedagogy as consisting of 5 stages of skill development, following the general model presented by two Berkley professors, the philosopher Hubert Dreyfus and his brother, computer scientist Stuart Dreyfus (1986). We begin with novices, who, with experience, develop into advanced beginners. Most of these individuals then go on to become competent teachers. It should be the goal of teacher education colleges to help prepare the novice and assist the advanced beginner to become a competent teacher. Competence, I believe, should be our goal. ... Perhaps in the fifth year [of teaching], a modest number of teachers may move into a further stage of development, that of proficient. Some of these proficient teachers will reach the highest stage, achieved by very few members of a field, that of expert. (pp. 2-3)

The current study makes no attempt to identify teachers' stage of chemical demonstration expertise. It does, however, attempt to
describe the characteristics of science teachers at relatively early and advanced stages of development in their pedagogical content knowledge of chemistry and demonstration teaching.

Our attention next turns to the influence of inservice workshops on promoting science teachers' professional development.

**Science Teacher Inservice Education**

The 1980's has seen an unprecedented interest in science teacher inservice education by the science education community and people concerned with improving the teaching and learning of science (Evans, 1987). Several factors and events that took place during the 1970's and early 1980's help explain the current interest in science teacher inservice education. These factors have included (1) the steady growth in the number of stable, tenured science teachers whose training was in need of updating, (2) the alarming findings of several federally funded studies and reports that documented a serious erosion in the quality and quantity of science taught in the U.S. at the K-12 levels (National Commission on Excellence in Education, 1983; National Science Board, 1983; National Academy of Science, 1982), and (3) recent educational reforms and initiatives attempting to set higher standards in science teaching and science teacher education (Bell, 1987; Holmes Group, 1986; National Commission for Excellence in Teacher Education, 1985; Joyce & Cliffs, 1984; Yankwich, 1984). One logical outcome of these developments has been the increased interest in science teacher inservice education.
The National Science Foundation and Inservice Programs

The federal government, through the agency of the National Science Foundation, has had a long and varied history in the inservice training of precollege science and mathematics teachers. Since the mid-1950's, NSF has spent over $750 million in support of inservice programs, the most familiar being the NSF summer institutes (Dyché, 1974; Willson & Lawrenz, 1980).

Summer institutes offered prior to 1970 had a central goal of increasing the effectiveness of teachers by broadening and updating their scientific backgrounds. During the 1970's there appeared to be a shift in NSF summer institute goals in support of curriculum implementation institutes. Efforts at addressing science teaching methodology were purposely omitted. Only recently have NSF inservice programs been implemented that have stressed teacher acquisition of specific science teaching skills, such as chemical demonstration teaching, as exemplified by the summer workshops offered by the Institute for Chemical Education (Bell, 1987; Chelimsky, 1984; Lippincott, 1985).

Evaluating the Effectiveness of Inservice Programs

Evaluation of Past NSF Inservice Programs

Much of the literature on NSF inservice programs indicates that these federally funded programs have received wide acceptance by universities and participants alike (Highwood & Mertens, 1972; Willson & Lawrenz, 1980). Most of these studies focused on participant perceptions of various aspects of NSF summer institute programs. Some represented follow-up studies on participants' self-assessed use of
workshop skills, curriculum, and supporting materials (While, 1984). Comparatively few studies exist on the influence NSF summer institutes have on variables such as student achievement and attitudes towards science. One study conducted by Willson and Geribaldi (1976) showed a consistent trend in the direction of better student performance with increased NSF participation. In another study, Willson and Lawrenz (1980) reported a small, but significant, relationship between institute attendance and student attitudes toward science. Studies examining the influence of NSF summer institutes on the development of teachers' pedagogical knowledge base seem to be lacking, a situation which this researcher seeks to address.

General Problems in Evaluating Inservice Programs

Reviews of the literature pertaining to the evaluation of science inservice education programs and inservice programs in general often concur with Hounshell and Liggett's (1976) assessment that "Research in the area of inservice education is meager and often poorly planned, organized, and executed." Such conditions have lead to numerous contradictory and confusing findings regarding whether implemented programs were effective in bringing about the desired changes in teachers and their students (Wade, 1984-1985).

One of the problems frequently encountered in the research and cited in reviews involves the lack of pretraining observations of teaching so that entry level skills of teachers prior to inservicing are documented (Joyce & Showers, 1980). In addition, many studies on inservice education lack sufficient descriptions to indicate what actually occurred during the training of teachers. Most inservice evaluation studies are typically non- or quasi-experimental studies.
Such designs prevent the random assignment of subjects into experimental and control groups. Therefore, thorough descriptions of teacher characteristics and inservice treatment should be collected when conducting research on teacher education programs (Strother, 1983). These descriptions are necessary to minimize threats to validity resulting from confounding variables and to maximize reliability and generalizability of the findings (Boulanger, 1981; Druva & Anderson, 1983).

Some educators have criticized inservice teacher education evaluation efforts in terms of the overreliance placed on self-reports to assess workshop success (Boschee & Hein, 1980). It is charged that these self-report measures have little relationship to teaching behavior or student achievement. Furthermore, self-reports of teachers' attitudes and satisfaction with various workshop components, although easily and economically obtained, may be subject to biases (e.g., leniency, lack of discrimination, lack of internal consistency). The measurement instruments used to assess teacher attitudes and perceptions of the workshop have also been questioned in terms of their validity (Jones & Hayes, 1980).

**Research on Teacher Education**

The literature on inservice education discusses several program elements that appear to contribute to changes in teacher behaviors. Gliessman's (1981) review of the literature on teacher education (preservice and inservice) indicated that simple and complex teaching skills can be learned through a number of well-defined processes. These processes include (1) learning through observation, (2) concept
learning, (3) learning through practice, and (4) learning from feedback.

According to Gliessman (1981), learning through observation (i.e., modeling or imitation) is a particularly effective strategy for helping beginning teachers acquire questioning skills as well as the emotive aspects of teaching, such as enthusiasm and warmth. Observation strategies have also been effective with preservice teachers in terms of influencing behaviors that give greater use to a student-centered teaching style.

Beginning and experienced teachers also learn to teach through the acquisition of concepts. In this regard, Gliessman (1981) stated the following, "Viewing a teaching skill as a concept to be acquired implies that the immediate goal of instruction is conceptual: To be learned are the essential characteristics of a skill, its specific uses in teaching, and how it is distinguishable from other skills." Conceptual learning has been particularly useful in changing teacher performance from teacher-centered to student-centered styles and in increasing teacher use of probing and informing skills during interactive teaching (Wagner, 1973).

Learning through practice refers to the act of teaching under controlled conditions with the intention of improving one's performance. Microteaching in a laboratory setting is probably the most familiar example of learning through practice (Allan, 1966; Brown, 1975). Gleissman (1981) indicated that, among preservice teachers, most microteaching efforts appear effective in a laboratory setting but often fail to produce transfer to classroom settings,
unless the acquired practices are philosophically accepted by trainees and modeled by supervising personnel.

Learning from feedback also contributes to the process of learning to teach. Various feedback media (for example, videotape replay, audiotape replay, and verbal report) can stimulate change in teacher performance. Changes that have been reported as a result of focused and immediate feedback include increased skill in varying the level of questions directed to students, greater interactions with lower ability students, and improved styles of body postures and teaching mannerism (reviewed by Gleissman, 1981).

Evans (1987) examined several research studies and reviews on inservice science teacher education in order to generate guidelines for conducting effective inservice programs. He suggests that science inservice education programs aimed at the enhancement of teaching skills should include modeling, practice, and feedback. Inservice education programs aimed at the acquisition of teaching skills should include theory, modeling, practice, and feedback.

Although the research literature suggests that inservice programs designed around these three or four training components would contribute to the acquisition of basic teaching skills, these studies fail to show how these training interventions influence knowledge growth in teaching of specific subject-matter topics. In this regard, the question of how science inservice workshops can influence the development of teachers' pedagogical reasoning skills and foster pedagogical content knowledge growth is of particular interest in the quest to understand the factors that influence science teachers' professional development and how this development impacts student
Assessing Teachers' Knowledge

Research in cognitive science has brought significant developments in methods for assessing knowledge, cognitive structures, and mental processes used by individuals engaged in complex, discipline-specific tasks. Most of these methods yield verbal data rather than numbers for their raw data. This section reviews some of the data gathering methods used to probe teachers' knowledge and thinking about pedagogy. A later section gives attention to the techniques used to analyze the verbal reports generated by these methods.

Data Gathering Methods

Educators have used several different qualitative methods to assess the various components of teachers' professional knowledge base. Three methods frequently used to probe teachers' knowledge and thinking have included: (1) clinical interviews using the think-aloud technique, (2) critical-incident methods, and (3) structured and semi-structured interviews. These strategies are particularly useful for assessing the nature of teachers' knowledge and thinking about students, classroom events, and pedagogy. Although each of these methods have distinctive characteristics, they are often used collectively or simultaneously in cognitive research studies. The major features that distinguish these methods are briefly discussed because they reflect characteristics of the methods used in this study.
to probe teachers' specialized knowledge of chemical demonstration teaching.

Clinical Interviews Using the Think-Aloud Technique.

In the field of cognitive science, the interview is one of the most direct and widely used methods to gather information about a subject's internal cognitive states (Ericsson & Simon, 1980; Garner, 1987). It consists of a face-to-face meeting where the interviewer seeks information from an individual in the form of verbalized thoughts. These verbalizations provide data on the interviewed subject's knowledge or thought processes within specific content domains. With interviews, known as clinical interviews, an individual is specifically asked to provide descriptions, predictions, and explanations of events relevant to the content domain of interest (Finley, 1986). They typically consist of one or more standardized think-aloud tasks along with interviewer questions to test the genuineness and consistency of the interviewee's response (Posner & Gertzog, 1982).

Clinical interviews can be designed to examine both the declarative and procedural knowledge held by an individual. Declarative knowledge represents the large body of facts and concepts, and their inter-relationships, that an individual stores in memory. Procedural knowledge refers to the mental processes an individual uses to manipulate these facts and concepts to solve problems or make decisions. Gitomer and Pellegrino (1985) describe declarative knowledge as "knowing what" or "knowing that" and procedural knowledge as "knowing how." This researcher's study focuses primarily on the retrieval of declarative information from science teachers (i.e., their
pedagogical content knowledge). Posner and Gertzog (1982) describe the knowledge-probing function of clinical interviewing as follows:

Its chief goal is to ascertain the nature and extent of an individual's knowledge about a particular domain by specifying the relevant conceptions he or she holds and the perceived relationship among those conceptions. Once obtained, this information could be represented in a suitable format, such as a semantic network, which would be equivalent to a partial representation of the individual's cognitive structure.

The most prevalent use of the clinical interview method has been in conjunction with studies probing students' cognitive structure (Finley, 1986; Posner & Gertzog, 1982). Science educators have found this interview strategy to be particularly effective in examining the process of conceptual development among students and inservice teachers learning abstract concepts in science, such as heat, temperature, equilibrium, pressure-related gas behavior, and magnetism through a variety of instructional strategies (Benbow, 1987; Crosby, 1987; Finley, 1986; Swamy, 1986; Layman & Krajcik, 1988). The term 'clinical interview' is encountered in the literature on teachers' thinking in the context of examining teachers' implicit theories of teaching and learning, and in the context of examining teachers' interactive thoughts and decisions (reviewed by Clark & Peterson, 1986).

The clinical interview format can vary from highly flexible (with both tasks and questions varying from subject to subject) to highly standardized (with carefully specified tasks and questioning patterns) (Novak & Gowin, 1984). Interviews designed to obtain a detailed picture of teachers' pedagogical knowledge often use think-aloud tasks that simulate various pre-active and interactive teaching behaviors.
Structured or semi-structured interview questions often accompany these simulated teaching tasks (Clark & Peterson, 1986; Medley, 1984). The think-aloud method has numerous research applications. It has been widely used in clinical interview studies where individuals are engaged in problem-solving or decision-making tasks. In studies examining teachers' thinking, these tasks have resembled simulated teaching tasks such as (1) lesson planning (Peterson, Marx, & Clark, 1978) or (2) making judgments about curriculum materials and students (Berlin, 1987a; Yinger & Clark, 1982). The teacher's verbalizations are recorded on audiotape and later transcribed to create protocols. The protocols are then analyzed according to various coding schemes to produce descriptions of the content of teacher thinking and of the sequence of cognitive processes that teachers follow while planning, making decisions, and teaching.

The think-aloud method has been used in several recent studies to examine expertise and the role of experience in teaching (Berlin, 1987a; Carter et al., 1988; Cushing et al., 1986; Leinhardt, 1983). In these studies experienced and novice classroom teachers were provided with tasks that required teachers to process classroom information and to discuss their thoughts about common pedagogical issues. One task required teachers to look very briefly at slides of mathematics and science classes, and describe what they saw (Carter et al., 1988; Cushing et al., 1986). Another task required teachers to look at multiple-choice items from a standardized test and to estimate the percentage of students at a specified-age and exposure to a specified curriculum, who would get such items correct and to explain why certain distractors would be frequently or infrequently chosen.
(Leinhardt, 1983). Another task required the viewing of three television screens simultaneously, each one showing different parts of a classroom during a lesson. The teachers had to provide think-aloud comments on what they were seeing and hearing, and then answer questions about their viewing when the videotaped lesson was over (Sabers et al., in progress; cited in Berliner, 1987a). These think-aloud tasks suggested that the experienced teachers possessed richer schemas about students than less experienced teachers, e.g., richer schemata for 'typical' or 'normal' students and for other sense-making categories for thinking about students. The findings obtained from these think-aloud tasks also suggested that experienced teachers possess many more cognitive skills of teaching (e.g., information processing skills, interpretive skills, problem-solving skills for addressing classroom events) than less experienced teachers.

The think-aloud task developed for this study has science teachers observing videotaped models of chemical demonstration teaching and, on second viewing, critiquing the performance at various teacher-selected intervals. In this think-aloud task, the primary stimuli provided to the teachers comes from the videotaped chemical demonstration presentations. Researcher-initiated clarification questions were also interjected during the think-aloud task as a secondary source of response stimuli. This think-aloud task, called the critical-stop task, was designed to help probe the content of experienced and novice chemical demonstrators' pedagogical knowledge base associated with the demonstration teaching of basic chemical concepts.
Critical-Incident Methods

A review of the literature reveals three types of critical-incident methods used in studying teachers' cognitions and the process of teaching. They include (1) the critical-incident technique, (2) critical-incident analysis, and (3) obtaining a critical incident record. While the names of these methods sound very much alike, they represent techniques obtained from different lines of qualitative research. The first two of these techniques show some similarities to the critical-stop task used in this study to probe teachers' knowledge of demonstration pedagogy. They are discussed in some detail, below. The third method, obtaining a critical incident record, refers to a strategy for making direct, systematic observations in an educational setting (Evertson & Green, 1986). It has little to do with making direct probes of teachers' knowledge in an interview setting and is therefore not part of this review.

Critical-incident technique. The critical-incident technique, as typically employed, uses interviews to obtain descriptions from a group of informed individuals (such as principals) who have knowledge about the performance of a group of target individuals (such as teachers) (Borg & Gall, 1983, p. 509). During the interview the informants describe "critical incidents" about the performance of the target group. Each critical incident provides a description of a specific behavior pattern that is considered critical to the skill or trait being studied. This technique offers a simple yet effective alternative to training observers and having them carry out lengthy observations on a group of individuals in a variety of educational settings. The technique, as it probes the knowledge of particular
individuals, is particularly useful in understanding the performance of a group of target individuals.

The critical-incident technique is well-suited for providing detailed case descriptions of behaviors and characteristics associated with a complex theoretical construct that is not well understood or defined, e.g., professionalism in education (Leles, 1968). A difficulty frequently encountered with the technique, however, is that many of the recorded incidents appear to be global evaluations about a subject’s performance rather than specific incidents involving the subject, e.g., see Flanagan (1954). The data often needs to be screened so that only specific incidents are used in the data analysis. Perhaps the most serious problem associated with the critical-incident technique is ascertaining whether identified incidents obtained from the interviewed informants are truly critical to the behavior or skill being studied, i.e., the incidents can truly differentiate between successful and unsuccessful behavior.

The critical-incident technique, even with some of its limitations, shows considerable utility in exploratory and theory-generating studies. The usefulness of this technique may be enhanced if the "interviewed" subjects rely less on their long term memory (LTM) and more on short term memory (STM) to discuss critical incidents. This may be possible by having interviewed informants observe and analyze videotaped segments of classroom teaching during a clinical interview (e.g., as described in chapter 3). This approach would be consistent with Ericsson and Simon’s (1980) claim that verbal reports tend to be more reliable and valid as data when a person
reports on the contents of short-term memory, that is, that which he or she is currently attending to.

**Critical-incident analysis.** Another critical-incident method used in qualitative research involves the use of informants analyzing researcher-identified critical incidents associated with teaching. The analyses are conducted in a think-aloud fashion. This technique, which I shall call critical-incident analysis, has been effectively used to assess teacher's knowledge of students and student misconceptions.

Hashweh (1986) used this technique when he presented science teachers with several critical teaching incidents involving hypothetical student answers to textbook questions. The fabricated student answers contained misconceptions that revealed learning difficulties commonly encountered by students solving work and energy problems in physics and photosynthesis problems in biology. The technique was designed in order to assess how topic-knowledgeable and unknowledgeable science teachers would respond to commonly encountered science teaching problems. Analysis of teachers' responses to these critical incidents revealed major differences between teachers' subject-matter knowledge in dealing with these general class difficulties.

Calderhead (1981a) also used this technique in a study on beginning and experienced teachers when he orally presented teachers with descriptions of common critical incidents related to classroom discipline and management. He then asked them how they might respond to these incidents during interactive teaching. The study showed a marked difference in the nature and sophistication of response between
experienced and novice teachers in their interpretation and analysis of classroom events.

The critical-stop task used in the present study asked teachers to both identify as well as analyze chemical demonstration teaching incidents observed on videotape. The data derived from such a critical-incident task helped explore science teachers' pedagogical knowledge of chemical demonstration teaching.

Semi-Structured Interviews

Semi-structured interviews have significant application in probing teachers' thinking (Calderhead, 1981a). A semi-structured interview is one where the interviewer asks a series of structured questions and then probes more deeply, using open-ended questions, to obtain a more thorough understanding of the respondent's answers and the reasons behind them. Semi-structured interview questions are often integrated into a larger clinical interview design.

Novak and Gowin (1984) provide several practical suggestions for conducting semi-structured interviews that probe conceptions and propositions that individuals hold in their cognitive structures. To conduct effective interviews, interviewers must be thoroughly familiar with the material to be covered, carefully listen to an informant's response, create a calm and relaxed interview atmosphere, use probes or rephrase questions when insufficient or "don't know" responses are provided (particularly with semi-structured interviews), use the informant's own language, avoid irrelevant discussion, and end the interview on a positive note.

In a study conducted by Peterson and Comeaux (1987), a set of structured interview questions were directed to teachers after
viewing videotaped teaching episodes of a high school history class. The interview questions asked novice and experienced teachers to recall as many classroom events as possible and to discuss alternative interactive decisions the videotaped teacher could have made. The interview helped these researchers distinguish between experienced and novice teachers in terms of their schemata for classroom events and their analysis of classroom management problems arising during interactive teaching. (See discussion of findings on p. 35).

Carter, Sabers, Cushing, Pinnegar, and Berliner (1987) employed interviewing techniques to examine teachers' knowledge of students. In their study, teachers were given 40 minutes to prepare a two-day lesson plan in mathematics or science after receiving extensive information about the class they were to take over. The semi-structured interview which followed this task asked teachers to recall, generalize, and explain issues related to their lesson plan and the students. The protocols obtained from the questions yielded basic data on the information processing abilities of experienced and novice teachers.

In this study, a semi-structured interview followed the critical-stop task. Its chief goal was to further determine the nature and extent of an individual's pedagogical content knowledge with respect to the demonstration teaching of two basic chemical concepts by soliciting and probing for information not volunteered during the think-aloud task.

Reliability and Validity in Qualitative Research

In as much as reliability is concerned with the replicability of scientific findings, validity is concerned with the accuracy of
scientific findings. Questions about reliability and validity can be raised at two levels in qualitative studies. One is at the data gathering (measurement) level, the second is at the analysis (interpretation) level.

**Reliability at the measurement level.** Discussions about the reliability of measurement typically center around the issue of whether repeated measures with the same instrument on a given sample would yield similar results. In qualitative studies, the reliability of the verbal report data themselves is seldomly discussed. This is because verbal protocols based on a subject’s performance on two equivalent interview tasks are not expected to be identical. Words, sentences, and paragraphs will differ with each administration of a task. In qualitative research the issue of reliability of verbal report data is sometimes resolved by determining its validity (e.g., predicting behavior on similar tasks) (Shavelson, Webb, & Burstein, 1986). Adequate reliability at the measurement level is inferred if predictive validity can be demonstrated.

**Reliability at the interpretation level.** Clearly, verbal protocols obtained from subjects engaged in equivalent tasks would not be identical. Nevertheless, one would expect that for similar tasks and levels of performance, similar decision-making or problem-solving processes would be evident. In this context, reliability estimates refer to the consistency with which a particular coding scheme can be applied – one that records, for example, the kinds and number of statements about subjects’ interactive verbal behaviors (Shavelson, Webb, & Burstein, 1986). This type of reliability is often referred to as intercoder reliability. It corresponds to a measure of
reliability at the data analysis level (not the data gathering level) of qualitative research. Goetz and LeCompte (1984, p. 210) similarly define (internal) reliability in qualitative research as follows: "Internal reliability refers to the degree to which other researchers, given a set of previously generated constructs, would match them with data in the same way as did the original researcher."

Reliability in coding verbal discourses can be estimated in several ways. The simplest estimate requires having two coders categorize subjects' statements into one of several pre-determined categories and then calculating percent coder agreement. The coding categories can be derived from theory or previous research, or they may emerge from the data itself through an iterative process. A combination of these two sources is also feasible. Borg and Gall (1983, p. 479) indicate that in observational research, intercoder agreement levels above 70% are usually obtained among trained observers who must make inferences or evaluations about a given behavior or set of behaviors. In coding interview protocols and journal entries, researchers have reported intercoder agreement levels of about 75% or above (Borko, Lalik & Tomchin, 1987; Johansson, Marton, & Svensson, 1985).

If the number of coding categories is small, e.g. less than 4, chance contributes measurably to intercoder agreement values. In such instances, Kang (1987) suggests using Scott's Pi to correct for chance coding agreement. This correction provides a less biased value for intercoder reliability.

Validity at the measurement level. Several validity issues arise when interview methods are used to gather information on an
individual's internal cognitive states. Schuster (1983) discusses some of these issues in terms of confounding variables that deserve attention when a researcher presents himself as the primary research instrument, i.e., as interviewer. These variables include cueing, prompting, and suggestibility by the interviewer. Other confounding variables include concept modification and learning by the interviewed subject during the interview session. Some of these potential threats to validity can be minimized through the acquisition of basic clinical interviewing skills. These skills, include keeping informants motivated and at ease, and avoiding the above-mentioned pitfalls discussed by Schuster. Such skills can be developed through practice, feedback, and conscious efforts (Pines, 1978; Posner & Gertzog, 1982). Field testing of interview questions in terms of clarity and proper sequencing can further contribute to the generation of accurate data.

Ericsson and Simon (1980) have theorized about the probable validity of verbal reports generated by several process-tracing techniques (e.g., think aloud, retrospective interview, stimulated recall) as a source of legitimate data on cognitive processes. On the basis of their theory of human cognition and from studies of the characteristics of the verbal reports produced by various process-tracing techniques, they reported that the think-aloud method, when applied to verbal tasks, theoretically produces the most valid data of an individual's cognitive processes. Shavelson, Webb, and Burstein (1986) indicate that the think-aloud method typically produces verbal protocols as complete as possible, has a negligible effect on processing time, and does not distort the structure and course of cognitive processes. When think-aloud methods are applied
to nonverbal (e.g., visual) tasks, it appears to increase interviewees' processing time but does not distort the data. Retrospective methods, on the other hand, are susceptible to some decrements in completeness and some distortion when subjects are asked to give an account of earlier thinking processes.

**Validity at the interpretation level.** During the process of interpreting verbal data, threats to internal and external validity need to be given careful consideration (Krathwohl, 1985; Goetz & LeCompte, 1984; Drew & Hardman, 1985). In experimental studies, internal validity is characterized by successfully controlling (or accounting for) all systematic influences between two groups except the one under study (Drew & Hardman, 1985). Internal validity in qualitative research more typically refers to the extent to which scientific observations and measures are authentic representations of a particular reality (Goetz & LeCompte, 1984). Threats to internal validity common to both research paradigms include history and maturation, observer effects (instrumentation), selection and regression, mortality, and interview/test practice.

External validity refers to the generalizability of results to other relatively similar situations. For qualitative research, Goetz and LeCompte (1984, p. 210) provide the following definition: "External validity refers to the degree to which representations [of some reality] can be compared legitimately across groups." Threats to external validity arise from population-sample differences, artificial research arrangements, and multiple treatment interference.
Analyzing Qualitative Data on Teachers’ Knowledge

Analysis of verbal data can take on two general forms: one focuses on the meaning of the content present in a written transcript, the other on the frequency with which specific forms of written communication appear in print. The first approach, with its emphasis on meaning, is characterized as Spradley’s approach, and consists of a collection of techniques for analyzing qualitative data. The second approach is a content analysis (Berelson, 1952; Williamson, Karp, Dalphin, & Gray, 1982). Both of these methods of analysis are discussed in the review which follows and represent techniques used in the present study.

Spradley’s Approach

Spradley (1980) recommends several useful methods for analyzing qualitative data. His description of these methods is given from an ethnographic perspective, but the methods are equally applicable to the analysis of qualitative data associated with science education research (Crosby, 1987; Swamy, 1986). His methods were written to provide ethnographic researchers with a systematic approach for analyzing field notes obtained from direct observation of a cultural setting and from interviews held with informants. Spradley’s techniques are particularly useful in generating grounded hypotheses and understanding the meaning of terms and ideas held by subjects in a given cultural setting. His approach consists of four analytic strategies: domain analysis, taxonomic analysis, componential analysis, and theme analysis. These four strategies were applied to the data gathered in this study.
Domain analysis. Domain analysis involves a systematic search for conceptual categories by grouping verbalizations that possess similar linguistic patterns or semantic relationships (Spradley, 1979, 1980). The first step in identifying semantic relationships in the verbal data is to identify meaningful statements derived from the written protocols. These statements, sometimes referred to as propositions (a statement with a subject and predicate), provide the raw data for a domain analysis. Domains emerge from the data by the nature of the semantic relationships that occurs between the subject and predicate in given propositions. These relationships may be characterized as descriptive, cause and effect, evaluative, rationale, attribution, function, sequence, or some other linguistic form. The purpose of a domain analysis is to provide a broad overview of the data (Spradley, 1980). Once such an analysis has been conducted, a taxonomic analysis can be performed on the propositions that have been coded into domains.

Taxonomic analysis. This analysis consists of a search for categories and subcategories within a recognized domain. Spradley (1980) provides an illustrative example of an ethnographer who seeks to understand the written forms of communication in a particular culture. From the researcher’s field notes he identifies several domains of printed materials, including books, journals, magazines, notes and letters. A taxonomic analysis of the magazine domain yielded several categories including literary magazines, practical magazines, comics, and news magazines. Further taxonomic analysis of the news magazines category yielded subcategories consisting of specific examples such as Time, Newsweek, and U.S. News & World
Report. Although this example involves an analysis of a cultural setting of interest to ethnographers, it brings out the purpose of a taxonomic analysis, namely, to search for similarities and differences within a specified domain. Collectively, a domain analysis and taxonomic analysis serve to organize and represent large quantities of verbal data in terms of meaningful categories.

Componential analysis. A componential analysis is a systematic search for contrasts within a domain or taxonomic category. Contrast may be found between terms (units of meaning) or between contrasting groups of subjects. With the available data, the researcher decides which domains and taxonomic categories receive a componential analysis. This analysis may extend to include all domains and categories identified by the researcher or it may include only those domains and categories most central to the study.

Theme analysis. A theme analysis involves a search for the relationships among domains and for how they are linked to a particular setting, e.g., middle school science teaching. A theme reflects a principle evident across a number of domains. Its presence is supported by implicit and explicit statements made by informants. In this study, the goal of the theme analysis was not to identify new themes or components of teachers' professional knowledge base, as much as it was to help verify the extent that the literature-identified themes, pedagogical content knowledge and general pedagogical knowledge, were actually evident in the data.

In the current study, the data analysis techniques recommended by Spradley (1979, 1980) are used to (1) examine the nature of chemical demonstrators' pedagogical discourses, (2) contrast chemical
demonstrators' pedagogical discourses, and (3) provide categories for a quantitative content analysis of the verbal data.

Content Analysis

Content analysis represents a broad and complex type of research technique for analyzing qualitative data. Berelson (1952) describes it as an "objective, systematic and quantitative description of the manifest content of communication." It is most often used to detail the frequency with which symbols, concepts, or themes appear in a written document (Williamson, Karp, Dalphin, & Gray, 1982). This technique has been successfully employed in several qualitative studies in education. They include studies that have examined the nature and emphasis of supervising teachers' written evaluations of student teachers (Cicirelli, 1969) and of college students' conceptions of chemical processes (Basili, 1988; Crosby, 1987; Swamy, 1986). It has also been used to study the relationship of science teachers' subject-matter knowledge to their thinking about preactive and interactive teaching (Hashweh, 1987). In each of these studies, the investigator coded and enumerated the frequency of verbal statements within pre-defined categories or categories that emerged from the data.

Content analysis places emphasis on a quantitative description of communications. It allows a researcher to characterize a large volume of materials rather efficiently with one or a small number of frequency tables. These frequency tables essentially summarize the number of times each content category or subcategory is present in a written document or a verbal protocol.
Chapter Summary

This chapter examined the components of teachers' professional knowledge base with particular emphasis on teachers' pedagogical content knowledge and its development through pedagogical reasoning. It also examined the influence of inservice education on science teachers' professional development. The chapter culminated with a review of several cognitive methods used to probe teachers' thinking. This body of information served as a theoretical and empirical base for the present study.
CHAPTER 3
RESEARCH DESIGN AND PROCEDURES

This study probes the pedagogical content knowledge and general pedagogical knowledge systems (Shulman, 1986, 1987) of experienced and novice chemical demonstrators. It also investigates the nature of novice chemical demonstrators' pedagogical knowledge growth resulting from participation in a two-week chemical demonstration workshop. This chapter describes the characteristics of the research subjects and inservice workshop, the methods used to assess teachers' pedagogical knowledge of chemical demonstrating, the research design, and the data analysis procedures.

Characteristics of Research Subjects

The research participants involved in this study consisted of eight science teachers who were novices at chemical demonstrating and five who served as experienced demonstrators. The novices were selected from a pool of workshop participants possessing lower levels of chemical demonstration teaching experience. The experienced demonstrators were instructors in a two-week chemical demonstration workshop (Workshop B: Chemistry Supplements for Pre-High School Classes). The workshop was offered by the Institute for Chemical Education (ICE) at the University of Maryland (UMCP) during the summer of 1987.

Enrollment in ICE Workshop B (Session II) consisted of twenty-three science teachers who were fully or provisionally certified at the elementary, middle, and high school level. All the
participants had teaching assignments that included physical science. ICE staff carefully selected the participants from a larger pool of applicants based on their potential to transfer the knowledge and skills acquired at the workshop to other science teachers in their school district. This potential was based on prior experience in conducting inservice science programs in their local school districts and on leadership skills reflected in their ICE workshop application (Appendix A, the second short answer question regarding applicants' prior experiences in presenting outreach programs and developing educational materials).

Before the inservice workshop began, pertinent background information on each of the summer institute participants was collected using the Participant Information Form (PIF) 1 and participants' application to the program.

The Participant Information Form was mailed to the participants three weeks before the workshop started. Twenty-two participants completed this questionnaire and returned it to the researcher prior to the start of the workshop. One person, living overseas, did not receive the questionnaire in time. The workshop instructors also completed the participant questionnaire.

This researcher rank-ordered all Workshop B participants on the basis of their self-reported confidence and weekly use of chemical demonstrations as indicated on the PIF. Appendix C shows the grouping of the ICE teachers according to demonstration confidence and experience. Those in the lower 50th percentile along both indices

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1 The PIF is described in a later section under Data Collection Procedures (p. 80). (See Appendix B for the PIF).
were considered novices and candidates for the study. A few subjects that ranked low on one index and not the other were also considered. One subject, (N6), reported novice-intermediate credentials on both scales, however, his limited teaching experience and limited chemistry background qualified him as a novice candidate. Two ICE workshop instructors later added support to his classification as a novice chemical demonstrator by providing this researcher with a general assessment of his public demonstrations.

The PIF identified twelve less experienced (novice) chemical demonstrators among the workshop participants. This identification was found to be consistent with background information provided on the workshop application form.

Each of the identified novice demonstrators was mailed a letter seven to ten days prior to the start of the workshop requesting voluntary participation in this research study (see Appendix D). Follow-up phone calls confirmed the voluntary participation of six novices. Two others confirmed their interest in the study on the day of their arrival. These eight teachers served as a group of novice chemical demonstrators and the workshop instructors served as experienced chemical demonstrators. The four novices who did not participate in the study either arrived at the workshop after the eight interview slots were filled or could not schedule time for a pre-workshop interview. Table 1 describes the self-assessed confidence and weekly use in conducting chemical demonstrations reported by the five experienced chemical demonstrators and eight novice chemical demonstrators who volunteered for this study. The
Table 1
Reported Confidence and Use of Science Demonstrations

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Novice (n = 8)</th>
<th>Experienced (n = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Confidence in using chemical demonstrations</td>
<td>2.4</td>
<td>4.8</td>
</tr>
<tr>
<td>2. Confidence in using other demonstrations</td>
<td>3.8</td>
<td>4.8</td>
</tr>
<tr>
<td>3. Number of chemical demonstrations per week</td>
<td>0.5 a</td>
<td>4.4</td>
</tr>
<tr>
<td>4. Number of other demonstrations per week</td>
<td>2.2 a</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Notes.
- Confidence Scale: 1/Low ---> 5/High
- a PIF response of < 1 was considered "zero" for the purpose of calculating a group mean.

The confidence scale consisted of a five-point rating scale with categories ranging from 1 (Low) to 5 (High).

The sampling strategy of using novices and experienced chemical demonstrators in this study served the purpose of potentially discriminating between subjects having high and low levels of specialized knowledge of chemical demonstration teaching. Novice demonstrators were also of interest to this study because they had the potential for showing the greatest cognitive gains resulting from workshop participation. Furthermore, the selection of novice subjects mitigated against possible ceiling effects that could have been encountered with more experienced workshop participants.

Description of the Experienced and Novice Chemical Demonstrators

The experienced chemical demonstrators were the instructors for ICE Workshop B. Their experience in conducting chemical demonstrations and in providing numerous inservice workshops on
chemistry teaching strategies provide justification for their classification as experienced chemical demonstrators. Because the research literature continues to debate the validity of the criteria used to identify expert pedagogues (Berliner, 1986; Sloan & Capie, 1987), the term "experienced chemical demonstrators" will be used instead. The term "proficient" (Berliner, 1988), which probably represents a conservative description of the modal skill level of the five workshop instructors, has not yet received wide adoption in the literature. Verification of even such skill levels, as with expert skill levels, remains a problem; therefore, the term "experienced" becomes the preferred descriptor for the workshop instructors examined in this study.

The five experienced demonstrators included the four instructors of ICE Workshop B and one special guest lecture-demonstrator who made two presentations at the workshop. The eight novice demonstrators represented about a third of the participants who enrolled in the 1987 ICE Workshop. The novice demonstrators included one elementary school teacher, five middle school teachers, and two high school teachers.

Tables 2 and 3 provide additional background information on the experienced and novice chemical demonstrators, in particular, their science teaching experience, college chemistry training, and experience in conducting chemical demonstrations workshops. The information suggests that the experienced demonstrators' specialized knowledge and skill in conducting chemical demonstrations is derived from their extensive (1) science/chemistry teaching experience, (2) upper-level college chemistry knowledge, and (3) experience (weekly
Table 2

Teaching Experience and Chemistry Training of the Novice and Experienced Chemical Demonstrators

<table>
<thead>
<tr>
<th>Teaching Experience and Chemistry Training</th>
<th>Group (Mean or Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novice</td>
</tr>
<tr>
<td>1. Number of years teaching experience in the sciences (bio, chem, phys sci)</td>
<td>7.0</td>
</tr>
<tr>
<td>2. Number of college chemistry courses</td>
<td>3.4</td>
</tr>
</tbody>
</table>

use) in conducting chemical demonstrations in science classrooms. These demonstrators have also had (4) considerable experience in conducting chemical demonstration workshops (Table 3). Novices' prior knowledge and skill in conducting chemical demonstrations was derived from their (1) physical science teaching experience, (2) introductory college chemistry coursework, and (3) occasional experience (weekly use) in conducting chemical/science demonstrations (see Tables 1 and 2). These teachers had essentially no experience in conducting chemical demonstration workshops (Table 3).

The pre-workshop grouping of the participants and instructors (Appendix C) reveals the range of demonstration experience and chemistry training found among the two groups of chemical demonstrators participating in this study. The background information obtained from the experienced subjects (workshop instructors) showed two distinct subgroups in terms of their chemistry training and teaching grade level (Appendix C, Table C-2). One subgroup consisted
Table 3
Confidence and Experience with Chemical Demonstration Outreach Programs

<table>
<thead>
<tr>
<th>Outreach-Related Criteria</th>
<th>Group (Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novice</td>
</tr>
<tr>
<td>1. Confidence in chemical demonstration outreach programs</td>
<td>2.6</td>
</tr>
<tr>
<td>2. Number of chemical demonstration outreach programs per year to students</td>
<td>0.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3. Number of chemical demonstration outreach programs per year to other teachers</td>
<td>0.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Notes.
- Confidence Scale: 1/Low ---> 5/High
- <sup>a</sup> PIF response of < 1 was considered "zero" for the purpose of calculating a group mean.

of an upper elementary and a middle school science teacher, (i.e., experienced demonstrators E1 and E2), who had completed two and seven courses in college-level chemistry, respectively. The other subgroup consists of two high school chemistry teachers and one community college chemistry teacher, all having completed over 12 college-level chemistry courses. Novices showed a smaller range of chemical demonstration experience and chemistry training (Appendix C, Table C-1). This limited range is partially attributed to the consistently low levels of chemical demonstration experience and basic college chemistry training the novice group possessed. Experienced and novice subjects showed a similar range in teaching grade level.

Throughout this document, the term "demonstrator" will refer to both the experienced and novice chemical demonstrators. When
referring to a specific group, the terms "experienced chemical demonstrator" or "novice chemical demonstrator" will be used.

**Characteristics of the Inservice Workshop**

This section describes the objectives and basic components of ICE Workshop B. It discusses the time allocated for the various workshop components, the content of the staff presentations, and the training model used to foster professional development among the participating teachers.

**Workshop Goals and Objectives**

The ICE workshops offered during the summer of 1987 were widely publicized through the mailing of several thousands of brochures to classroom teachers around the country. ICE Workshop B (Chemistry Supplements for Pre-High School Classes) was one of the workshops for which teachers could apply. Workshop B was offered at four sites around the country, including the University of Maryland (College Park). The 1987 ICE brochure and application form (Appendix A) describes the dual objectives of Workshop B: To help teachers (1) "learn and practice effective and safe demonstrations, experiments, and activities appropriate for younger students and (2) learn interactive teaching methods." These objectives are consistent with the goal of all ICE workshops: "to provide first-hand experience with descriptive teaching methods, and to help participants strengthen their background in chemistry so that they can encourage more questioning and exploration by students ... [and] to help participants
prepare to present in-service workshops for teachers at other schools in their communities.

Workshop Components and Schedule

ICE Workshop B was designed around five inservice workshop components (Bell, 1987; O'Brien, 1987). These components included:

1. Staff content presentations and demonstrations - model presentations and teaching tips on how to utilize demonstrations in a classroom setting and how to design outreach programs;
2. Participant "library" research - an opportunity to examine various sourcebooks of chemical demonstrations to select suitable demonstrations;
3. Individual participant "lab time" to practice self-selected demonstrations from 50 boxed demonstrations (listed in Appendix E);
4. Individual presentations of demonstrations before peers (microteaching); and
5. Work with the laboratory-based Summer Chem Camp for sixth through eighth graders.

A schedule of the workshop (Appendix F) shows how time was allocated for the major workshop components. Table 4 summarizes the time distribution. This table shows that Workshop B provided participants with over 70 hours of chemical demonstration education across a two-week period. Approximately one-third of this time was devoted to staff and guest presentations. Participant preparation, presentation, and feedback of chemical demonstrations performed before peers and middle school students accounted for most of the remaining two-thirds of the workshop.

Each staff presentation was videotaped or audiotaped in order to capture the content of the presentations and to document the formal
Table 4
Core Training Components for All Participants

<table>
<thead>
<tr>
<th>Component</th>
<th>Allocated Time (Hours)</th>
<th>% Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Theory and Modeling:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction/Logistics</td>
<td>4.5</td>
<td>6</td>
</tr>
<tr>
<td>Staff Presentations</td>
<td>15.5</td>
<td>21</td>
</tr>
<tr>
<td>Guest Presentations</td>
<td>4.5</td>
<td>6</td>
</tr>
<tr>
<td><strong>Subtotal:</strong></td>
<td><strong>24.5</strong></td>
<td><strong>34</strong></td>
</tr>
<tr>
<td><strong>Practice and Feedback:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant laboratory time</td>
<td>18.5</td>
<td>25</td>
</tr>
<tr>
<td>Participant public demos w. feedback</td>
<td>26.0</td>
<td>35</td>
</tr>
<tr>
<td>Videotape Feedback</td>
<td>1.25</td>
<td>2</td>
</tr>
<tr>
<td>(Individually scheduled)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal:</strong></td>
<td><strong>45.75</strong></td>
<td><strong>62</strong></td>
</tr>
<tr>
<td>Social events</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Evaluation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>74.25</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

instruction the participants received. Appendix G gives a brief description of the formal staff presentations. The first staff presentation addressed the expectations for the workshop participants. A workshop handout summarizes these expectations (Appendix H).

The Microteaching Model

Three of the five workshop components (1, 3, and 4 listed above) approximate an "observe, practice, and critique" model of microteaching (McIntyre, MacLeod, & Griffiths, 1977). This model is frequently incorporated into preservice and inservice programs that stress the acquisition of teaching skills (Gliessman, 1981). During
the observation phase of the microteaching model, participants would observe workshop instructors perform several chemical demonstrations. This would be followed by brief discussions of the characteristics of effective demonstration teaching as modeled by the workshop instructors. This training strategy assumed that participants would transfer some of the knowledge and skills acquired by observational learning (Hunter, 1984) to their own chemical demonstration performances.

The workshop participants indicated that they practiced about 15 different boxed chemical demonstrations during the course of the workshop (Appendix E). These boxed chemical demonstrations were different from those modeled by the workshop instructors. The workshop participants publicly performed at least three of the demonstrations they practiced. Participants were assigned their first chemical demonstration for presentation, whereas they could select demonstrations for subsequent presentations. With the exception of the Chem Camp presentations, each public presentation represented a different chemical demonstration. Furthermore, the public presentations given by novice participants represented chemical demonstrations other than the two observed on videotape during the pre- and post-workshop interviews.

After the workshop participants practiced and presented a chemical demonstration, the workshop instructors and the workshop participants provided brief verbal feedback to the presenter. This researcher, or one of the ICE workshop instructors, would also provide feedback to the participants in a private session using a videotape of their presentation. Providing workshop participants with group and
private feedback on their public performance was an important design characteristic of the workshop.

During the videotape playback sessions, novice demonstrators would observe their demonstration performances and critique them using the critical-stop method described later in the methods section of this chapter (p. 86). Following this self-evaluation task, an ICE instructor, or this researcher, would ask the demonstrator to think about and discuss any additional strengths and weaknesses that would come to mind. The workshop staff (instructors and this researcher) would usually provide a few additional comments at the end of the self-evaluation session in order to reinforce issues discussed during (1) the formal staff presentations and (2) the feedback sessions that followed the public presentations. The primary emphasis of these private feedback sessions, however, was on having the workshop participants observe, identify, and discuss salient features of their public presentations as seen on videotape.¹

Novice participants involved in this study received feedback on two (in some cases three) of their public demonstrations by critically viewing their videotaped presentations in private session with this researcher. The remaining workshop participants observed their videotaped performances on only one occasion (a half-hour private

¹ It is assumed, here, that the closing comments provided by this researcher, who attended all staff presentations, were similar in nature to the comments provided by other workshop instructors. This researcher’s closing comments were based on each novice demonstrators’ self-evaluations as well as on select issues discussed during earlier staff presentations. The workshop instructors did not provide this researcher with formal instructions as to what to say during these private sessions, although on one or two occasions they did suggest bringing up a particular point that may not have been adequately addressed in a given public feedback session.
The teach-reteach cycle frequently associated with microteaching was implemented during the later part of the workshop as teachers presented some of their publically performed demonstrations a second time to Chem Camp Kids. The workshop training model differed from microteaching model in that instead of focusing on and modeling one teaching skill (e.g., questioning for feedback, clarity of explanation, use of examples, higher order questioning and probing), the workshop focused on the integration of several demonstration teaching skills simultaneously.

Research Methods

This research examined science teachers’ pedagogical content knowledge and general pedagogical knowledge (Shulman, 1986, 1987) by eliciting teachers’ think-aloud critiques of selected chemical demonstration videotapes and by conducting semi-structured interviews. These two techniques helped generate qualitative data on the influence of a short-term intensive inservice workshop on novice chemical demonstrators’ pedagogical knowledge growth. The two techniques also served as a probe of experienced chemical demonstrators’ pedagogical knowledge so that their knowledge of chemical demonstrating could be compared to that of pre- and post-workshop novices.

Videotape Selection

Experienced and novice chemical demonstrators viewed two videotaped chemical demonstrations: the Collapsing Aluminum Can demonstration (Demo A) and the Density Column demonstration (Demo B). These two demonstrations address the concepts of air pressure and
density, respectively, and represent two concepts that receive repeated emphasis in pre-college physical science classes and in the ICE workshop.

A favorable and unfavorable videotaped version of Demo A and Demo B were selected from a collection of videotapes obtained during the 1986 and 1987 (Session I) ICE workshops. Demonstration performance quality was determined by a panel of experienced science teachers (i.e., three science education graduate students and five certified high school science teachers) during the pilot phase of the study.

Performance quality was gauged in two ways: (1) the ratio of strengths to weaknesses identified in each videotape using the critical-stop method (described in detail below) and (2) the overall performance rating of the videotaped demonstration on a Likert-type scale (See Clinical Interview Guide, Question I. 6, Appendix I). These two criteria were used to help select the videotapes and to assign a general performance rating to the videotaped presentation as either favorable (+) or unfavorable (-).

Ten videotapes were evaluated during the pilot phase of the study. Four of the tapes showed the desired characteristics using the critical-stop task and Likert-type rating. These four videotapes featured chemical demonstrations performed by four different chemistry/physical science teachers. The targeted chemical concept and the general performance rating reflected by the teachers in the four videotapes are summarized in Table 5. The playing times of the videotapes ranged from 3.5 to 9.5 minutes.

Using parallel versions of Demonstrations A and B prevented teachers from having to evaluate the same videotapes at the beginning
Table 5
Descriptive Overview of the Four Videotapes Used in the Critical-Stop Task

<table>
<thead>
<tr>
<th>Demo. ID Code (A./B.)</th>
<th>Videotape #, Title of Demonstration</th>
<th>Chemical Concept, General Rating, +/-</th>
<th>Duration of Videotape (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>#1 Collapsing Aluminum Can</td>
<td>Air Pressure, +</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>#2 Collapsing Aluminum Can</td>
<td>Air Pressure, -</td>
<td>3.5</td>
</tr>
<tr>
<td>B.</td>
<td>#3 Density Column</td>
<td>Density, +</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>#4 Density Column</td>
<td>Density, -</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Note. + = Favorable Model    - = Unfavorable Model

and end of the workshop. This strategy was designed to minimize problems associated with "test practice" that may influence subsequent test response and threaten the internal validity of the investigation (Drew & Hardman, 1985; Isaac & Michael, 1983). In this study, a parallel set of tapes refers to two videotapes of a specific chemical demonstration that differ notably in overall performance quality.

The average Likert-type performance rating and the number of strengths to weaknesses observed in the four videotapes selected for the study are given in Table 6. These data represent the general findings of a panel of experienced science teachers and science education graduate students who critiqued the videotapes during the pilot phase of the study. The data provided preliminary evidence that Tapes #1 and #2 (The Collapsing Aluminum Can Demo) and Tapes #3 and #4 (The Density Column Demo) represented parallel sets of videotapes.
Table 6
Critical-Stop Piloting of Videotapes #1-4

<table>
<thead>
<tr>
<th>Concept</th>
<th>Videotape #, Type of Model, No. Raters (n)</th>
<th>Average Number</th>
<th>Performance Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Str</td>
<td>Wk</td>
</tr>
<tr>
<td>A. Air Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#1</td>
<td>Favorable Model, (3)</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>#2</td>
<td>Unfavorable Model, (4)</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>B. Density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td>Favorable Model, (4)</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>#4</td>
<td>Unfavorable Model&lt;sup&gt;a&lt;/sup&gt;, (2)</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

Notes:
(1) Str = Strengths, Wk = Weaknesses
(2) Rating Scale: 1/Low ---> 5/High
<sup>a</sup> Because the average number of strengths and weaknesses identified for this videotape was similar, the "Unfavorable" designation was determined by the Likert-type rating.

Analyses of these videotapes by the experienced chemical demonstrators in this study later verified these ratings (See the data discussed in Chapter 4, p. 123. For a list of the major strengths and weaknesses identified by the experienced group, see also Appendix Q). The first tape in each set (#1 and #3) represents a favorable model of chemical demonstration teaching. The second tape in each set (#2 and #4) represents an unfavorable model. These ratings were gauged by the relative number of strengths and weaknesses identified for each videotape and the Likert-type overall performance rating.

Videotapes #2 and #3 were obtained from the 1986 ICE Workshop B offered at the University of Maryland. Videotape #1, which paralleled videotape #2, was obtained during the first summer session of Workshop
B (1987). Because no equivalent videotape could be found during summer session I (1987) that would parallel Videotape #3, Videotape #4 was staged. The staged performance involved a certified science teacher performing the Density Column demonstration in front of a small group of science education graduate students. The volunteer teacher received the ICE workshop sourcebook several days before being videotaped so she could familiarize herself with the demonstration. She also received the same demonstration materials the workshop participants used to help her practice and perform the demonstration.

Appendix J provides the scripts of the four videotaped presentations. A description of the Collapsing Aluminum Can demonstration and the Density Column demonstration is given in Appendix K. The descriptions come from the ICE demonstration sourcebook (Sarquis & Sarquis, 1987). The four videotapes provided close-up shots of a chemical demonstrator performing the selected air pressure or density demonstration. The "student audience" for three of the videotapes consisted of Summer Session I workshop participants asked to play the role of middle school students. The staged videotape (Videotape #4) used science education graduate students to play the role of middle school students. These "students" were not seen on videotape unless one was asked to be a volunteer to assist with the demonstration. The sound track on the videotape, however, revealed considerable teacher-student interactions. A content analysis of the scripts showed that about 23% of the statements across the four videotapes consisted of teacher questions and about 54% consisted of declarative teacher statements. Student talk comprised about 24% of the statements. Most of the questions asked by the
videotaped teachers were direct questions aimed at the "student" audience; a smaller number (about 6%) were rhetorical questions. A content analysis of the verbal interactions recorded on each videotape is provided at the end of Appendix J (Videotape Scripts, Table J.1).

Data Collection Procedures

Participant questionnaires and qualitative research methods were used to help answer the four research questions presented in chapter 1 regarding teachers' pedagogical content knowledge. The qualitative methods consisted of a think-aloud task and a semi-structured interview which together constituted the clinical interview.

Participant Questionnaires

Participant Information Form, PIF. The Participant Information Form (Appendix B) provided this researcher with background information on the workshop participants and instructors. Its purpose was to obtain a pre-workshop assessment of the general level of experience each research subject possessed with respect to chemical demonstration teaching. The data helped identify the less experienced/novice chemical demonstrators participating in the workshop based on their self-reported confidence and weekly use in conducting chemical demonstrations.

The PIF used in this study was a modification of a PIF originally developed by O'Brien (1987). The original questionnaire was shortened for this study by deleting two sections that were not pertinent to this researcher or to the workshop designers. The modified form also simplified the response to one item and added a question about teachers' confidence in conducting outreach programs involving
chemical demonstrations. The form was reviewed for clarity and completeness by a second science educator before it was mailed to the participants.

The PIF contained questions about the research subjects' science teaching experience, number of college chemistry courses taken, confidence in conducting chemical demonstrations, and weekly frequency in conducting chemical and other science demonstrations. It also asked about the research subjects' awareness and use of various chemical demonstration sourcebooks. The remaining three questions on the questionnaire contained items that were of interest to the workshop designers. The confidence scale used in the questionnaire consisted of a five-point weighted judgment rating scale (i.e., 1 = low, 5 = high).

Demonstration Log. This questionnaire/form provided information on the chemical demonstrations that the novice demonstrators had an opportunity to practice. The Log (Appendix L) accompanied each of the 50 boxed demonstrations. Workshop participants were asked to sign the designated Log after successfully practicing a boxed demonstration. The information obtained from this Log aided this researcher in keeping track of the kinds and number of chemical demonstrations practiced by the participants during the workshop.

Density and Air Pressure Demonstration Checklist. This form helped verify the information provided by the Demonstration Log. It also provide information on the demonstrations the workshop participants had seen performed by an ICE workshop instructor or a workshop peer. This form (Appendix M) contains the titles of all the boxed demonstrations that related to the concepts of density and air
pressure. The titles were taken from the ICE sourcebook (Sarquis & Sarquis, 1987). At the end of the workshop, novice demonstrators were asked to indicate on the checklist which of the listed demonstrations they had an opportunity to observe or perform during the workshop. Responses obtained from this checklist were cross-examined with responses obtained from the Demonstration Log as well as a posted workshop schedule of publicly performed demonstrations. The data obtained from the Checklist provided useful information pertaining to the nature of the workshop intervention experienced by the inservice science teachers, e.g., the number of boxed demonstrations novices actually practiced with respect to the targeted concepts. These numbers also made it possible to compare the frequency of novices' post-workshop responses to interview question I.9 (Appendix I) regarding alternative chemical demonstrations on the targeted concepts, to the number of demonstrations they actually performed (or observed) on these concepts.

Clinical Interview

A clinical interview was used to assess subjects' pedagogical content knowledge. The clinical interview consisted of two parts, a think-aloud critical-stop task and a semi-structured interview. Novice demonstrators participated in the clinical interviews at the beginning and the end of the two-week workshop. Experienced demonstrators were also interviewed twice as their schedules permitted, i.e., either before, during, and/or after the workshop.

Ericsson and Simon (1984) point out that the type of probes used during clinical interviews (e.g., questions, tasks, and visual stimuli) specifies the type of information reported by individuals.
Consequently, this study used two research methods (a think-aloud task and a semi-structured interview), two chemical concepts (air pressure and density), and four videotapes to help ensure validity of assessment. The strategy served to increase the chance of obtaining a full picture of teachers' pedagogical knowledge of demonstrating fundamental chemical concepts.

Research subjects were randomly assigned to one of two clinical interview testing groups. Half of the experienced and novice subjects were randomly assigned to view Tapes #1 and #4 during the pre-workshop interviews while the remaining subjects were assigned to view a parallel set of these Tapes (#2 and #3). This viewing arrangement was reversed in the post-workshop interviews. The technique of counterbalancing the order of administration of the two sets of videotapes was designed to eliminate the possible confounding of order of testing effects with treatment effects. Each viewing session presented the more highly rated demonstration first so that the viewing sessions could begin in a positive manner and with an atmosphere of trust and candor between the researcher and the subject.

Critical-stop task. During the first part of the clinical interview, subjects (i.e., the experienced and novice chemical demonstrators) were engaged in a critical-stop task. This task required the subjects to first view the videotaped demonstration in its entirety, then view it again, stopping the videotape player whenever the subject judged a critical incident to have occurred on the tape. Thus, critical stops were initiated by the subjects. Critical incidents (or critical points) were defined for the subjects as: strengths or weaknesses in the presentation of the demonstration.
With each critical stop, the subjects thought-aloud and discussed features they perceived hindered or promoted effective chemical demonstration teaching. The task served as a probe of demonstrators' pedagogical knowledge of chemical demonstration teaching of two chemical concepts at a middle school level.

Appendix I contains specific instructions that the researcher gave to the demonstrators for the critical-stop task. Before beginning the task, the demonstrators were introduced to the purpose of the interview and the study. They were then provided with instructions on how to conduct the critical-stop task. The demonstrators were asked to think-aloud and discuss features they perceived hindered or promoted effective chemical demonstration teaching during a critical stop. Subjects were told to assume that the demonstrations were presented at the middle school level. As the demonstrators described the critical features, the interviewer did not provide specific reinforcements but indicated that the subjects were providing acceptable responses by saying, "Uh huh," "I see," or "Please tell me more about that." (Novak & Gowin, 1984, p. 130).

Semi-structured interview. The critical-stop task was followed by a semi-structured interview. During this interview, the researcher asked his subjects seven structured questions (Questions I.4 – I.10) and then probed more deeply using open-ended questions in order to obtain more complete data. Borg and Gall (1983) describe this type of interview as a semi-structured interview because of the combined use of structured questions and open-ended questions that vary with the nature of the response provided by the interviewee.
The interview guide found in Appendix I begins with a few warm-up questions (Questions I.1 - I.3), that include questions such as, "Have you ever examined your own or someone else's teaching on videotape? What setting was that in?" and "Have you ever seen this demo before? Have you ever performed this demo before?" asked before the critical-stop task. Next, the researcher asked several questions designed to give the demonstrators an opportunity to identify additional critical features in the videotaped presentation they did not comment on during the critical-stop task (Question I.4) and to summarize the major critical features they observed on videotape (Question I.5). Questions of this nature included, "Are there any other specific strong or weak points in the presentation you haven't already mentioned? What are they? Anything else?" "How would you summarize the major strengths (weaknesses) of the presentation?"

The semi-structured interview was also designed to elicit subjects' overall reaction to the demonstration performance (Question I.6), understanding of the lesson objective (Question I.7), knowledge of alternative demonstrations that could meet the same lesson objective (Questions I.8 and I.9), and understanding of the scientific principles illustrated in the videotaped demonstration (Question I.10). Pertinent questions included, "Do you know of any variation, twist, or extension of this particular demonstration that could be performed? What would it be? Any others?" "Do you know of any other demonstration that shows the effects of air pressure (shows the concept of density)? What would it be? What other demonstrations do you know that shows the effects of air pressure (shows the concept of density)?"
Question I.7 (the intended lesson objective) and Question I.10 (concept explanations) were considered optional items and asked by the interviewer only if there was sufficient time to obtain responses.

The demonstrators were given 50-60 minutes for the critical-stop task and follow-up interview. The interviewer used non-directive questions and responses to help minimize distortion of teachers' evaluative judgments of the videotaped teaching episodes (Shavelson, Webb, & Burstein, 1986). After each response the interviewer prompted the teacher with additional questions such as "Anything else?" or "Can you think of other items?" or "Can you clarify that for me, please?" After the subjects described as many critical features (demonstrations or variations) as he or she was able, the interviewer proceeded to the next item in the interview guide, using the same questioning pattern.

The interview questions served as probes of teachers' thoughts stored in Long Term Memory (LTM) (Shavelson, Webb, & Burstein, 1986). If experienced chemical demonstrators possess richer and more complete pedagogical content knowledge of demonstration teaching of chemical concepts, it would be expected that they would also be able to provide more thorough and detailed responses to the interview questions than the novices. Given that the novice chemical demonstrators had numerous opportunities to observe, practice, and/or perform chemical demonstrations during the inservice workshop, it would also be expected that they could provide more complete answers to the interview questions after the workshop intervention.

**Pilot Study**

The clinical interview method that was used to probe teachers' pedagogical knowledge was piloted prior to and during Summer Session I
of ICE Workshop B. During this time a collection of ten videotapes that addressed the targeted concepts was reduced to four. The early pilot studies used an alternate set of air pressure and density demonstration videotapes because parallel sets were not available during this phase of the research.

The pilot study also provided opportunities to clarify the interview instructions and reduce the ambiguity of interview questions (Appendix I). While piloting the interview guide, the volunteer science teachers were asked at the end of the interview about the ways the instructions and questions could be improved in light of the research goals. These insights were incorporated into the revised interview guide and again tested on selected ICE Workshop participants during Summer Session I. This strategy helped increase the face validity and construct validity of the interview guide in assessing teachers’ pedagogical content knowledge.

The feedback obtained during the pilot phase included comments that suggested the need for this researcher to alter or delete some of the interview questions in order to reduce redundancy in responses. Several subjects also suggested that the term "variation", and other phrases used by the interviewer, be explained to the interviewee. The revisions made prompted this researcher to collapse similar questions into more inclusive interview questions (I.4 - I.5) and define selected terms and phrases more explicitly for the subjects (I.8 - I.10) as shown in the final Interview Guide (Appendix I).

Piloting also made it possible to examine how long it would take to complete the interview and assess testing fatigue. Finally, the pilot phase of the study helped this researcher develop confidence
that the clinical interview research strategies developed for this study could effectively discriminate subjects based on their prior chemistry demonstration teaching experience.

**Research Design to Study Pedagogical Knowledge Growth**

The assessment of pedagogical knowledge growth among novice chemical demonstrators was addressed by a one-group quasi-experimental design (Isaac & Michael, 1983). This design is appropriate when a researcher attempts to study a human behavior, attitude, or cognitive characteristic that is fairly stable without intervention efforts (Borg & Gall, 1983, p.659).

In this study, the dependent variables (e.g., the general characteristics of teachers' critical-stop comments and the number of times they elicited responses in a given taxonomic category) were gathered before and after teachers received the inservice workshop intervention (the independent variable).

Several null hypotheses (where $u_1$ = pretest and $u_2$ = posttest) were tested to assess the impact of the workshop on novice demonstrators' pedagogical knowledge growth (e.g., changes in discourse frequency within specified taxonomic categories).

$$H_0: u_1 - u_2 > 0$$ for the mean number of critical incidents critiqued, (e.g., Str, Wk)

$$H_0: u_1 - u_2 > 0$$ for the mean number of Pedagogical Enhancements, Variations, and Demonstrations elicited during the clinical interview (free-recall).

Similar null hypotheses (where $u_1$ = experienced demonstrators and $u_2$ = pre-workshop novice demonstrators or post-workshop novice demonstrators) were tested to assess quantitative differences in experienced and novice chemical demonstrators' pedagogical knowledge.
base (e.g., differences in discourse frequency within specified
taxonomic categories). The data used to run these tests were taken
from a content analysis of the protocols. Null hypotheses involving
frequency of response to several semi-structured interview questions
(I.6, I.8, & I.9, Appendix I) were tested with parametric statistical
tests. Hypotheses involving critical-stop task critique frequency
required the use of non-parametric statistical tests.

Rejection of the null hypothesis would support the notion that a
two-week, skills-oriented workshop can foster pedagogical knowledge
growth among novice chemical demonstrators in the realm of
demonstrating fundamental chemical concepts to students at the
pre-college level. It would also indicate experienced-novice
demonstrator differences with respect to chemical demonstration
teaching knowledge.

Moreover, qualitative analyses of demonstrators' clinical
interview discourses were conducted to examine experienced and novice
chemical demonstrator differences and pedagogical knowledge growth
from a qualitative perspective. The methods used to conduct the
qualitative analyses of the verbal reports are discussed in detail in
the following section.

**Qualitative Analysis of the Clinical Interview Protocols**

This section describes the various types of analyses conducted on
the protocols containing the record of participants' responses during
the critical-stop task and follow-up interview. It specifies how the
protocols generated information about teachers' pedagogical knowledge
of chemical demonstration teaching. All of the following analyses
were conducted by this researcher, many of which were verified by independent coders.

Analysis of the Critical-Stop Protocols

The research methods of Spradley (1979, 1980) guided the analysis of the verbal data obtained from the think-aloud critical-stop task. These methods included a domain analysis, a taxonomic analysis, a componential analysis, and a theme analysis. This section discusses these four qualitative methods as well as a content analysis technique that permits a quantitative examination of the verbal data (Borg & Gall, 1983).

Domain Analysis

A domain analysis (Spradley, 1979, 1980) was performed on the data by identifying in the written protocols meaningful propositions related to demonstration teaching pedagogy. This was followed by a systematic search for conceptual categories that would group propositions possessing a similar semantic relationship between the subject and predicate. Spradley (1980) provides a list and description of nine domains a researcher could begin with in analyzing verbal reports. These nine domains were included in the domain analysis conducted in this study. Additional domains were generated whenever propositions did not satisfactorily reflect Spradley's suggested nine.

The domain analysis of the teachers' critical-stop discourses showed that most propositions reflected one of four basic domains or semantic relationships. The four domains included one suggested by Spradley and three identified by this researcher. Although a few other semantic relationships were occasionally evident in the verbatim
transcripts, this study did not attempt to come up with the most comprehensive coding scheme, but one that was sound, robust, and in accord with the research goals. Other semantic relationships suggested by Spradley were evident but occurred infrequently. Several of these "infrequent" discourses were shown to adequately fit under one of the four domains identified by this researcher. Chapter 4 shows that these four domains provide a suitable framework for organizing the critical-stop data and for comparing experienced and novice chemical demonstrators' pedagogical knowledge discourses.

Examples of the four semantic forms are provided in Chapter 4 using data (verbal discourses) obtained from the verbatim transcripts. The domain analysis helped identify the major domains describing teachers' pedagogical knowledge discourses (Research Question 1). Inter-coder reliability in encoding individual propositions from the verbatim transcripts into the hypothesized domains was determined. Coding instructions for this task are provided in Appendix N.

**Taxonomic analysis**

After identifying the major domains and classifying propositions according to these domains, a taxonomic analysis was conducted. This analysis consisted of a search for categories and subcategories within each of the domains by searching for similarities and contrasts within the verbal data (Spradley, 1979, 1980).

The taxonomic analysis began by inducing categories of pedagogical issues within an identified domain. If, after generating several categories, a given proposition did not code into an existing category, a new category was generated. After identifying the major
domains, categories, and subcategories, inferences were made about the content of teachers' pedagogical knowledge discourses.

This study identified the most prevalent categories within each domain. It did not attempt to systematically identify the optimal clustering of subcategories and categories to describe teachers' pedagogical knowledge discourses because several legitimate ways of grouping the data emerged. In any case, once the categories and subcategories within a domain were identified, a taxonomy of teachers' pedagogical knowledge discourses was formulated in the form of an outline.

The domains, categories, and subcategories that emerged from the critical-stop data became useful in coding the semi-structured interview protocols and for providing a framework for discussing pedagogical content knowledge differences between experienced and novice chemical demonstrators. The categories generated by a taxonomic analysis within the four domains provided the coding schemes needed to conduct content analyses of the verbal data (see discussion below).

**Componential Analysis**

Spradley (1979) defines componential analysis as a search for formal and logical differences among members of the contrast group. In this study, the dimensions of contrast included differences between experienced and novice chemical demonstrators' discourse along identified taxonomic categories. Similar contrasts were sought between pre- and post-workshop novice demonstrators regarding their discourses on the attributes associated with effective chemical
demonstration teaching of targeted chemical concepts and their knowledge of alternative demonstrations on these concepts.

Content Analysis

Content analysis is commonly used to detail the frequency with which symbols or themes appear in a written document (Williamson, Karp, Dalphin, & Gray, 1982). This technique was used to provide a quantitative description of the verbal data gathered in this study. The domains, categories, and themes identified through Spradley's techniques provided the coding categories for the content analyses. Given that the clinical interview generated over 400 pages of transcripts, the content analyses permitted this researcher to characterize a large volume of material rather efficiently using a few frequency tables. These frequency tables summarized the number of times subjects made comments within each of the pre-defined content categories or subcategories in their verbal discourses. They provided a general assessment of the breadth (or extent) of teachers' pedagogical knowledge of effective chemical demonstration teaching.

All critical-stop task and follow-up interview protocols were subjected to content analysis using several coding schemes that included: frequency counts of (1) the number of critical stops and the number of perceived strengths, weaknesses, and acceptable-but-could-be-better ratings identified during the think-aloud task, (2) the content focus of teachers' pedagogical critiques along nine content categories, (3) the number of suggestions for pedagogically enhancing the videotaped demonstrations, (4) the number of variations on the observed chemical demonstration, (5) the number of other demonstrations mentioned that address the targeted chemical concept,
(6) the number of extraneous suggestions, and (7) the distribution of critical-stop and interview comments according to general pedagogical knowledge and pedagogical content knowledge (Wilson, Shulman, & Richert, 1987). The instructions for encoding the protocols according to these schemes are provided in Appendices N, O, and P. Trained coders used these instructions as a guide for coding a set of logically-sampled protocols (usually a sample of 4-6 critical-stop protocols and 4-6 semi-structured interview protocols). Appendix N shows the coding instructions used to code individual propositions according to the four pedagogical knowledge domains. Appendices O and P provide the instructions for coding the protocols according to schemes (1) - (7) listed above. Borg and Gall (1983) discuss the counting procedures used to perform the content analyses.

Reliability in coding the data was obtained by determining percent agreement between this researcher and a second coder in coding propositions from a set of logically-sampled protocols into pre-defined coding categories. This researcher trained three coders. Two of the coders have Ph.D.'s in science education and a third coder had a Ph.D. nearing completion (ABD status). All had at least six years of science teaching experience. Each coder received training on a different content analysis coding scheme, i.e., a coding scheme for a domain, taxonomic, and theme analysis. The tallies obtained from the three coders were compared to this researchers' coding and percent agreement computed for each scheme. Because this agreement index does not consider the extent of inter-coder agreement which may result from chance, Scott's Pi was computed. This index of reliability provides a suitable correction for chance agreement when coding verbal data
(Kang, 1987). The inter-coder agreements (reliabilities) are reported and discussed together with the quantitative findings presented in Chapter 4.

A non-parametric Wilcoxon matched-pairs ranked-signs test (Hull & Nie, 1981) tested for total frequency differences between the experienced and novice demonstrators conducting the critical-stop task. The two groups of demonstrators each critiqued a total of four videotapes, providing four matched pairs of observations for the ranked-signs test (e.g., experienced and novice group mean frequency scores were paired on each videotape). Wilcoxon matched-pairs ranked-signs tests were also performed on each of the nine taxonomic categories that emerged from the taxonomic analysis, e.g., the categories of Inquiry, Questioning Strategy, New Terms, Mechanics of Demonstration. Summed frequency tallies across the taxonomic categories yielded an additional non-parametric test. The unit of analysis used to run the statistical tests associated with the critical-stop data represented the group frequency means calculated for each videotape. This yielded four sets of paired values.

Differences between experienced and novice demonstrators in terms of the average number of demonstrations, demonstration variations, pedagogical enhancements, etc., elicited during the semi-structured interview (see coding schemes 3-7, listed above on pp. 96-97) were assessed using an independent t-test and a more conservative non-parametric Mann-Whitney U test. The U-test was conducted because its tolerance for using a small sample size and for working with data that deviate from normality.
Frequently-Cited Critical Features

Content analysis of the critical-stop data provided a means for assessing the level of agreement among experienced and novice demonstrators in identifying videotaped features critical to effective chemical demonstrating. The criteria used to identify a "frequently-cited" critical feature was 50% within-group agreement. This meant that at least half the subjects in the experienced or novice group would need to identify and discuss the same critical feature displayed by the videotaped teachers. The remaining features were labeled "infrequently-cited" critical features. This convention simplified the protocol analysis task and the search for a set of critical incidents frequently discussed by experienced and/or novice demonstrators.

Assessing Pedagogical Knowledge Growth in Novice Demonstrators

Changes in novice demonstrators' performance on the critical-stop task and semi-structured interview were examined both quantitatively and qualitatively.

A Wilcoxon matched-pairs ranked-signs test (Hull & Nie, 1981) tested for experienced and novice chemical demonstrator differences (Research Question 2) and for quantitative changes in novice performance on the critical-stop task resulting from the workshop intervention (Research Question 3). This non-parametric test was conducted whenever quantitative differences in critical-stop task performance was assessed. This test was selected because it permitted mean critical-incident frequency scores for the comparison groups (e.g., pre- and post-workshop novices, or pre-workshop novices and experienced demonstrators) to be paired with respect to the four
videotapes. Pair-wise grouping of scores was necessary because the four videotapes used in this study had very different playing times (3.5 - 9.5 minutes), a variable that correlated strongly with the number of critical incidents discussed by participants. It was also necessary because the counterbalanced design used in this study had novices randomly assigned to one of two videotape viewing groups, with each subgroup viewing a different set of two videotapes. Attempts at using statistical tests that ignored the pairing of videotape scores yielded large variances in scores and no statistical differences in group performance on the think-aloud task, (p > .30). Total scores across the four videotapes could not be used as a unit of analysis because each novice demonstrator only analyzed two of the four videotapes during the pre-workshop and post-workshop clinical interviews. These conditions made the Wilcoxon matched-pairs ranked-sign test the most suitable statistical test for analyzing the quantitative aspects of the critical-stop data.

Analyzing quantitative changes in novices' responses during the semi-structured interview helped gauge their knowledge growth in demonstrating targeted chemical concepts. One-tailed dependent t-tests and non-parametric Mann-Whitney U tests tested for statistically significant changes in the number of (1) alternative chemical demonstrations, (2) demonstration variations, and (3) extraneous examples elicited during the interview. These tests also served to compare the semi-structured interview responses of experienced and novice chemical demonstrators. All t-tests were performed using a microcomputer and a statistical software package
After novice demonstrators' pre- and post-workshop transcripts were read, coded, summarized, and contrasted, qualitative changes in novices' pedagogical knowledge resulting from workshop participation were captured through descriptive summaries and illustrated with quotes taken from the verbatim transcripts. Quotes from experienced chemical demonstrators were also provided for comparison. These summaries/quotes included the kinds of representative comments made, examples provided, demonstrations suggested, and illustrations cited by the two groups of demonstrators during the think-aloud task and semi-structured interview. These pre- and post-workshop quotes, together with the descriptive summaries, taxonomic outlines, and the statistical tests run on the frequency data, provide a body of evidence for generating and testing hypotheses regarding (1) pedagogical content knowledge differences between experienced and novice chemical demonstrators and (2) pedagogical knowledge growth among novice chemical demonstrators.

Chapter Summary

This chapter described the research subjects, instrumentation, inservice treatment, and data analysis procedures used to address Research Questions 1, 2, and 3. A clinical interview, consisting of a critical-stop task and a semi-structured interview, served to probe various aspects of experienced chemical demonstrators' PCK and novice chemical demonstrators' PCK prior to and after participating in an NSF-supported summer workshop. Domain, taxonomic, componential, and
theme analyses and several content analyses guided the qualitative
analysis of the interview protocols. These research methods provided
the means for investigating the nature of chemical demonstrators'
pedagogical content knowledge and general pedagogical knowledge of
demonstrating fundamental chemical concepts. They also provide the
means for examining the nature of pedagogical knowledge growth in an
inservice context.
CHAPTER 4
FINDINGS OF THE STUDY

Introduction

This chapter presents the findings related to the three major research questions stated in Chapter 1. Research Questions 1 and 2 focus on the commonalities and differences between experienced and novice chemical demonstrators' pedagogical knowledge (i.e., their pedagogical content knowledge, PCK, and general pedagogical knowledge, GPK) with respect to the demonstration teaching of two chemical concepts. Research Question 3 addresses the issue of how intensive inservice can influence science teachers' pedagogical knowledge growth. Chapter 4 is organized around these three research questions.

This chapter specifically identifies and discusses the patterns observed in the verbal reports obtained from participating teachers. The identification of these patterns are based on Spradley's (1980) methods for analyzing qualitative data, and include a domain, taxonomic, componential, theme, and content analysis. The findings from each of these analyses are presented below and provide insights into answering the three research questions posed by this study.

The Identification of the Domains Characterizing Experienced and Novice Chemical Demonstrators' Think-Aloud Discourses

The critical-stop protocols obtained from five experienced chemical demonstrators and eight novice chemical demonstrators were used to address Research Question 1. This question asks about the domains of knowledge that characterize experienced and novice chemical
demonstrators' pedagogical comments on effective chemical demonstration teaching.

**General Findings**

A domain analysis (Spradley, 1980) of demonstrators' think-aloud, critical-stop discourses of Videotapes #1-4 identified four major domains of verbalization. The analysis showed that greater than 95% of the subjects' verbal propositions reflected one of the following four knowledge domains pertaining to effective demonstration teaching:

a. Evaluative Judgments  
b. Descriptive Knowledge  
c. Knowledge of Alternatives  
d. Rationales

During each critical-stop of the videotape, the research participant would offer at least one, usually several verbal propositions about the quality of the critical features displayed by the videotaped model. Most of the verbal propositions in the verbatim transcripts (> 98%) reflected meaningful, comprehensible statements about chemical demonstration teaching. The rest of the propositions in the transcripts (< 2%) represented exclamatory comments, incomplete comments, and comments that were undecipherable during the audiotape transcription. According to two independent coders, less than 5% the comprehensible comments present in the data did not code into one of the four domains. These comments were placed into a fifth domain labeled "Other Knowledge" (See Instructions for Coding Propositions into Domains, Appendix N). The "fifth domain" consists of a cluster of eight other domains discussed by Spradley (1980) but rarely used in teachers' discourses. Although some of these domains were
infrequently used, coders were still instructed to consider all 12 domains in the process of coding the verbal data.

Intercoder reliability in coding teachers' critical-stop discourses into the domains was 73.5%. Scott's Pi coefficient was calculated to be 71.1% when coding into the 12 domains. Coder differences are accounted for, in part, by the fact that some propositions were complex and could be assigned to more than one domain.

The nature of the four major domains stated above are now illustrated with think-aloud discourses obtained from two experienced and two novice chemical demonstrators. These four discourses give an example of the robustness of the domains across experienced and novice subjects and across favorably and unfavorably-rated critical incidents. These discourses also provide evidence for the face validity of the four domains used to organize the clinical interview data.

The first critical incident critiqued represents a "perceived strength" discussed by experienced demonstrator E2 and novice demonstrator N7 individually observing Videotape #1 (A favorable model of the Collapsing Aluminum Can Demonstration which deals with the concept of air pressure). The critical incident relates to the selection and use of a student volunteer during the beginning of the chemical demonstration.

Analysis of Critical Incident A

E2's Discourse on Critical Incident A:

That's a really good thing to do, to get participation from everybody like that, [i.e., polling the class along a given criterion to select a student volunteer to hand-crush an aluminum can (see Video Script, Appendix
I]. It makes it, not cutesy, but if he's working with middle school kids, then that particular technique is excellent 'cause they want as much involvement as they can and you can see that when we work with the little kids, as soon as you ask for a volunteer, everyones' hand goes up. So everyone wants to participate. (Videotape #1, S:4).

Experienced demonstrator E2 stopped the videotape at point S:4 (Videotape Statement 4 out of 97) and discussed this critical incident involving the videotaped teacher's selection and use of a student volunteer. A domain analysis of the propositions in the above discourse reveals the presence of three of the four coding domains, namely, a, b, and d.

a. Evaluative - That's a really good thing to do, ...

b. Descriptive - to get participation from everybody like that, [i.e., polling the class along a given criteria to select a student volunteer to hand-crush an aluminum can].

d. Rationale - It makes it, not cutesy, but if he's working with middle school kids, ...

a. Evaluative - then that particular technique is excellent ...

d. Rationale - 'cause they want as much involvement as they can and you can see that when we work with the little kids, as soon as you ask for a volunteer, everyones' hand goes up. So everyone wants to participate.

The above clustering of propositions illustrates three of the four domains. The opening phrase, "That's a really good thing to do," reveals that a positive evaluative judgment was rendered by E2 on the observed critical incident. This judgment is evidenced by the fact that the proposition contains the value terms "really good." The semantic relationship reflected in this opening statement can be represented by: X (a really good thing) is an evaluation of Y (polling
Another statement in E2's discourse also reflects this semantic relationship, namely the statement, "then that particular technique is excellent." It too was coded into the evaluative judgment domain.

The presence of "positive" value terms, such as "really good" and "excellent", in a think-aloud discourse causes the entire discourse and corresponding critical incident to be classified as a perceived "strength." This coding procedure is important to the next level of data analysis, i.e., a taxonomic analysis of chemical demonstrators' evaluative judgments. (See Research Question 2, p. 114).

The remaining portion of the first statement in the discourse above, "... [for him] to get participation from everybody like that..." represents a brief description of the critical incident observed on Videotape #1 as perceived by experienced demonstrator E2. The description refers to the method used by the videotaped teacher for selecting a student to participate in the demonstration. The semantic relationship among the terms in this proposition is descriptive [X is a behavior of Y]. The proposition provides a basic description of the observed teaching behavior that E2 associated with effective chemical demonstrating. It reflects descriptive knowledge of chemical demonstration pedagogy, a second domain in the scheme.

The remaining comments in the above discourse represent a rationale for why chemical demonstrator E2 rated the critical incident as "really good." This demonstrator reasoned that the technique of calling on student volunteers can be an important part of effective chemical demonstration teaching at the middle school level because students at this age have a strong tendency to enjoy and desire...
participation in classroom demonstrations, ["... 'cause they want as much involvement as they can..."]). The semantic relationship of the terms in this proposition reflects yet another pattern, [X is a reason for Y]. Such propositions represent knowledge of why specific teaching strategies are able to motivate and interest students to learn science. They are indicative of the domain, "Rationales."

Analysis of the above discourse shows that experienced demonstrator E2 discussed the student volunteer incident evoking three domains of pedagogical knowledge: descriptive knowledge of demonstration teaching, evaluative judgments of effective demonstrating, and a rationale for why the observed critical incident was judged favorably. A domain analysis of a novice demonstrator's critique of virtually the same critical incident is examined next.

N7's Discourse on Critical Incident A:

And then what he is going to do right now is in-class participation of the students [i.e., selecting a student volunteer to hand crush the can]. Again, this gets their attention and I think that is really important. He's just not the only one doing the demonstration. In addition, he is getting the class involved. (Videotape #1, S:7).

A domain analysis reveals the following:

b. Descriptive - And then what he is going to do right now is in-class participation of the students [student volunteer to hand crush the can].

d. Rationale - Again, this gets their attention and ...

a. Evaluative - I think that is really important.

d. Rationale - He's just not the only one doing the demonstration. In addition, he is getting the class involved. (Videotape #1, S:7).
From the above domain analysis it is clear that novice chemical demonstrator N7 discusses the student volunteer incident invoking the same three domains of knowledge as experienced demonstrator E2. These three domains held up equally well in novices’ pre- and post-workshop think-aloud discourses. The presence of these three domains reflects one of the strongest commonalities observed in the discourses of experienced and novice demonstrators’ critique of favorably rated critical incidents.

The coding scheme is also applicable when teachers critique critical incidents that are viewed unfavorably. The next two discourses illustrate the scheme using unfavorable incidents. These two discourses differ from the ones discussed above in three respects; namely, they come from different chemical demonstrators commenting on a different videotape illustrating a different chemical concept. The first of these discourses comes from subject E5 critiquing Videotape #3 showing a teacher demonstrating relative densities with a density column.

Analysis of Critical Incident B

E5’s Discourse on Critical Incident B:

One of the weaknesses is that he seems to be continually walking from the front to the back of the [demonstration] bench while he was asking the [class] questions. And he knew he was going to write [the answers] down. He probably should stay at the back or if he wanted to have one student act as a secretary, it would probably be better to get that arrangement out of the way at the very beginning before the demonstration starts because it’s distracting to arrange for that in the middle of the demonstration. (VT #3, S:7)

A domain analysis of this discourse reveals the following domains:

a. Evaluative - One of the weaknesses is that ...
b. Descriptive - he seems to be continually walking from the front to the back of the [demonstration] bench while he was asking the [class] questions. And he knew he was going to write [the answers] down.

c. Knowledge of Alternatives - He probably should stay at the back or if he wanted to have one student act as a secretary, it would probably be better to get that arrangement out of the way at the very beginning before the demonstration starts ...

d. Rationale - because it's distracting to arrange for that in the middle of the demonstration.

The critical incident E5 chose to discuss involves the presence of a large demonstration table which hindered the videotaped teacher's access to the blackboard. It was E5's perception that the videotaped teachers' frequent movement around the table to get to the blackboard hindered the effectiveness of the chemical demonstration presentation. The value term "weaknesses" in the opening proposition explicitly indicates that the experienced demonstrator made a negative, or unfavorable, judgment about the incident. The semantic relationship of the terms in this proposition is of the form: X (one of the weaknesses) is a judgment of Y (continually walking from the front to the back ...).

The discourse above also provides a brief description of the critical incident being evaluated, namely that of the videotaped demonstrator walking back and forth around the demonstration table to get to the blackboard. The semantic relationship reflected in this proposition can be represented by: X (walking from the front to the back) is a behavior of Y (videotaped teacher). The proposition therefore illustrates descriptive knowledge of chemical demonstration teaching, domain b.
Experienced demonstrator E5 also provides a suggestion for dealing with the dilemma of confronting a large demonstration table that makes accessing the blackboard difficult. Subject E5 indicates that simply staying back behind the demonstration table would facilitate access to the blackboard. He also indicates that the teacher’s eventual use of a student secretary at the blackboard could be further enhanced by arranging for the selection of the student recorder at the beginning rather than during the middle of the demonstration. Both comments represent solutions to the "blackboard problem" and the task of coordinating the various components of effective chemical demonstration teaching. The semantic relationship of the terms in these two statements \( [X \text{ is another way to do } Y] \) provides evidence for the domain – Knowledge of Alternatives, domain c.

Experienced demonstrator E5 also provides a justification for one of the improvements he advanced. The remark, "... because it’s distracting to arrange for that in the middle of the demonstration", represents a practical justification for why the observed teaching behavior (asking for a student recorder \( \text{after} \) several students provided answers to an open-ended question) is perceived to hinder effective demonstration teaching. The terms in this proposition are characteristic of a rationale statement, and its presence provides support for the rationale domain in the coding scheme. An examination of many other critical-stop discourses by this researcher showed that rationale statements were found in conjunction with demonstrators’ evaluative judgments as well as their suggestions for alternative behaviors.
The comments of a novice chemical demonstrator critiquing the same general incident mentioned above is now examined for the four domains.

N2’s Discourse on Critical Incident B:

I think it’s difficult to have to walk around the table as much as he does. Maybe he can walk around the other end because it’s shorter. But you still want to be with the kids and not separate it [the presentation?] from your audience. (VT #3, S:3)

A domain analysis of this discourse reveals the following domains:

a. Evaluative - I think it’s difficult ...

b. Descriptive - to have to walk around the table as much as he did.

c. Knowledge of Alternatives - Maybe he can walk around the other end ...

d. Rationale - because it’s shorter. But you still want to be with the kids and not separate it [the presentation?] from your audience.

In this discourse novice demonstrator N2 deals with the critical incident of the videotaped teacher having to walk around the demonstration table to get to the blackboard. A domain analysis illustrates that novice demonstrator N2 evoked the same knowledge domains as experienced demonstrator E5 in her critique of this particular incident. Both judged the incident as contributing to ineffective chemical demonstration teaching. The evaluative judgment rendered by experienced and novice demonstrators in the four discourses discussed above were stated rather explicitly. Occasionally, demonstrators rendered judgments in an implicit manner. When this occurred, the direction of the evaluative judgments, strength or weakness, needed to be inferred from
the available text. An example of an incident where the evaluative judgment was implicitly rather than explicitly stated is given in Appendix O (Coder Instructions: Step 14., Example #3). Most critical-stop discourses coded in this study (> 94%, based on two independent coders) contained evaluative judgments that were either explicitly stated or could be implicitly derived from the text.

The domain analysis conducted on the four discourses above illustrates a general pattern observed in coding the remaining critical-stop discourses. Discourses of favorably rated critical incidents usually contained three major domains (a,b,d), whereas discourses of unfavorably rated incidents contained four (a-d).

**Summary of the Domains Characterizing Experienced and Novice Demonstrators’ Pedagogical Discourses**

Research Question 1 asks about the identity of the major knowledge domains that characterize experienced and novice chemical demonstrators’ comments pertaining to effective chemical demonstration teaching. A domain analysis of the critical-stop discourses suggested that the domains (i) descriptive knowledge, (ii) evaluative judgments, (iii) knowledge of alternatives, and (iv) rationales characterize these teachers’ pedagogical comments. These four domains highlight a major commonality between the two groups of chemical demonstrators in terms of their think-aloud discourses on chemical demonstration teaching. These four domains also serve as a useful organizing scheme to present the findings associated with the second research question. The identified domains appear to be logically consistent with the kinds of information one would expect to obtain from a clinical
interview designed to probe science teachers' knowledge of chemical demonstrating.

Having defined the domains that reflect the nature of demonstrators’ pedagogical discourses, a more detailed taxonomic analysis of the verbal data can now be conducted. This taxonomic analysis, together with a quantitative content analysis, will help highlight some major differences between the two groups of demonstrators in each of the four knowledge domains discussed above.

**Pedagogical Knowledge Differences Between Experienced and Novice Chemical Demonstrators**

An analysis of the verbal data gathered from experienced and novice demonstrators during the critical-stop task and semi-structured interview addresses Research Question 2. This question explores more deeply the commonalities and differences between experienced and novice chemical demonstrators' knowledge of effective chemical demonstration teaching of specific subject-matter topics.

Two different methods of data analysis were used to help answer the second research question. One was a taxonomic analysis of the categories and subcategories within the four pedagogical knowledge domains discussed above (Spradley, 1980). The second method was a quantitative content analysis showing how experienced and novice demonstrators’ think-aloud comments were distributed across the taxonomic categories and subcategories (Ericsson & Simon, 1984). Because of the close relationship between taxonomic analysis and content analysis, the findings based on these two methods are presented concurrently.
The findings related to Research Question 2 are presented in four parts. Each part focuses on one of the domains that describe the general nature of demonstrators' pedagogical discourses. Data pertaining to teachers' evaluative judgment is presented first followed by an analysis of their descriptive comments. Separate attention is then given to each of the domains: knowledge of alternatives and rationales. In this section, all references to novice chemical demonstrators are in regards to novices prior to their involvement in the chemical demonstration workshop.

**Chemical Demonstrators' Evaluative Judgments**

**The Nature of the Evaluative Judgments**

The evaluative judgments rendered by experienced and novice chemical demonstrators during the critical-stop task were subjected to a taxonomic analysis. This analysis revealed that the two groups of demonstrators classified most critical features (> 90%) as either a "Strength" or "Weakness." In part, this evaluation scheme was imposed on the subjects by the researcher when the subjects were provided with the critical-stop instructions (Appendix I). It should be noted here, that in this dissertation, the terms critical features and critical incidents may be discussed interchangeably. The differences are subtle, but worth noting. Critical features refer to specific chemical demonstration teaching behaviors. Critical incidents refer to the occurrence of those behaviors in an instructional setting. (See Chapter 1, Definition of Terms).

Some of the subjects devised an "acceptable-but-could-be-better" judgment to evaluate a few critical features. This judgment was
unprompted by the researcher and was more evident among the experienced
demonstrators. These judgments were reflected in statements such as:
"I would have liked to have heard it earlier, but I still think it's
good ..." (E2); "Or better yet ..." (E3); "It would probably be even
more effective if she would have ..." (E4); and "It might be
infrequently cited, but it effected me when he ..." (E1). Such
statements suggest that experienced demonstrators were able to
articulate judgments that indicated that they recognized good and
acceptable demonstration teaching behaviors that could be even further
enhanced. Subject E3 summed up this form of evaluative judgments with
the following statement:

E3: Most of the strengths and weaknesses, it's a matter of
degree. It's not so much, in the sense of a weakness, that he
did something that was totally wrong. Some of his strengths
he could have done better on in terms of visibility and in
terms of drawing out more examples from the students' lives.
So, most of the characteristics of a good demo seem to be
exemplified in this demonstration, in some form. It's more a
matter, he could improve what is already a pretty good
demonstration. (VT #3; I. 5)

Although this third category of evaluative judgments was not used
as frequently as the strength-weakness categories, differences between
the experienced and novice groups of demonstrators on the use of this
evaluative judgment category are apparent (see Table 7, page 118).

A small percentage (6%) of teachers' judgments were neutral or
nebulous in nature. This brings to a total of five the categories
used by teachers to render evaluative judgments during the
critical-stop task, i.e., strength, weakness, acceptable-but-could-
be-better, neutral, and nebulous. This researcher used this taxonomy
of evaluative categories to perform a quantitative content analysis of
teachers' critical-stop discourses (see page 118).
Inter-Coder Reliabilities

Teachers’ evaluative judgments of critical features were encoded from the protocols with 84.2% coder agreement. This agreement value indicates that two trained coders agreed 84.2% of the time in the three-fold task of identifying evaluative propositions in the verbatim transcripts, associating these evaluative propositions with the description of the incident, and then categorizing the incident into an evaluative category. (Scott’s Pi was calculated to be 80.2%). Most of the disagreements between coders involved differences in coder perception of the number of critical incidents discussed by the demonstrators, i.e., present in the protocols. One coder, for example, might read two successive verbal propositions in a given discourse and consider the first to be an elaboration of the second and therefore code the discourse as representing only one perceived strength or critical incident. A second coder might consider the two propositions as representing two different pedagogical issues, and thus code the discourse as representing two perceived strengths or critical incidents. Most coder disagreements were of this nature. The remaining cases of coding disagreement involved critical incidents coded "neutral" or "nebulous" by one coder and as a "strength" or "weakness" by another. This error was infrequent, as suggested by the fact that whenever a particular critical incident discourse was identified by both coders, it was encoded with 97% coder agreement into the same evaluative category.

Assessing Critical-Incident Frequency

Experienced and novice demonstrators showed considerable differences in the number of critical incidents discussed during the
critical-stop task. This difference in performance is shown in Table 7. From this table we see that experienced demonstrators, on the average, make more critical stops of the videotapes (p = .0625) and discuss more critical incidents (strengths and weaknesses; p = .125 and .0625, respectively) than do their novice counterparts. They basically identified more than one-and-a-half as many critical

Table 7

<table>
<thead>
<tr>
<th>Evaluative Judgment</th>
<th>Average Number and Percent Change (or % Difference) in Critical Comments Made by Chemical Demonstrators</th>
<th>Pre-Workshop Novices, Ave.</th>
<th>Post-Workshop Novices C, Ave. % Change</th>
<th>Experienced Demonstrators C, Ave. % Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td></td>
<td>14.2</td>
<td>21.2 +49</td>
<td>26.8 * +83</td>
</tr>
<tr>
<td>Weakness</td>
<td></td>
<td>34.2</td>
<td>30.0 -12</td>
<td>54.5 ** +59</td>
</tr>
<tr>
<td>Acceptable d</td>
<td></td>
<td>(0.5)</td>
<td>(2.2)</td>
<td>(4.2) *</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>48.4</td>
<td>51.2 +6</td>
<td>81.3 ** +68</td>
</tr>
<tr>
<td>Critical Stops e</td>
<td></td>
<td>41.8</td>
<td>39.2 -6</td>
<td>63.2 ** +51</td>
</tr>
</tbody>
</table>

Notes.

n = 4-5 subjects per experienced group; n = 8 per novice group.

a Total uninterrupted playing time = 27.5 minutes.

b All comparison are with respect to pre-workshop novices.

c All probabilities in comparison to pre-workshop novice scores.

d Values in parenthesis represent a subset of those in the weakness column. They were obtained by researcher after obtaining coder reliabilities.

e Critical stops do not include neutral or nebulous discourses.

** p = .0625       * p = .125
features that hinder or promote effective chemical demonstrating as novice demonstrators did.

The probabilities reported above represent meaningful group differences in performance on the critical-stop task as determined by a non-parametric Wilcoxon matched-pairs ranked-signs test. In this study, probabilities of \( p \leq .187 \) were considered to reflect meaningful group differences using this non-parametric test. This probability level was considered meaningful because of the small sample size (four pair-wise values used to run the test). In using a rank-order statistical test with a very small sample size, probabilities became greatly inflated whenever the novice group out-performed the experienced demonstrators in one of the four pair-wise comparisons, i.e., on one of the four videotapes. Further support for establishing \( p \leq .187 \) as a meaningful difference comes from the fact that experienced demonstrators' performance at this level was consistently 25% greater than that of the novices, as suggested by the data presented throughout this chapter. Thus, the data in Table 7 indicate that experienced demonstrators made meaningfully (\( p = .0625 \)) more comments than novices during the critical-stop task regarding effective and ineffective chemical demonstration teaching of specific chemical concepts.

Table 7, as well as several other tables in this chapter, include performance data on novice demonstrators after they received the workshop intervention. This information will be discussed separately in a section devoted to post-workshop novice performance (see Influence of Intensive Inservicing, p. 198).
Group performance on the critical-stop task, when defined in terms of the number of critical features discussed, shows a reasonable amount of variance. This variance is illustrated in Table 8 by the range of critical-stop frequency scores obtained for Videotape #3. It is apparent from this table that experienced demonstrators do not always identify the same number of critical features related to effective demonstrating nor do the most experienced chemical demonstrators, such as E3 and E5, always make the most frequent critiques. This range of performance among experienced demonstrators was also observed in their critiques of Videotapes #1, #2, and #4 (Appendix Q). Novices showed similar variability in performance.

Table 8

Number of Critical Features Identified by Experienced/Novice Chemical Demonstrators for Videotape #3 (Density, +)

<table>
<thead>
<tr>
<th>Evaluative Judgment</th>
<th>Number of Critical Comments Made by Chemical Demonstrators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Workshop Novices( ^a )</td>
</tr>
<tr>
<td></td>
<td>N1  N2  N3  N4  Ave</td>
</tr>
<tr>
<td>Strength</td>
<td>7    7   4   2   5.0</td>
</tr>
<tr>
<td>Weakness</td>
<td>5    2   10  4   5.2</td>
</tr>
<tr>
<td>Acceptable( ^b )</td>
<td>(0  0   1   0   0.2)</td>
</tr>
<tr>
<td>Total</td>
<td>12   9   14  6   10.2</td>
</tr>
<tr>
<td>Critical Stops</td>
<td>9    9   12  5   8.8</td>
</tr>
</tbody>
</table>

Notes.
\( ^a \) N1-N4 represent the novices that saw videotape #3 before the workshop intervention.
\( ^b \) Values in parenthesis represent a subset of those in the weakness column.
The range of critical-stop frequency scores for the experienced and novice groups was large enough to produce some overlap in group performance. The data in Table 8 and Appendix Q indicate that a novice would occasionally identify and discuss just as many critical features as an experienced demonstrator. Table 8, for example, shows the performance of novice demonstrator N3 matched (see number of "Strengths" identified) and even exceeded that of experienced demonstrator E5 (see the remaining categories). This frequency comparison, however, ignores qualitative distinctions in the comments made by the two demonstrators. These distinctions are important and are examined later.

In terms of overall group performance on the critical-stop task (as defined by average frequency scores; Table 7), the experienced group of chemical demonstrators out-performed the novice group in every respect. A non-parametric Wilcoxon Matched-Pairs Ranked-Signs test showed that there was a meaningful difference \( p \leq .125 \) in the performance of the two groups along each critical-stop parameter, i.e., the number of critical stops and the number of critical incidents (strengths, weaknesses, total) identified.

Levels of Agreement in Identifying Critical Incidents

The level of agreement among experienced chemical demonstrators and among novice chemical demonstrators in identifying the same critical incidents can be determined from the data in Table 8. Again, the data obtained on Videotape #3 (Density Column demo, favorable model) illustrate these agreement levels. Table 8 shows that E2 identified as many as 25 critical incidents whereas E5 only identified twelve. Percent agreement based on these two subjects alone shows
that group agreement levels can not exceed 48% (12/25). This maximum value assumes that the twelve features identified by E5 were also identified by E2 (and by the remaining three experienced demonstrators).

A content analysis that uses each unique critical incident as a coding category provides the most accurate estimate of group agreement levels. Such an analysis records the nature of each critical incident discussed by a group of demonstrators and then confirms its occurrence in the demonstration videotape. A tally is kept of critical incidents discussed by more than one subject. Finally, the total number of common incidents critiqued are compared to the total number of incidents discussed. Such an analysis was conducted on the discourses for Videotape #3, with the findings shown in Table 9. The first row of numbers in this table shows that there isn’t a single critical incident that all five experienced demonstrators identified and discussed. The third row in the table shows that most of the demonstrators (> 50%) did identify and discuss nine of the same critical incidents. This number, when compared to the 61 incidents collectively discussed by the group for Videotape #3, indicates that the nine “frequently cited” incidents represent only 15% of the total identified.

A content analysis of novice chemical demonstrators’ discourses of Videotape #3 also showed low levels of group agreement in identifying and discussing the same critical incidents. A total of 31 critical incidents were discussed by the novice group, however, only six were identified as frequently cited, i.e., identified by at least half the novice subjects. These frequently cited incidents represent
Table 9
Percent Agreement Among Five Experienced Chemical Demonstrators’ Performance on the Critical-Stop Task for Videotape #3

<table>
<thead>
<tr>
<th>Agreement Criteria</th>
<th>No. Common Critical Incidents</th>
<th>Percent of Total Incidents, Common</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Exp. Demonstrators</td>
<td>Percent of Group</td>
<td>Absolute</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>13</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>39 (Unique)</td>
</tr>
</tbody>
</table>

about 19% of the total incidents this group identified.

The agreement data presented so far indicates that experienced and novice chemical demonstrators both show low levels of within group agreement in identifying identical critical incidents in Videotape #3. These agreement findings are now extended to a quantitative content analysis of frequently cited incidents identified by experienced and novice demonstrators across the four videotapes.

Identifying Frequently Cited Features

Frequently cited critical features are those demonstration teaching behaviors that at least half of the subjects in the experienced or novice group identified during the critical-stop task. These frequently cited features represent a set of think-aloud discourses that permitted between-group comparisons and within-group
generalizations to be made regarding experienced and novice
demonstrators' conceptualizations of effective chemical demonstrating
derived from commonly discussed critical incidents. "Infrequently
cited" features, on the other hand, represent those features that less
than half of the subjects in the experienced or novice group
identified during the critical-stop task. Although these features do
not provide a constant context for meaningful group comparisons, they
do provide valuable information on demonstrators' discourse focus
during the critical-stop task.

Table 10 shows the total number of frequently cited features
identified by the two groups of chemical demonstrators critiquing the
four videotapes. Table 10 shows that the experienced demonstrators
identified a total of 30 frequently cited features while the novice

Table 10

Total Number of "Frequently Cited" Critical Features
Identified and Evaluated by Experienced and Novice
Chemical Demonstrators Critiquing Four Videotapes

<table>
<thead>
<tr>
<th>Evaluative Judgment</th>
<th>Total Number of Critical Comments Made by Chemical Demonstrators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Workshop Novices,</td>
</tr>
<tr>
<td>Frequently Cited</td>
<td>9</td>
</tr>
<tr>
<td>Strengths</td>
<td></td>
</tr>
<tr>
<td>Frequently Cited</td>
<td>10</td>
</tr>
<tr>
<td>Weaknesses</td>
<td></td>
</tr>
<tr>
<td>Frequently Cited</td>
<td>19</td>
</tr>
<tr>
<td>Str + Wk</td>
<td></td>
</tr>
</tbody>
</table>

Note. This table shows group totals, not group means, therefore no
statistical difference tests were conducted between groups.
demonstrators identified 19 frequently cited features. This indicates that the experienced demonstrators rendered judgments on about one-and-a-half times as many frequently cited critical features as the novices. The data reflects a pattern similar to one observed in Table 7 which shows the average number of critical features identified per group (76 and 48, respectively). In both instances, the experienced demonstrators critiqued about one-and-a-half times as many critical features as the novices.

An examination of the frequently cited features identified by experienced and novice demonstrators across the four videotapes reveals a total of 43 different frequently cited features. One-sentence summary statements of these 43 features are given in Appendix R. This list of statements shows that the two groups of demonstrators generally did not critique the same set of frequently cited features. Of the 43 frequently cited features discussed by the two groups of demonstrators, twenty-three (54%) were discussed by only the experienced demonstrators, thirteen (30%) by only the novice group, and seven (16%) by both the experienced and novice demonstrators.

A total of 274 different critical features (both frequently cited and infrequently cited features) were identified by the experienced group of demonstrators in their critique of the four videotapes. When this number is compared to the total number of frequently cited features identified by the experienced group, i.e., 30, it is evident that frequently cited features represent a very small percentage of the total identified (10.9%). This finding indicates that the critical-stop task shows a very low level of within group agreement.
among experienced demonstrators in identifying and evaluating identical critical features observed on videotape. Within group agreement among novice chemical demonstrators in identifying and evaluating the same critical features was also low (11.3% using a > 50% group agreement criteria).

Experienced and novice chemical demonstrators clearly differed in their performance on the critical-stop task. These differences were apparent in the number of critical stops made and number of evaluative judgments rendered. In the section that follows, the content of the critical incidents discussed by the experienced and novice chemical demonstrators is closely examined. The discussion now shifts from the evaluative judgment domain (domain a) to the descriptive knowledge domain (domain b).

Analysis of Demonstrators' Descriptive Knowledge Domain

A taxonomic analysis of the 274 critical features identified and evaluated by the experienced demonstrators and the 177 features identified and evaluated by the novices shows that they address nine recurring pedagogical issues. These nine issues, or categories, were derived entirely from the verbal data. The names given to the categories were either taken from the literature or created by the researcher. The nine categories that emerged presumably contribute to effective chemical demonstration teaching. They include an investigative/inquiry approach to chemical demonstrating, questioning strategies, addressing new terms, quality of explanations, interactive/participatory style, mechanics of the demonstration, use of blackboards and visual aids, overall organization, and presentation style.
Table 11 shows the frequency with which these nine pedagogical issues were discussed during the critical-stop task by both experienced and novice chemical demonstrators. Overall group differences along each of the nine taxonomic categories were assessed using the Wilcoxon Matched-Pairs Ranked-Signs test. With this test, significance levels of $p = .0625$ were obtained whenever the

Table 11  
Average Number of Critical Comments Made by Experienced and Novice Chemical Demonstrators According to Pedagogical Knowledge Category

<table>
<thead>
<tr>
<th>Pedagogical Categories</th>
<th>Average Number of Critical Comments Made by Chemical Demonstrators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novice Pre-Workshop</td>
</tr>
<tr>
<td>1. Investigative, Inquiry Approach</td>
<td>6.2</td>
</tr>
<tr>
<td>2. Questioning Strategies</td>
<td>6.8</td>
</tr>
<tr>
<td>3. New Terms</td>
<td>6.0</td>
</tr>
<tr>
<td>4. Quality of Explanations</td>
<td>8.2</td>
</tr>
<tr>
<td>5. Interactive, Participatory Style</td>
<td>2.2</td>
</tr>
<tr>
<td>6. Mechanics of Demonstration</td>
<td>4.2</td>
</tr>
<tr>
<td>7. Use of Blackboard/Visual Aids</td>
<td>3.5</td>
</tr>
<tr>
<td>8. Overall Organization</td>
<td>7.8</td>
</tr>
<tr>
<td>9. Presentation Style</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Ave. Individual Totals: 46.7 50.3 77.5 ***

Notes.  
\(a\) All probabilities in comparison to pre-workshop novice scores.  
*** $p = .0625$  ** $p = .125$  * $p = .187$
experienced demonstrators made more frequent critical comments than novices on all four videotapes. This probability level (i.e., \( p = .0625 \)) also represents the lowest achievable probability when working with four pair-wise comparisons and the Wilcoxon pair-wise test, \( (p < .0625 \) was never obtained with a sample size of four and this non-parametric test). Significance levels of \( p = .125 \) were observed whenever an equivalent number of critical comments were made by the experienced and novice group of demonstrators on one of the four videotapes. Probabilities of .187 were observed whenever there was a greater number of critical comments cited by novice demonstrators on one of the four videotapes. Probabilities exceeding .187 were observed whenever there was a greater number of critical comments cited by novice demonstrators on two or more of the four videotapes. For the purpose of this study, non-parametric probabilities showing \( p < .187 \) were considered a reasonable indicator of meaningful group differences. This level was selected for reasons cited earlier (see p. 119).

Table 11 highlights with asterisks the categories showing the most meaningful group differences between experienced and pre-workshop novice demonstrators. The numerical entries in the table reflect the mean frequencies with which the nine pedagogical issues were cited and discussed by the two groups of demonstrators critiquing the four videotapes.

Reliability of the Taxonomic Analysis

The reliability of coding critical-stop discourses into the nine pedagogical categories showed 74.3% coder agreement. (Scott’s Pi was 72.0%). Some of the differences in coding are accounted for by simple
coder oversight (forgetting or not observing specific coding rules) and cases where one coder placed too much emphasis on one term in a given discourse. Most differences in coding are accounted for by the somewhat subjective, interpretive nature of applying coding rules (Appendix P) to complex written text. For example, some critical incident discourses coded into more than one category, depending upon which statement(s) in the discourse a coder perceived was being emphasized. Coding difficulties were also encountered whenever critical-stop discourses addressed demonstration teaching behaviors that served more than one function, e.g., behaviors that concurrently promoted an "Investigative, Inquiry Approach (Category 1) and an Interactive, Participatory Style (Category 5)" or any other combination of categories. Although the coding instructions provided rules to help guide the coding of complex discourses and verbal propositions, interpretive differences in understanding the content of the protocols and applying coding rules to these complex propositions prevented the attainment of high levels of coder agreement (> 80%). In spite of these difficulties, acceptable levels of coder agreement were obtained.

Content Analysis

The information presented in Table 11 shows that the experienced demonstrator made significantly more critical comments than pre-workshop novice subjects in seven out of nine pedagogical categories. These seven categories include Investigative/Inquiry Approach, Questioning Strategies, New Terms, Quality of Explanation, Interactive Participatory Style, Mechanics of Demonstration, and Presentation Style. Once again, probabilities computed with p = .187
were considered to reflect meaningful group differences using the Wilcoxon matched-pairs ranked-sign test. Thus, Table 11, indicates that experienced demonstrators made meaningfully ($p = .187$) more comments than novices related to inquiry. ¹

Table 11 shows that experienced demonstrators made more frequent mention of two teaching strategies, investigative/inquiry approach (Category 1) and interactive, participatory style (Category 5), that can be performed in conjunction with a chemical demonstration. Furthermore, they made more frequent critiques on pedagogical issues closely related to chemical content, such as questions strategies and the clarity of presenting new terms and concepts (Categories 2–4). The experienced demonstrators also made considerably more critical comments about the mechanics of the demonstration (Category 6) than the novice group. This finding would be expected, given their experience, i.e., weekly use in conducting chemical demonstrations (Table 1).

Critical-stop comments related to visual aids and organizational issues (Categories 7 and 8) were treated similarly by the experienced and novice demonstrators. These two issues are not necessarily tied to knowledge of chemistry and were therefore confidently discussed by the novice group. Finally, experienced demonstrators were more attuned to elements of presentation style in conducting chemical

¹ This level of significance corresponded to a probability of $p = .068$ when individual scores rather than group scores were also used to run the Wilcoxon Matched-pairs test on the "Inquiry" category. The difficulty with this latter approach, however, is that the probability level is unstable, ranging from $p = .028 - .086$: changing with each attempt to randomly pair scores of individual novices with individual experienced demonstrators.
demonstrations than novices ($p = .0625$).

Table 12 recasts the data presented in Table 11. It shows the similarities and differences between experienced and novice chemical demonstrators in terms of the relative focus of their critical-stop critiques. It contrasts the two groups of demonstrators in a manner that shows novices' giving greater relative focus to certain pedagogical issues than is apparent from the frequency data given in Table 12.

### Focus of Experienced and Novice Chemical Demonstrators' Evaluative Judgments on the Critical-Stop Task

<table>
<thead>
<tr>
<th>Pedagogical Categories</th>
<th>Relative Frequencies of Critical Comments Made by Chemical Demonstrators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novice</td>
</tr>
<tr>
<td>Pre-Workshop</td>
<td></td>
</tr>
<tr>
<td>Questioning Strategies</td>
<td>.15 *</td>
</tr>
<tr>
<td>New Terms</td>
<td>.13</td>
</tr>
<tr>
<td>Quality of Explanations</td>
<td>.18 *</td>
</tr>
<tr>
<td>Interactive Participatory Style</td>
<td>.05</td>
</tr>
<tr>
<td>Mechanics of Demonstration</td>
<td>.09</td>
</tr>
<tr>
<td>Use of Blackboard/Visual Aids</td>
<td>.08</td>
</tr>
<tr>
<td>Overall Organization</td>
<td>.17 *</td>
</tr>
<tr>
<td>Presentation Style</td>
<td>.04</td>
</tr>
<tr>
<td><strong>Total</strong>:</td>
<td><strong>1.02</strong></td>
</tr>
</tbody>
</table>

**Notes.**

1. Totals that do not sum to 1.00 represent rounding errors.
2. The asterisk (*) represents the top three focus categories for each group.
A within-group comparison of the nine pedagogical categories addressed by the two groups of demonstrators shows that two of the top three issues addressed by experienced and novice demonstrators were questioning strategies (Category 2) and the quality of explanations (Category 4). The third major concern of experienced demonstrators involved issues related to the basic mechanics of the demonstration and how they can contribute to effective demonstrating (Category 6). For the novices, the third major concern involved organizational issues (Category 8). Experienced and novice demonstrators showed considerable difference in their relative focus on presentation style (Category 9), an issue which was of greater relative concern to experienced demonstrators than to novices. There was some variation in demonstrators' content focus depending on the videotape being critiqued, namely, a + .03 average variation in relative discourse frequency per category, (mean frequencies are given in Table 12).

A between-group comparison of the data in Table 12 shows that novice chemical demonstrators gave greater relative emphasis to four pedagogical issues. These issues include attention to new terms (Category 2), quality of explanations (Category 4), use of blackboard/visual aids (Category 7) and overall organization (Category 8). Two pedagogical issues received equal relative emphasis by the two groups of demonstrators: investigative/inquiry approach (Category 1) and interactive participatory style (Category 5). Although novices showed equal or greater relative focus on several pedagogical issues, the experienced demonstrators still critiqued these issues as
frequently or more frequently than novice demonstrators in absolute terms (see Table 11).

**Qualitative Differences in Demonstrators' Critical-Stop Comments in the Nine Pedagogical Categories**

The next level of analysis, a componential analysis, focuses on the qualitative differences between experienced and novice demonstrators' critical-stop discourses. These differences are examined in terms of the kinds of comments made in each of the nine taxonomic categories identified above (Tables 11 and 12). All nine categories deal with pedagogical issues germane to effective chemical demonstration teaching.

Differences between experienced and novice chemical demonstrators' thinking about effective chemical demonstrating are highlighted with quotes. These quotes are taken from demonstrators' think-aloud critiques of major as well as minor critical incidents. Space only permits a small sampling of comments from the two groups of subjects. To supplement the quotes supporting the componential analysis, the reader may refer to Appendix S, which contains additional quotes, and to Appendix R, which contains a comprehensive list of all major critical incidents identified and discussed by the two groups of demonstrators. Appendix Y provides a comprehensive list of all major and minor critical incidents identified by the subjects of this study examining Videotape #3. (Again, space prevents the inclusion of comprehensive critical incident lists obtained for Videotapes #1, #2, and #4). In each of the aforementioned appendices, critical incidents are organized taxonomically according to the nine
categories discussed above. Samples of complete interview discourses are provided in Appendix T.

Inquiry, Investigative Approach. One distinctive difference between experienced and novice chemical demonstrators in their discourses on effective chemical demonstrating is that the former group tended to make more frequent reference to the term "inquiry" when describing how to go about demonstrating chemical concepts to middle school students. The following quotes illustrate this global perspective of experienced demonstrators. (See also Appendix S.) Note that in these quotes the letter "E" refers to an experienced chemical demonstrator.

E1: Didn’t use probably as much inquiry as he should have used either. That’s a good demonstration. You can really pull things out of people. And there could have been more questions. [VT #3, Q.4]

E2: My main [concern] with her, I think, is the same thing as it was with the first demonstration, is the questioning. It seems as if these people are not trained to use inquiry. And not that I think inquiry is "it" but as far as demonstrations go, it is "it." I mean, you don’t want to tell them the whole answer and then say, "Here it is!" [VT #4, Q.4]

Novice demonstrators essentially made no direct reference to the term "inquiry" or an inquiry approach to chemical demonstrating in the critiques of the four videotapes. This global conceptualization of effective chemical demonstrating at the middle school level was a distinct characteristic of the experienced demonstrators.

As well as making direct references to inquiry, the experienced subjects identified and discussed several inquiry issues, including the importance of encouraging student observations, predictions, hypotheses, supportive evidence, and conclusions, as well as the
testing and discussion of student ideas. Novices discussed several, but not all, of these inquiry behaviors. The most notable differences between the two groups of subjects regarding inquiry issues are illustrated by the quotes and discussion below.

Experienced demonstrators frequently discussed the value of drawing students into the demonstrations by encouraging them to verbalize their observations. These demonstrators would also indicate that an effective chemical demonstrator models good observation skills and generally does not provide students with basic site observations that students could make themselves. The following quotes, and Appendix S, illustrate this perspective. The term "he" refers to the videotaped teacher being critiqued.

E1: That was another good point that he made when he held it up and he said "I want you to make careful observations." And he's observing too. He's actively observing which is also good. It's not as if he is passively looking around the audience. (VT #3, S:17)

E3: Here he's involving students. Rather than him just talking and showing, he's already asked students for their input [i.e., their observations on the density column]. (VT #3, S:24)

E4: The other good thing he has been saying, "Give me more observations on this." He has been asking for observations at this point. (VT #3, S:45)

Only one novice, N7, made any mention of the value of verbalizing observations during a demonstration, however, the emphasis was on the value of teacher-centered observations when conducting chemical demonstrations.

N7: That's good because it's possible that the students in the back might not be able to see what is going on. [Videotaped teacher said, "I can feel (the water) boiling and perhaps you can hear it boiling"]. And he's telling them what is going on even though they probably know what's going
on. So, so far he's given a pretty detailed account of what he's doing.  [VT #1, S:52]

A componential analysis of demonstrator discourses on inquiry demonstrating showed that only the experienced demonstrators discussed the strategy of having students regularly verbalize their observations when a teacher performs a chemical demonstration.

Experienced and novice chemical demonstrators both discussed critical incidents dealing with students making predictions of demonstration outcomes, e.g., expected properties of a chemical system to be demonstrated, or anticipated outcomes of a set of physical measurements. Both groups considered this a relevant issue associated with effective chemical demonstration teaching. The two groups of demonstrators also made frequent mention of the importance of effectively fielding multiple student responses generated by divergent, inquiry-oriented questions, e.g., observation and prediction questions.

Novice demonstrators placed somewhat greater importance on having students try to explain the observed phenomenon by using questions such as, "Why did the can collapse?" and "Why is the mineral sitting on top?", questions that go beyond the demonstration. The following quotes provide illustrations of this thinking. (See Appendix S for additional quotes.)

N6: So, now he is bringing in some thought questions [e.g., "What forces are responsible for crushing that can?"] for them to ponder and to use their thinking process to go ahead and say why this is happening. Then he said, "Are there any other options available to you?" So, instead of just saying, "That's right," and going on with that, he is trying out more thinking process which is probably more toward the objective of it.  (VT #1, S:21)
In this section he asks [the student] to explain why he was able to crush the can. And the student explained well. And it was good the way he kept probing him, you know, "Is there more? Is there more?". (VT #1, S:24)

Again, good questioning ["How did this occur?"] . He's still keeping it going. He's trying to get it out of them, trying to make them actually follow through. (VT #2, S:34)

Experienced demonstrators, however, went beyond the issue of having students provide hypotheses to account for a phenomenon, to the issue of having students provide supportive evidence to substantiate their hypotheses and to the testing of some of the students' ideas. The focus was more on the demonstration than on the "answers" to the demonstration. The following quotes taken from various critical incidents illustrate this difference.

E2: OK, I like that question, ["Is there any evidence to support that?"] . That's one of my favorite questions to use. In fact, no matter what level I teach, elementary all the way through college, that if they are going to give me some kind of response I want some kind of evidence for it. (VT #1, S:46)

E4: Now someone (a student) did come back with the water (vapor) pressure pressing [the air] up [out of the can]. And he did ask, "Is there any evidence?". That was a good point. "What are you basing this upon?" Again, I didn't get the answer all that well. But [a student] would have an expectation based on their experience that this would probably occur. And that's fine to bring in previous experience. That's a good strong point. The question did come up, but if it didn't, that's one of the things you should try to get the group to explain. (VT #1, S:50)

E3: Here again he is being interactive with the students asking them to make hypotheses [about the identity of the liquids in the column] and then following up with, "How would we know if that were true?" In this particular case, he asked them a very broad question, "What liquids might be in the container?" which they probably don't have a whole lot of experiences for, but [the students provide a] couple guesses and then he follows it up with, "Well, how can we determine it, if those guesses are in fact valid?". (VT #3, S:70)
Novices paid very little attention to the value of having students provide evidence for their predictions or hypotheses in response to teacher's questions. One novice that did address the issue of supportive evidence commented on the importance of the teacher providing more evidence for the students so they would be better able to answer the teacher's questions.

NB: Most students know that a cork board will float on the water, but since she hasn't given the value for the density of the cork. She hasn't given them enough information to be able to, for them, to deduce accurately [the answer to: "And what do you think the cork will do?"] (VT #4, S:116)

Experienced demonstrators were more prone to point out that an effective demonstrator will not spend an excessive amount of time talking or lecturing to the students during a demonstration but will draw students into the process of having them think about possible explanations for the demonstrated chemical phenomenon as well as help them draw conclusions from the resulting class discussions.

The final issue raised by demonstrators in terms of an inquiry approach to chemical demonstrating was that of "forecasting": the videotaped demonstrator telling the audience what to expect. Experienced demonstrators viewed the issue of "forecasting" as a legitimate threat to an effective chemical demonstration. This issue was raised frequently and in several different contexts by the experienced group. Novices also recognized this issue in several different contexts but it was discussed in slightly fewer critical incidents.

The two groups of demonstrators viewed forecasting from three basic perspectives: forecasting procedures to be performed, forecasting observations to be noticed, and forecasting explanations
of an observed chemical phenomenon. These three levels of forecasting are exemplified by the critical-stop discourses of experienced and novice demonstrators.

Forecasting observations:

E3: He sort of forecasts there that, "In a minute or two we are going to see some vapor," and I seem to recall from the first run through where he said something about, "He could hear it boiling." Those are both things he could have asked the students to make observations on rather than to state. So that it would have been better to let the student make the observation rather than to forecast it. (VT #1, S:53)

Forecasting procedures:

N1: I'm not so sure I would have told them what it was I was going to do. I think it's two different ways of looking at it. But maybe if he had just done it, he could have opened up more questions as to why, instead of telling them exactly what he's going to do. (VT #2, S:22)

Forecasting explanations of phenomenon:

N2: I get the feeling he's telling them what's going to happen instead of letting them find out. I'm not sure I like that.
Interviewer: How's he telling them what's going to happen?
N2: Well, he's explaining that we have all this air pushing on us, and he could do the experiment and let the kids tell him that there's air pushing. Let them investigate a little more. (VT #2, S:3)

The critical-stop discourses of experienced and novice chemical demonstrators reveal that the inquiry approach to chemical demonstrating plays a very important role in their thinking about demonstrating abstract chemical concepts to middle school students. The fact that the experienced demonstrators discussed these issues more frequently suggests a greater knowledge of integrating inquiry methods and demonstration teaching.

Questioning Strategies. The next taxonomic category discussed by experienced and novice demonstrators during the critical-stop task
involves the effective use of teacher questioning strategies during a demonstration. In general, the experienced demonstrator discussed more critical incidents pertaining to the issue of questioning than novices discussed (see Table 11). A content analysis of these discourses on teacher questioning strategies showed several commonalities and differences between the two groups of demonstrators. In terms of differences, the experienced demonstrators showed greater proficiency in evaluating the many questions presented by the videotaped teachers. Novices also showed proficiency, but simply evaluated fewer of the questions presented in the videotapes. (Appendix J, Table J.1 shows that 86 questions were asked by the videotaped teachers. More than half were critiqued by the two groups of chemical demonstrators during the critical-stop task). A componential analysis showed that the experienced and novice demonstrators gave similar attention to questioning issues such as the timing of questions, fielding and probing of responses to questions, and providing of appropriate feedback and wait time. Many of these issues pertain to generic teaching skills applicable to chemical demonstration teaching.

Experienced demonstrators also recognized and discussed more critical incidents pertaining to the use of leading-questions. They consistently mentioned the ineffectiveness of such questions in checking for student understanding.

E2: But the next question I thought was leading, ["Do you think that there was possibly a force resisting your hand?" (S:17)]. I mean he was giving them essentially the answer and just waiting for them to comment on it. He does that throughout his demonstration. (VT #1, S:17)
E4: I think it's good that he's trying to indicate that these are solids, "Is this a solid or a liquid?", but I think if he had worked on the observation a little bit more he probably would have gotten that out of the group rather than have to lead them in. Although I'm going to write that off as a function of time factor in this case. (VT #3, S:62).

N6: She's trying to ask very leading questions, very helpful questions, but she's hand feeding the people there and if she doesn't change that type of pattern, then kids will make her do all the work. She's doing all the work. The audience is not doing the work that is involved. (VT #4, S:94)

Experienced chemical demonstrators were also more inclined to discuss critical incidents involving teacher questions that probed students' prior knowledge of science concepts. Most novices tended to ignore these incidents in their evaluation of the videotaped teachers. Those novices and experienced demonstrators that did address this issue of probing prior knowledge indicated that the probing process helps the demonstrator fine tune the presentation to the level of the student. This type of discourse is illustrated with critical incidents taken from the Density Column Demonstration videotapes.

E2: And here there are opportunities to have the kids come up and feel the substance, to talk about it a little bit, "Have you ever used oil?", "Have you ever seen - have you ever poured oil on water? "What happens?" I mean all these different things could happen. None of this happened. She just dumps it (the liquids) in there. (VT #4, S:72)

E5: I think one of the strengths of the lesson is to start with what the students already know and build from there because, I guess learning, seems to me, attaches very easily, or more easily, to things that they already know. (VT #3, S:3)

N1: The fact that he is asking them about their past experience, what it is they know already, so he has a clearer idea of where to start with them, instead of assuming that they all know it or assuming that they don't know it, he's really getting a hold on, at least, where a few people in the class are. (VT #3, S:3)
Experienced demonstrators evaluated the quality of the videotaped teachers' questions more often and along more criteria than novice demonstrators. The experienced demonstrators were more critical of the clarity of questions asked, the appropriateness of the question for middle school students (i.e., above or below level), and the intrinsic value of higher-order questions to generate student thinking. The following quotes illustrate experienced and novice demonstrators' thoughts on the first of these issues, question clarity. (See Appendix S for additional quotes.) A similar pattern was observed for the other two questioning issues.

E3 (Clarity): That seems like she asked the question, expecting an answer, and then shifted it suddenly before the students had a chance to think about that. "What does it mean [that is has a larger density]?" is an incredibly vague question. If she asks, "Given these numbers, practically, what does that mean?" or "What does that translate to?" But just to ask that question [that way is vague]. (VT #4, S:30)

E4 (Phrasing): She had a little phrasing [problem there with], "... more or less dense?" She probably would have been better off saying, "How would you compare the mineral oil to the water?" or "How would you compare the density of mineral oil to the density of water?", something like that. (VT #4, S:77)

N5 (Phrasing): It would be nice to have a more dramatic opening, you know, some way of getting them excited because that is a flat start, to start with a question like that ["Can anybody tell me what density means? Do you remember hearing that term before?"]; and regardless of how it is said or who is saying it, is just a flat way to start. (VT #4, S:3)

N7 (Phrasing): Her wording even, it's just not proper. It just doesn't sound right. ["So alcohol has a greater or less density than water?"]). (VT #4, S:32)

These quotes, those in Appendix S, Table 11 (Category 2), and a componential analysis of experienced and novice demonstrators' discourses on "Questioning" illustrate that the experienced
demonstrators not only made more comments than the novices regarding how to appropriately ask questions, they provided more penetrating analyses of the unsound questions they heard during the critical-stop task by discussing ways of improving poorly phrased questions (domain c; discussed further on p. 150).

New Terms. Experienced and novice demonstrators made frequent references to the importance of addressing new scientific terms while conducting a chemical demonstration at the middle school level. Table 11 shows that the experienced group discussed slightly more critical incidents than novices on this issue. Experienced demonstrators indicated that effective chemical demonstrating at the middle school level requires careful attention to the use of terms such as mass, unit volume, interface, phenolphthalein, solubility, cubic centimeter, barometer, and altimeter when conducting chemical demonstrations on density and air pressure. Their critiques generally indicated that scientific terms need to be defined, given greater attention, or deleted in favor of simpler, more appropriate terms. Novices addressed most, though not all, of the terms experienced demonstrators addressed. The nature of their critiques were comparable to those of the experienced subjects in cases involving favorably rated critical incidents (see Appendix S). The experienced subjects were more thorough in their discussion of unfavorably rated critical incidents involving teachers’ use of new terms (see domain c, Knowledge of Alternatives, pp. 152-155).

Quality of Explanations. Both groups of demonstrators frequently discussed the quality of the explanations provided by the
videotaped teachers. The explanations that were critiqued included explanations of the demonstration observations, procedures, materials, and chemical concepts. These explanations were evaluated in terms of their accuracy, clarity, completeness, and usefulness to middle school learners.

The greatest difference between experienced and novice chemical demonstrators within the category of Quality of Explanations is in their critique of the accuracy of the chemistry information presented in the four videotapes. The experienced demonstrators were much more skilled in identifying and discussing informational inaccuracies than were the novices. For example, in Videotape #3, three of the sixty-one critical features identified by the experienced demonstrators dealt with inaccurate chemistry concept statements made by the videotaped teachers. The following quotes illustrate the three inaccuracies identified by the experienced group.

E4: He doesn’t understand that [phenolphthalein is] more soluble in alcohol than it is in water. He has it backwards. It just so happens he added something to the water to give it color. I know that phenolphthalein is more soluble in alcohol. So he actually had that wrong. In alcohol, the OH group is slightly acidic, so it tends to keep phenolphthalein colorless. It would tend to end up even more in the alcohol than the water layer. (VT #3; S:88)

E5: The generalization, ... "Solids are more dense than liquids?" ... I don’t think that is necessarily true, or I don’t think you want to teach that. There are couple of things that float. (VT #3; S:93)

E3: Well, basically, he sort of generalized and said that solids are generally more dense than liquids, and with gases it’s difficult to see them, and so that’s why he (the videotaped teacher) [said he] was working with liquids. But in fact there are dense gases that are colored. (VT #3; S:97)
Each of these comments represents the identification of a chemical knowledge or generalization inaccuracy made by the videotaped teacher demonstrating relative densities. These inaccuracies were identified exclusively by the experienced chemical demonstrators. Novices never discussed these inaccuracies during their critique of Videotape #3. Similar pattern emerged in novices' critique of the other three videotapes. Knowledge inaccuracies were rarely discussed by novices.

Three points can be made about the two groups of demonstrators with respect to these critical-stop comments. First, prior to the workshop, novices did not identify any of the three critical features discussed above. This finding agrees with the participant background information given in Table 2 which shows that novices only completed foundational courses in college chemistry. Second, subjects E3-E5, all of whom possess college chemistry degrees, did not identify all three inaccurate chemical propositions. They generally only identified one each. This finding further illustrates the low within-group agreement levels found in experienced and novice demonstrators' critical-stop discourses. Third, some of the experienced demonstrators (E1 and E2) did not identify any of the three knowledge inaccuracies in Videotape #3, although they did identify a few in the other videotapes. These demonstrators, although experienced at conducting chemical demonstrations at the middle school level, did not appear to possess as much chemistry content knowledge as did E3-E5. This finding is also in agreement with the background information obtained on the five experienced chemical demonstrators concerning their college chemistry training (Table 2).
A content analysis of several other critical-stop discourses on Videotapes #1-4 shows that there is a considerable difference in performance between experienced and novice demonstrators in the subcategory Identifying Knowledge Inaccuracies that forms a part of Category 4 (Quality of Explanations). This difference is attributed to these demonstrators' college chemistry training. Although these critical features represent a very small percentage of the total number of critical features identified (approx. 6%), this data shows that the critical-stop technique is able to discriminate subjects on the basis of their subject matter knowledge and how this knowledge influences effective chemical demonstration teaching.

Interactive, Participatory Style. In several critical-stop discourses, experienced and novice demonstrators discussed the value of involving student participants when conducting a chemical demonstration. This would include the use of student volunteers to assist with the mechanics of the demonstration, to make close-up observations, and to record student observations on the blackboard. The demonstrators further indicated that a good interactive, participatory style includes promoting continuous student-teacher and student-student dialogs, and calling on students by name. Experienced demonstrators addressed these issues more frequently than novices in their critical-stop discourses. Qualitative differences between experienced and novice demonstrators in their discourse on these issues were not apparent.

Mechanics of Demonstration. Pedagogical issues related to the mechanics of the demonstration, as discussed during the critical-stop
task, included the issues of visibility, handling of equipment, safety, verification, and controls. Experienced demonstrators made more numerous comments than novices regarding the need for enhanced visibility of demonstration materials. This was particularly apparent in their discussions of the Density Column Demonstration where the size of the graduated cylinder and the use of food coloring notably affects the visibility of the density column. The experienced demonstrator also appeared to be more familiar with the demonstration chemicals as suggested by their more frequent discourse on safety and chemical demonstrating.

Experienced demonstrators appeared to address the issue of verification more frequently than novices. Verification involves the act of demonstrating to students some of the prior preparation work that was conducted by the science teacher. In the case of the Collapsing Aluminum Can demonstration, the teachers in both videotapes added water to an aluminum can before the demonstration started and had it sitting over a Bunsen Burner ready to be heated. The following quotes represent the reactions of two experienced chemical demonstrators to this critical incident. (See Appendix S for additional discourses.)

E1: Here he says, "There is a little bit of water in this can," and I’m wondering what is a little bit of water. And I want to see you put the water in the can. I want to know what’s in there. Don’t just tell me it’s in there, show me. (VT #2, S:16)

E5: I think it’s much better to actually pour the water into the can. You really want the kids to see this. (VT #2, S:17)
Only one novice addressed this critical incident, and from his perspective, the incident was considered a minor issue in the overall scheme of things.

N5: At that point it might have been nice to go ahead and pour the water in just so the kids could see that it was just water and maybe even take it right out of the tap. But that is just really minor details. (VT #1, S:33)

According to the experienced demonstrators, verification of procedural steps taken prior to the demonstration is an important pedagogical principle when demonstrating chemical processes to students at the middle school level.

Use of Visual Aids. Table 11 shows that experienced and novice demonstrators identified and discussed a similar number of critical incidents related to the effective use of the blackboard and visual aids during a chemical demonstration. This category covered a broad range of topics that include discussions of what should be visualized on the board, such as the physical system being demonstrated, new terms, numerical values, and important questions. Their discourses also included critiques on the quality of these blackboard visualizations, in terms of accuracy, completeness, organization, neatness, and visibility.

The experienced chemical demonstrators voiced concern about the importance of a blackboard drawing of the physical system being demonstrated while novices focused more on using the blackboard to record student observations. The following quotes illustrate this difference.

E2: I think it’s much better to actually pour the water into the [aluminum] can. You really want the kids to see this. And, when I do this with students, I originally draw
on the board a can and I have it filled with steam, and then
draw another picture of it being inverted. It’s easy to
[just] talk about these things in a fuzzy way, [the way he
did]. (VT #2, S:17)

N4: Taking down the [student] observations and putting it
where everyone could see them is real important for junior
high school because they are visually oriented. (VT #3,
S:49)

Overall Organization. Experienced and novice chemical
demonstrators discussed organizational issues with about the same
absolute frequency during the critical-stop task. These discourses
are characterized by discussions of motivational strategies, pacing,
sequencing, closure, transitions, relevancy, and complexity of student
activities that followed some of the videotaped demonstrations. The
experienced demonstrators tended to identify a few more problems
associated with closure and the sequencing of ideas and demonstration
tasks than novice chemical demonstrators. The following quotes, and
those in Appendix S, illustrate the thoughts of the experienced
demonstrators on the sequencing of events and ideas.

E1 (Ideas): Probably the first thing he did incorrectly was
try to introduce two concepts at one time. Maybe he should
have started with one and later into the lesson, if he had
the time, gone to the second one, but that’s very confusing
for kids to introduce two concepts at one time. (VT #3, S:2)

E4 (Tasks): I personally like to have things like that
[can] heat while I’m talking and developing the subject.
[With this] variation [I] put the water in the can, set it up
on the burner, then go back to the [first] question, and pose
the second question while it’s heating, ["Can the air crush
an aluminum can?"] That makes a little bit more effective
use of time. One of the problems I have here is - of course
we have limited time in class, and you have to be effective -
try to be effective on time. It also makes it easier since
you don’t have to stand there holding it. (VT #1, S:31)
Novices only discussed the first of these sequence issues, namely the critical incident involving the introduction of two concepts at once at the beginning of the demonstration.

N3 (Ideas): O.K. The first thing I suggest that needs to be mentioned: he "has two ideas that we are going to be concerned with," and he mentions 'density' and starts walking off immediately [towards the blackboard]. And I would think, perhaps, as a good overview, mention what the two [ideas] are. (VT #3, S:3)

Presentation Style. Experienced demonstrators discussed several issues pertaining to an effective chemical demonstration presentation style, including appropriate non-verbal gestures, courtesy/rapport, speech characteristics, humor, enthusiasm, and efficient movement around the classroom. The novices discussed the first three of these issues to a limited extent but made no mention of the latter three in their analysis of the videotapes.

This section highlighted several experienced and novice chemical demonstrator differences and similarities in their descriptive knowledge discourses (domain b). The section that follows examines demonstrators' knowledge of alternatives (domain c).

Experienced and Novice Demonstrators' Knowledge of Alternatives

This section examines the various suggestions made by experienced and novice chemical demonstrators for improving critical features that received a "weakness" evaluation during the critical-stop task. This section also examines demonstrators' knowledge of alternative chemical demonstrations related to the concepts of density and air pressure.

Collectively, these responses reflect the third domain of science
teachers' discourse on chemical demonstration teaching called Knowledge of Alternatives (Domain c, p.104).

A taxonomic analysis of demonstrators' discourses identified as "Knowledge of Alternatives" yielded the following four taxonomic categories: Pedagogical Enhancements, Demonstration Variations, Alternative Demonstrations, and Extraneous Examples. The data obtained from both the critical-stop task and semi-structured interview supported this taxonomy for the "Knowledge of Alternatives" domain.

**Pedagogical Enhancements**

Pedagogical enhancements (P) refer to any suggestion for improving the videotaped demonstrations. Most of these suggestions stem from discourses made during the critical-stop task, although some were also obtained during the semi-structured interview. Subjects frequently suggested pedagogical enhancements in conjunction with critical incidents considered to hinder effective chemical demonstrating, i.e., incidents given a "weakness" evaluation (Table 7). Pedagogical enhancements do not include suggestions that refer to variations on the observed demonstration (V) or to alternative demonstrations (D) on the targeted concepts.

Table 13 provides a summary of the number of pedagogical enhancements cited by experienced and novice chemical demonstrators during the clinical interview. Inter-rater reliability in identifying these pedagogical enhancements from the verbatim transcripts was 83.0%. The data in Table 13 shows that experienced demonstrators made considerably more suggestions than novices for improving the chemical demonstration teaching observed on videotape (p = .0625, using the
Table 13

Frequency of Pedagogical Enhancements Cited by Experienced and Novice Chemical Demonstrators

<table>
<thead>
<tr>
<th>Concept</th>
<th>Videotape</th>
<th>Average No. P’s Cited</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N, Pre</td>
</tr>
<tr>
<td>Air Pressure</td>
<td>1</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>Density</td>
<td>3</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>12.0</td>
</tr>
<tr>
<td>Totals</td>
<td>1-4</td>
<td>25.3</td>
</tr>
</tbody>
</table>

* \( p = 0.0625 \), when comparing the number of P’s cited by experienced demonstrators with the numbers cited by pre- or post-workshop novices across the four videotapes.

Note.

A taxonomic analysis of the pedagogical enhancements mentioned by the experienced and novice demonstrators showed that these statements classify into the same nine pedagogical categories identified for domain b, descriptive knowledge of demonstration teaching. A content analysis of these statements indicated that the experienced demonstrators made considerably more suggestions than novices in four of the nine categories (Table 14). They made more suggestions on improving inquiry, attention to new terms, mechanics of the
Table 14
Average Number of Pedagogical Enhancements Made by Experienced and Novice Chemical Demonstrators According to Pedagogical Knowledge Category

<table>
<thead>
<tr>
<th>Pedagogical Categories</th>
<th>Average Number of Pedagogical Enhancements Made by Chemical Demonstrators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novice</td>
</tr>
<tr>
<td>Investigative, Inquiry Approach</td>
<td>3.0</td>
</tr>
<tr>
<td>Questioning Strategies</td>
<td>2.2</td>
</tr>
<tr>
<td>New Terms</td>
<td>2.5</td>
</tr>
<tr>
<td>Quality of Explanations</td>
<td>2.5</td>
</tr>
<tr>
<td>Interactive, Participatory Style</td>
<td>4.8</td>
</tr>
<tr>
<td>Mechanics of Demonstration</td>
<td>1.8</td>
</tr>
<tr>
<td>Use of Blackboard/Visual Aids</td>
<td>4.8</td>
</tr>
<tr>
<td>Overall Organization</td>
<td>4.8</td>
</tr>
<tr>
<td>Presentation Style</td>
<td>0.2</td>
</tr>
<tr>
<td>Ave. Individual Totals:</td>
<td>25.3</td>
</tr>
</tbody>
</table>

Notes. 
* All probabilities in comparison to pre-workshop novice scores. 
** p = .0625  
* p = .125

demonstration, and overall organization of the density and air pressure demonstration.

The Wilcoxon matched-pairs ranked-sign test was used to determine group differences along the nine pedagogical categories. Again, for the purpose of this study, non-parametric probabilities showing
p < .185 were considered reasonable indicators of meaningful group differences.

A few quotes taken from Category 3, the use of new science terms, illustrate some of the qualitative differences in pedagogical enhancements discussed by experienced and novice chemical demonstrators. The discourses of experienced chemical demonstrators reveals that there are more and less appropriate choices of chemical terms to explain a demonstration and related concepts to middle school students.

E1: Right there he says, "What would happen if we eliminated the pressure inside the can?" I think it would have been more effective had he said, "Suppose we took the air out of the can?" But by saying, "... pressure" it's like saying pressure is an object that he's going to take out as opposed to air. (VT #2, S:15)

E2: I thought that was a strange comment. I mean, if you're not going to worry about it (phenolphthalein), why bring it up? Why don't you say it's 'coloring'. (VT #3, S:83)

E3: Also, that definition 'mass per' [unit volume'] - middle school, even high school people, if you say 'per' they don't necessarily equate that with the division sign. So, even though that's the classic definition, I don't think it does much for most people (students). ... This right here, it would be far, far more effective to either sketch a cubic centimeter on the board or even better to have people sketch a cubic centimeter and/or to give them a little sugar cube which is essentially a cubic centimeter, so they get some sense of what that is. ... Just doing it visually [using fingers] ... is not effective. (VT #4, S:10, 15)

The experienced demonstrators identified several critical incidents where science terms were either improperly used or ineffectively explained to students. In these instances, the experienced demonstrators often provided suggestions (pedagogical enhancements) for more appropriate science terms and explanations to use with middle school students.
Novices also identified several potentially troublesome science words and phrases for middle school students, but they did not offer as many ideas of how to pedagogically enhance the videotaped teacher's explanations to promote student understanding. In cases where they did provide solutions, the nature of their pedagogical enhancements were often quite general ("He should bring in a few examples." "He should tell the students that he will explain that term later." "He should maybe put something on the board.") rather than content-specific solutions, as illustrated in the quotes above. The following discourses show novices identifying a difficulty associated with the use of a new science term or phrase and then volunteering a rather general solution, or pedagogical enhancement (P), to the problem.

N4: Here he goes right into the experiment and what I would rather see, especially at the middle school, is more of a discussion. 'Mass per unit volume' is so vague that maybe one or two kids might understand it but certainly not the whole class. If he brought in a few examples or had the kids think of examples of that, or things they were familiar with that would explain it (density), rather than a textbook definition. (VT #4, S:14)

N3: Again, with middle school students, "We won't worry about what that (phenolphthalein) is used for...." but immediately kids would want to know and would really want to have a bit more information. Perhaps later he might say, "If you are interested, etcetera, I'll be happy to explain more about it." (VT #3, S:84)

N5: In terms of the rest of the presentation, I thought it went really well. Right at the end, I don't feel he really cleared up what the concept was, with 'air pressure'. There were a lot of confused people in the room still. They were definitely on the right track and getting real hot but I don't think he really finished it off. He could have maybe put something on the board or had something else to really hammer it (the concept) home. (VT #1, S:5)

In general, the experienced chemical demonstrators provided quantitatively more and qualitatively different pedagogical
enhancements than novice demonstrators for critical incidents judged to be weak. The experienced subjects volunteered numerous content-specific solutions/suggestions to help middle school students better understand abstract chemical terms and concepts mentioned during a demonstration. Novices tended to volunteer more generic teaching solutions to the same problems.

Variations, Alternative Demonstrations, and Extraneous Examples

"Variations" (V) represent any alternative approach to performing the Collapsing Aluminum Can demonstration or Density Column demonstration observed on videotape. Variations typically pertain to alternative demonstration materials or alternative sequences of events that can enhance a demonstration performance.

"Alternative Demonstrations" (D) represent chemical demonstrations that differ markedly from the two demonstrations observed on videotape, yet they still address the concepts of air pressure or density. "Demonstration Variations" (DV) represent twists or extensions on suggested alternative demonstrations (D). "Extraneous Examples" (XTOT) refer to (1) non-demonstration teaching strategies that address the targeted chemical concepts, e.g., labs, discussions, and activities, (coded XPOS), as well as (2) inappropriate chemical demonstrations for teaching the targeted concepts (coded XNEG).

Tables 15 and 16 show that experienced chemical demonstrators made meaningfully more suggestions than pre-workshop novices in terms of discussing variations and alternative chemical demonstrations on air pressure and density. A list of the variations and alternative demonstrations discussed by the demonstrators are given in Appendices
Table 15
Frequency of AIR PRESSURE Demonstrations Cited by Experienced and Novice Chemical Demonstrators

<table>
<thead>
<tr>
<th>Type of Demonstration Citation</th>
<th>Novices (Pre-workshop)</th>
<th>Experienced Demonstrators</th>
<th>t ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Variations (V)</td>
<td>0.5</td>
<td>0.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Demonstrations (D)</td>
<td>0.8</td>
<td>1.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Demonstration Variations (DV)</td>
<td>0.0</td>
<td>0.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Extraneous Examples, Total (XTOT)</td>
<td>0.6</td>
<td>0.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Extraneous Examples, Negative (XNEG)</td>
<td>0.4</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Extraneous Examples, Positive (XPOS)</td>
<td>0.1</td>
<td>0.4</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Notes.
(1) XTOT = Sum of XPOS and XNEG.
(2) DV = Variations on alternative air pressure demonstrations.
*p < .01. **p < .001.

V and W. Attention should also be given to the finding that the experienced demonstrators cited fewer extraneous examples than novices in their discourse of how to demonstrate the targeted concepts. This was particularly true for the concept, density.

Knowledge of Variations. Five out of eight novice chemical demonstrators were aware of at least one variation on the Collapsing Aluminum Can demonstration. This variation involved the popular use of a larger, ditto-fluid size can instead of a soda can to demonstrate the influence of air pressure. The following two discourses illustrate their knowledge of variations on the Collapsing Aluminum
Table 16
Frequency of DENSITY Demonstrations Cited by Experienced and Novice Chemical Demonstrators

<table>
<thead>
<tr>
<th>Type of Demonstration Citation</th>
<th>Novices (Pre-workshop)</th>
<th>Experienced Demonstrators</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Variations (V)</td>
<td>0.4</td>
<td>0.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Demonstrations (D)</td>
<td>1.1</td>
<td>1.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Demonstration Variations (DV)</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Extraneous Examples, Total (XTOT)</td>
<td>1.8</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Extraneous Negative (XNEG)</td>
<td>0.9</td>
<td>0.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Extraneous Examples, Positive (XPOS)</td>
<td>1.0</td>
<td>1.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*p < .05.   **p < .01.   ***p < .001.

Can demonstration. (Appendix U contains additional quotes).

N4: The way I do it with [a] ditto can is a little different. There's a very small hole in the top just to let the steam escape, and I have it on a hot plate with a small amount of water. The students don't know the water is in there. When I feel the water has evaporated, I put a plug in the top and it crumples right there on the hot plate. You don't have to use the ice. (VT #2, I. 8)

N2: You can use the gasoline type can, with the water heated, and then cap it off, well, cut the heat and cap it off. And watch it shrink on its own. And if you want to increase it, pour ice water over it. It'd shrink much more demonstrably - much more dramatically. (VT, #2, I. 8)

The experienced demonstrators also discussed this variation, but in greater scientific detail and suggesting a greater variety of
E3: One can also do [this] on a larger scale with the classic demonstration using duplicating fluid cans, and either inverting them in water, running cold water over them, or simply stoppering it and letting it sit. And you’ll see a similar effect which is not quite as quick, but quite dramatic, because the can is crushed. Those cans are quite strong, and not able to be crushed with one’s hands.

So there are some nice variations or extensions of the demo.

(VT #2, I. 8)

E4: There is another variation on [this demonstration] I just thought of a few seconds ago. You can use a fifty-five gallon drum on a big fire, with some water in the bottom, boil it, get it boiling quite well, get the whole can hot, take away the heat, throw a stopper in the can the same way you do with a gallon duplicator fluid can, and sit down and wait. And when the pressure differential gets great enough, the fifty-five gallon drum will go "BOOM!!!"

The "large-can" variation of the Collapsing Aluminum Can demonstration was discussed by half the novice chemical demonstrators. These demonstrators, however, were generally unable to think of additional variations that would be instructive. The experienced demonstrators, on the other hand, were each able to think of at least one or two other variations of this demonstration as having instructional value. These variations include the use of a full or empty aluminum can to conduct the demonstration so that the can’s collapse under these two conditions could be compared with that of the partially-filled can. Some of the experienced demonstrators also suggested the possibility of spraying the can with water instead of inverting it into a pool of ice water to more clearly illustrate the influence of air pressure. Others indicated that the demonstration could be repeated to see if the same effect would occur using an iron can or in cooling the can with its spout right-side up. The novice
demonstrators appeared to have little knowledge of these additional variations that could be performed, and thus help students explore and understand the factors influencing the can's sudden collapse. The verbal reports, therefore, revealed quantitative and qualitative differences between experienced and novice subjects regarding chemical demonstration variations.

Experienced and novice chemical demonstrators also showed quantitative and qualitative differences in their knowledge of variations on the Density Column demonstration. During the semi-structured interview, less than half the novices were able to discuss a variation of this demonstration that differed from the one they observed on videotape. The few novices that did discuss a variation, suggested a more dynamic approach to the demonstration involving the step-wise addition of the liquids to the cylinder to show students how the column was formed. A few others suggested the addition of more solids objects to the completed liquid column. The following quotes illustrate these novices' pedagogical knowledge of dynamic variations on the Density Column Demonstration.

N1 (Construct a column): [He could have] taken different samples of liquids, shown them in those little tiny beakers, that they all had 10 mls and somehow gotten some sort of mass for them, and then ask, "Which one do you think is gonna go on the bottom? Which one is gonna go on the top?" and then do it to see if it's actually gonna happen. I think that would have pulled it all together. All they've seen is that [column] already being there. They didn't see it actually happen. (VT #3, I. 8)

N8 (Add more solid objects): I think I have done this. I have used more solid objects; rubber, cork, but I can't remember what the other one is. [Subject basically reiterates objects observed on videotape]. (VT #4, I. 7)
The experienced demonstrators also discussed several dynamic variations on the Density Column demonstration. In addition, they freely verbalized their personal preference for a particular variation, justifying their preference in terms of the impact it has on student learning. The following quotes illustrate how experienced demonstrators responded. (Appendix U provides additional quotes).

E1 (Construct a column): Instead of trying to introduce three or four liquids, whatever that was in there, maybe starting with two first and then going to four might have made it a little bit easier, or a stepping stone to the larger concept. Or, I don’t know, I think with that idea I think it’s fun for the kids to sit and watch it, to actually do the pouring right there with them using just two liquids and that way they can kind of guess what they think is going to happen and then they can watch it happen. And I think in watching it happen they might remember it a little bit better. (VT #3, I. 8)

E2 (Construct a column): I always like them to add, actually add the liquid in front of the students and have the students watch the things separating and layer out. I would have liked to have seen that done. (VT #3, I. 8)

E5 (Construct a column and add solid objects): And again, I would build a density column in front of the students and certainly drop in objects. (VT #3, I. 9)

Irrespective of the chemical demonstration observed (Collapsing Aluminum Can or Density Column), analysis of the experienced demonstrators’ transcripts indicate that they discussed more variations on these chemical demonstrations, discussed them in greater detail, and discussed more of their implications for learning than the novice demonstrators.

Knowledge of Alternative Demonstrations. Besides having a greater awareness of variations on specific chemical demonstrations, experienced demonstrators also have greater pedagogical knowledge of alternative demonstrations on air pressure and density (see Tables 15
and 16, respectively). The verbatim transcripts showed that the experienced subjects were able to suggest significantly more concept-specific demonstrations that could be performed with middle school students than novice chemical demonstrators could suggest. The discourses of novices, when compared to the discourses of experienced demonstrators' (p. 161-165), revealed their limited breadth and depth of knowledge of alternative air pressure and density demonstrations. The following quotes illustrate the brevity, and in one case the uncertainty, of novices' discourse on air pressure demonstrations.

N2 (Vacuum chamber): Yeah, you can take a balloon and put it in a bell jar, and evaporate the air around it and the balloon expands in volume. (VT #3, I. 9)

N2 (Barometer): Oh, a barometer. Sure, where you invert a vacuum tube — well, you evacuate air from the tube and invert it upside down; let the air pressure push the liquid up into the tube. (VT #3, I. 9)

N3 (Barometer): You could use a mercury barometer, a really old-fashioned mercury barometer, to let them see that. (VT #3, I. 9)

N3 (Cartesian Diver): Cartesian diver, I guess, wouldn't really necessarily show just air pressure — but it would be, I guess. You could use a Cartesian diver. Interviewer: What part of it would show air pressure? N3: Well, that's what I'm thinking. I'm not sure. I'd have to think about it. (VT #3, I. 9)

Experienced chemical demonstrators also discussed the first two demonstrations mentioned above. The Cartesian Diver demonstration was not discussed by the experienced group probably because it illustrates changes in density much more clearly than it does the concept of air pressure. In any case, the experienced demonstrators provided much more information on the first two demonstrations by discussing practical variations that could be performed on these familiar
demonstrations. The following quotes illustrate the depth of pedagogical knowledge held by the experienced demonstrators.

E3 (Vacuum chamber): Well, the other way of [showing] air pressure, or the effect of the absence of [air pressure], is any number of demonstrations that use a vacuum pump, either an electric one or a mechanical hand pump, where you withdraw air pressure from a closed container. And if one has balloons inside such a container, one can watch the balloon blow up; or marshmallows, or shaving cream, any substance that contains a gas can sort of self-expand, seemingly, until air pressure is allowed to reenter, in which case those items will then return to their previous volume. So, many demonstrations can be used with a vacuum pump or water aspirator, or a hand pump. (VT #2, I. 9)

E5 (Vacuum chamber): You can even put - you can soak some dried fruit, and put it into a bell jar, and the fruit will regain its shape. You can especially do it with ... raisins, and it will come back into the form of a grape. That's something that was done back in the 1800s.

Interviewer: I never knew that.

E5: I think you need to soak the grapes first so they become a little pliable, and that there's enough gas inside that when you put it in a vacuum it will expand to a grape.

E5 (Barometer): Well, I used to set up the mercury manometers, but because of the hazards, we don't do that. Many of the classrooms have a mercury barometer attached to the wall, and I think it's interesting and informative to bring the class around that, look at it, and relate pressure to what they hear on the radio, it being 32 inches of mercury today, pressure; or 'highs and the lows', because these are things that the kids hear about, and they're directly related to atmospheric pressure. Perhaps mentioning that the atmospheric pressure changes from day to day would be an important thing to bring into the lesson.

Besides discussing these common demonstrations on air pressure, the experienced chemical demonstrators also discussed numerous other demonstrations that can be used to teach the concept of air pressure and its influence on objects. The following quotes illustrate this breadth of pedagogical knowledge. (Additional quotes may be found in Appendix U.)

E1 (Breaking a Stick with a Sheet of Newspaper): Air pressure. Oh, there's so many of them. Gracious! You can
get into things like taking a stick and hanging it over a table and placing newspaper over the top of that, and whacking that, and of course air pressure is going to hold it down so that you can snap it. There's a tremendous amount of things you can do with air pressure. (VT #2, I. 9)

E2 (Egg in the Bottle): Oh yeh. I like the Egg in the Bottle. That's always one of my favorite ones. ... I like it when you [take] a big milk bottle and hard boiled egg; and you light the piece of paper, and you stick it down in there, and the flames shoot up, and the egg sucks down. I love that! That's one of my favorite ones for air pressure.

E3 (Ammonia Fountain): An additional one would be the classic ammonia fountain reaction, where you simply boil a little ammonia in a flask with a stopper - one hole stopper and a tube. And ammonia, or hydrochloric acid, are very very soluble in water, so if you get the steam filling the container, the gaseous ammonia rather, filling the container and invert it, as the gaseous ammonia dissolves in water, air pressure on the outside will force the liquid up a tube and cause a fountain type effect. That's another example of air pressure. (VT #2, I. 8)

The experienced demonstrators, as a group, discussed several additional chemical demonstrations that illustrate air pressure. A list of these additional air pressure demonstrations can be found in Appendix V.

When it came to discussing demonstrations dealing with the concept of density, novices mentioned several more than they did with air pressure (compare Tables 15 and 16). However, these numbers did not nearly approach the number of density demonstrations discussed by experienced chemical demonstrators. Each novice generally discussed only one other density demonstration during the clinical interview. As a group they mentioned seven different demonstrations that illustrates the concept of density. Each experienced chemical demonstrator, by contrast, freely recalled and discussed an average of about five density demonstrations. Collectively, they mentioned 17 different chemical demonstrations on density. A list of these density
and air pressure demonstrations, appropriate for the middle school level, is provided in Appendices V and W.

Other distinguishing characteristics observed in the protocols were that the experienced demonstrators were usually more able than novices to specify (1) the kinds of chemical substances that are well-suited for a particular chemical demonstration as well as (2) the outcomes that are associated with a given demonstration. Consider the information volunteered by novice N3 and experienced demonstrators E3 and E5 in their discussion of a demonstration involving the density of gases.

N3: As he was talking I was trying to think of the density of gases, showing, you know, balloons with various gases in them, but other than that, I wish I did know some demos to do on density. (VT #3, I. 9)

E3: Somewhere in his discussion he mentions what he really wanted to talk about was density of gases. There are a number of ways to show the density of gases. You could contrast helium versus air versus some dense gas like freon or sulfur hexafluoride, all of which can be placed in balloons and one can watch the rate of fall or rate of ascent and compare densities that way. (VT #3, I. 8)

E5: You can fill a balloon with freon and it sinks it’s so heavy. You can fill a balloon with hydrogen or helium. This is less dense than air so it rises. (VT #3, I. 8)

In the general descriptions of the The Great Balloon Race demonstration provided above, the experienced demonstrator’s provided details regarding the number of systems to be compared, the materials to be used, and, the kinds of observations that would be apparent to students. Much of this information was not noticed in novices’ protocols.

Besides differing in the specificity of information provided in their descriptions of chemical demonstrations, the experienced group
also discussed (1) the importance of using simple materials/systems and (2) the importance of student involvement and hands-on experiences during a chemical demonstration more so than novices. These patterns are exemplified in the following discourses taken from a novice and two experienced demonstrators as they discussed demonstrations pertaining to the relative density of solid objects.

N5: Let's see. Well, certainly there's a lot that has to do with density when you're dealing with rocks. I do a unit on rocks and certainly some elements are more dense than others. And I try to get that idea across to the kids, you know that the rocks that are full of metals and stuff like that are going to be more dense and are heavier, even if you have two rock samples that are approximately the same volume. You (students? teacher?) can pick up two rocks; if one's very much denser than the other, then you get a handle on it. So indirect things like that. (VT #4, I. 9)

Contrast this selection of materials and extent of student involvement with that of two experienced chemical demonstrators' discourses.

E4: The one that I use is metal cubes of all the same size, but different metals, ranging from aluminum through steel to lead and brass, so that when you try to pick up any two cubes, the difference in mass is obvious. Interviewer: How do you do that as a demo? E4: I literally pass them around [and say,] "Tell me about these four metal cubes." And they're all different metals. That's obvious without even identifying them. And they will realize that some are heavier than others. (VT #4, I. 9)

E5: Instead of mixing things with different densities I would consider, you know - very often people have this piece of granite and a piece of foam that looks like granite and they are the same size and they look the same and you can, passing that around, you can actually feel the difference. (VT #3, I. 9)

A comparison of the variations of the "Hand-Weighing" demonstration discussed by the experienced and novice chemical demonstrators shows that the three subjects selected different
materials to perform this demonstration. The novice selected two objects with complex compositions and different appearances. The experienced subjects selected simpler substances, choosing objects that were either uniform in composition or objects that were visual look-alikes. In other cases, where experienced and novice demonstrators discussed similar demonstrations, the experienced demonstrators generally preferred to use simpler systems to demonstrate abstract ideas to middle school students.

In the above discourses, one may also notice that the experienced demonstrators made more passing references to student involvement in a chemical demonstration, even if the demonstration is very simple and easy to perform.

In several instances, the experienced demonstrators would volunteer information about the kinds of sensory or cognitive experiences that students would have during a demonstration. This information was volunteered less often by novices. This difference is somewhat apparent in the last three discourses given above.

**Extraneous Examples.** Novice chemical demonstrators were more inclined than experienced chemical demonstrators to discuss non-demonstration teaching strategies that are suitable for teaching density and air pressure, (See Tables 15 and 16, XPOS). Some of the novices, especially when they were prompted by this researcher to discuss additional demonstrations related to the targeted chemical concepts, would frequently discuss a lab, class activity, or class discussion that would help students learn about the concepts. The following discourses illustrate this. (Additional examples are provided in Appendix U.)
N8 (Lab): I think what I’d do is I’d take different sizes and see - I’d figure out the densities for different size objects and different objects that look the same size but they have different densities and I have one that is made out of rubber and one that is made out of aluminum and one made out of steel and one made out of wood. They are all the same size. Then they have to figure out what the density of each one of these even if they are the same size because when you look at the volume, the volume looks the same. I have them use a ruler and then I have them do water displacement and then I have them measure density and measure the grams. Then I think it comes more clear to them. Then I always have them bar graph so they can see which one has the higher density. Then I ask them questions. (VT #4, I. 8)

N5 (Activity): Well, I did a neat thing with density with the planets, where you take all the planets and you take their sizes and their masses, and then you plot their densities. You can get some interesting relationships going on there. Predictions you’d make about their densities are often different than what their actual densities are. And that’s kind of neat. According to them, you know, like Jupiters huge. The kids - if they have a misconception about density, which a lot of people do, they walk around with how big it is when it’s how dense it is and I try and get that fallacy out of the way. It’s kind of neat, if you plot density of the planets, and you plot their masses and their volumes as well, you start seeing some neat relationships. (VT #4, I. 9)

N7 (Discussion): What I did myself, I asked students why ice floats and we talked about that; and they came up with some pretty interesting answers. (VT #4, I. 8)

Most of these non-demonstration examples represent legitimate teaching strategies related to the teaching of density but they did not address the interviewer’s question about demonstrations that illustrate the concept of density (Question I 9. of Interview Guide, Appendix I). These non-demonstration responses may represent brainstorming efforts on the part of the novices to answer the interviewer’s questions when they could not think of actual demonstrations. Experienced demonstrators, after discussing several suitable demonstrations, openly indicated they could not respond any further to this researcher’s probing of additional demonstrations.
Instead of supplying non-demonstration teaching strategies to illustrate the density concept, they usually made the following comments: "I'm sure there are many other ones (E1)"; "Those are the ones that come to mind right now (E4)"; "No other ones come to mind right now, but I'm sure there are many others (E3)"; "It's hard to think off the top of my head. I'm sure there are hundreds of others (E5)."

Some of the conceptions that novices had regarding suitable demonstrations on the concepts of density or air pressure were found to be erroneous, or at least pedagogically unsound, (See Tables 15 and 16, XNEG). Such misconceptions represented 43% of the demonstrations (10 of 23 demonstrations) discussed by the novice chemical demonstrators. These erroneous or pedagogically unsound conceptions represented only 6% percent of the demonstrations (4 of 63 demonstrations) discussed by the experienced subjects during the semi-structured interview. Some of these conceptions are now examined in detail.

A few novices considered the demonstration of Archimedes principle a legitimate example of a density demonstration. The following quotes illustrate this understanding.

N2: The [demonstration] where you fill the container and then insert something and watch the water displaced. Or you use the container that has the side arm where water can go out. And that helps illustrate density by showing volume displaced. (VT #3, I. 9)

N3: ... displacement of water by objects in the water. (VT #3, I. 9)

N5: I think Archimedes principle could have been talked about a little. There's a neat story that goes along with Archimedes principle. The guy that has the 'Eureka' experience in the bathtub. My kids enjoy that story. And Archimedes is kind of an interesting name anyway. It seems
to stick in peoples minds. Really, when she [the videotaped model] was floating the different things, that’s really what she was talking about. Things that are less dense are going to float on things that are more dense. (VT #4, I. 10)

The comments above suggest that these three novices consider the demonstration or discussion of Archimedes principle to be synonymous with the demonstration or discussion of the concept of density. This conceptual association influenced their understanding of how to effectively demonstrate the relative densities of substances. The experienced subjects did not make this false association. Although it is true that Archimedes Principle is useful for determining an object’s absolute density and that such a demonstration could also illustrate the relative density of a solid object with respect to a liquid, a demonstration that merely illustrates water displacement by a solid object (an indicator of its volume) is not strictly synonymous with a demonstration on density (mass/volume). The close conceptual association between volume displacement and density apparently influenced novices’ understanding of how to effectively demonstrate the density concept.

Novices also suggested a few other demonstrations as illustrating density, when they, in fact, addressed other physical science concepts, such as surface tension and sedimentation rates. The following discourse of N5 illustrates an interesting discrepant event involving density, but does not effectively illustrate the targeted concept.

N5 (Surface tension): What I would like to do is after we talked about density with chemistry students, or with higher level elementary students, doing something like showing them that [concept] with just a razor blade and just saying, "Obviously, steel is greater in density than water. So I am going to drop this in this [container of water] and what is
going to happen?" "Well, it is supposed to sink." "Why
doesn't it sink?" So, then you [talk] about that [razor
blade] expanding on to that [water surface?]. But it is a
little bit too much, I would think, for younger students
because you are not trying to confuse them you are trying to
straighten them out. It is a twist or so for a little kid.
(VT #4, I. 9)

Although novice N5 had some notion that this demonstration would
be a suitable discrepant event on density (demonstrations that are
contrary to students’ intuitive understandings of density), the
suggested demonstration actually illustrated another basic science
concept much better, and was therefore coded as XNEG (extraneous,
negative). It basically reflected a pedagogically unsound
demonstration on density. Such discrepant event items, though not too
often encountered in the protocols, presented some difficulty for
independent coders, e.g., whether they should be coded as D (density
demonstration) or U (pedagogically unsound demonstration). The
clarity of the discourses provided by the demonstrators sometimes
influenced the direction of coding. In any case, novices discussed
such discrepant examples as suitable density demonstrations more
frequently than experienced demonstrators.

One novice demonstrator and one experienced demonstrator
discussed a demonstration involving sedimentation layers and
sedimentation rates as suitable for illustrating differences in the
density of solids.

N8 (Sedimentation rates): I’ve used a density one where I
take some mud and I put it in some water and I shake it. And
obviously the gravel and the sand - well, gravel first, sand,
and then the clay particles will sit there for a while. That
shows different levels of density. I do that. I forgot to
tell you that but that’s in earth science. (VT #4, I. 10)

E4 (Sedimentation rates): Density of course is just - you
can just drop different things into liquids, and watch the
rate at which they fall, to look at differences in densities. (VT #4, I. 9)

Although the sedimentation rate of particles (and the corresponding sedimentation layers generated) correlates with particle density, other factors, such as the viscosity of the liquid, particle size, and particle shape also have an influence on the overall sedimentation rate and layering effect. Because of the number of variables interacting in this system, this demonstration would probably be considered an unsound demonstration of the concept of relative density at the middle school level.

A similar pattern of erroneous and pedagogical unsound demonstrations were discussed by several novices and one experienced demonstrator on the topic of air pressure. These subjects suggested that air pressure could be demonstrated by observing the rate of expansion of balloons covering the tops of heated flasks containing different liquids. These examples more accurately demonstrate vapor pressure and rates of evaporation of various liquids. Consequently, these demonstrations would also be considered pedagogically unsound methods for illustrating ambient air pressure and its influence on common objects.

A few subjects suggested demonstrations involving air foils and flight to illustrate air pressure. These demonstrations, however, illustrate Bernoulli’s Principle and the laminar flow of air around objects much better than it illustrates the simple presence of air pressure. Although these demonstrations have value in their own right, they too were considered unsound selections of demonstrations to illustrate the simple presence of air pressure. These examples
constitute some of the XNEG entries (Extraneous Examples, Negative) in Table 15.

A comparison of experienced and novice chemical demonstrators' discourses on alternative chemical demonstrations that effectively illustrate air pressure and density shows that novices' conceptions contain many more examples of erroneous or pedagogically unsound demonstrations they associate with the targeted concepts. The pedagogically unsound demonstrations were classified as "unsound" because they better illustrate related chemical and physical concepts, and not the ones of interest.

Having examined experienced and novice chemical demonstrators' knowledge of alternatives in conducting chemical demonstrations (domain c), the discussion next turns to these teachers' Rationales (domain d) for their suggestions and evaluative judgments.

**Experienced and Novice Demonstrators' Rationales**

During the clinical interview, demonstrators frequently gave rationales, or reasons, for their evaluative judgments and suggestions on how to improve a chemical demonstration performance. These rationales were usually given after demonstrators rendered a favorable or unfavorable judgment of a critical incident or after suggesting a pedagogical enhancement (P), variation (V), or alternative demonstration (D). Collectively, these rationales represent the fourth domain (domain d) of chemical demonstrators' pedagogical comments.

A taxonomic analysis of demonstrators' rationales showed that most rationales could be coded into one of four knowledge areas: (1)
the learner, (2) the demonstration system, (3) the subject matter, or
(4) teaching strategies. Rationale statements from each of these four
areas are exemplified by the following quotes and discussion.

**Knowledge of the Learner**

Experienced and novice chemical demonstrators frequently
justified their evaluative judgments and suggestions for improvement
based on their knowledge of middle school students. Thus, whenever
demonstrators judged a videotaped teacher as teaching above or below
the level of the student, judgments were usually premised on
demonstrators' understanding of learner characteristics. This
understanding included an awareness of students' (1) prior knowledge
of science terms and concepts, (2) scientific reasoning skills,
(3) motivation to learn, and (4) attention spans. Two of these
knowledge-of-the-learner rationales are exemplified in the following
discourses. (Other "learner" discourses are presented in the pages
that follow).

E2 (prior knowledge): He let him (the student) get away
with that [answer]. I would have said, "Well, tell me what
an 'interface' is? What do you mean by that? Can you
explain that to me?" Maybe not everybody understands the
term. (VT #3; S:41)

N3 (motivation to learn): Again, with middle school
students, [when he says], "We won't worry about what
[phenolphthalein] is used for ...," but immediately, kids
would want to know and would really want to have a bit more
information. (VT #3, S:84)

Knowing what middle school students know and what they don't know
about science, and knowing the level of student motivation to learn
science, provided demonstrators E2 and N3, respectively, with a basis
for making evaluative judgments. Nearly all experienced and novice
demonstrators used a knowledge-of-the-learner rationale to support a significant proportion of their evaluative judgments regarding effective and ineffective chemical demonstrating.

Discourses that contained a notably high percentage of rationales reflecting a knowledge of the learner included think-aloud comments on the teacher's use of new science terms (Category 3) and the quality of explanations (Category 4), (see Table 11). Within these categories, experienced demonstrators evoked the learner rationale more frequently than novices. Although a quantitative content analysis was not conducted on demonstrators' rationales, the differences between the two groups appeared approximately proportional to the number of critical-stop judgments rendered (see Table 7). Qualitative differences in learner rationales were not discernable between the two groups of demonstrators discussing new terms and explanations.

In another context, the experienced demonstrators provided most of the discussions on student misconceptions and how these misconceptions could arise during a chemical demonstration. With the Collapsing Aluminum Can demonstration, for example, only the experienced demonstrators discussed the kinds of misconceptions students could develop after seeing the aluminum can suddenly collapse. These comments not only reveal experienced demonstrators' understanding of the demonstration and the science behind the demonstration, they reveal a knowledge of middle school students' thinking about the demonstration outcomes. The following quotes illustrate this unique knowledge of the learner.

E3 (Students' reasoning): Well, one potential factor that can confuse students' understanding in the [Collapsing Aluminum Can] demonstration that was done, or the classic
duplicating fluid can demonstration, is that water on the outside of the can ...

Interviewer: [You mean] the vapor, the moisture in the air?
E3: No, the liquid water on the outside of the can, since you’re inverting it into [a pan of] water, that somehow liquid water on the outside of the can is crushing the can. Or in the duplicating fluid can experiment, the classic version of this [collapsing aluminum can demonstration], they run it under water, a stream of water, and so students can quite easily conclude that it’s water pressure that’s crushing the can, and you have a total misconception of what’s going on. (VT #2, I. 8)

E1 (Students’ reasoning): Probably a better way to teach that would be, as has been mentioned many times, the kids get confused when you’re taking those tongs [to grab the can] and squashing that can [in a pool of ice water]. They really feel like you have done that, [i.e., squeeze the tongs too hard while transferring the can to the ice water]. And probably it’s a good reason for having a child do that [transfer] as opposed to you doing that so that they know that it has not been crushed by the instructor [with his tongs]. (VT #2, I. 8)

The discourse of experienced chemical demonstrator E3 extended beyond the recognition of potential "misconceptions" that students could develop from a demonstration, to ways of addressing the misconceptions. The following quote illustrates how subject E3 addressed a potential student misunderstanding regarding the Collapsing Aluminum Can demonstration. A second example is provided in Appendix X.

E3 (Dealing with student misunderstandings): Using the procedures he had, one thing that students often confuse with this demo and the classic variation that has been around for a long time, the duplicating fluid can, is that somehow it is water pressure that is crushing the can. And an alternative route, after the heating, would have been to cap it, simply cap the can and let it cool to room temperature at a normal rate and that excludes the notion of the external water pressure having anything to do with the crushing of the can. And that could be done either with these soda cans or it could be done with the duplicating fluid can. (VT #2, I. 8)
E3’s suggestions on how to keep students from developing misconceptions essentially involved a simplification of the original demonstration system so that middle school students would not focus on the many extraneous variables operating on the system, i.e., variables that students may falsely attribute to the can’s collapse.

The experienced demonstrators considered simplified variations of a demonstration as a way of reducing student learning difficulties.

Novice demonstrators rarely discussed such potential sources of student misunderstandings stemming from a demonstration. However, one novice, critiquing the Density Column demonstration, did discuss sources of confusion for the learner but showed some uncertainty about the importance of these critiqued features.

N4: There are two things that— I don’t know if they are important— but as I teach middle school I know the types of things to look for. One is that each one of those layers (liquids in the column) should be an equal amount. And kids would think that was a setup. Maybe it’s different [i.e., the way the liquids order in the density column], because this one [liquid] takes up more space than that one. ... Those are just things that I was looking for that a middle school kid would look for. They would say, "This wasn’t fair, because this one [layer] is bigger than the other." [VT #3, S:96]

N4: The other thing that I’m not too sure if it’s fair to use a solid because I don’t know if that’s— I don’t know. I might be wrong about that. That (using solids) might not be the right concept to do with density, with the lab (density demonstration) that he was doing. [VT #3, S:96]

The quotes presented above show that experienced demonstrators not only knew of misunderstandings that students could develop during a chemical demonstration, they also knew of ways of remedying the problem. Their suggestions frequently involved the use of simplified variations of a demonstration that remove potentially confusing
variables. In contrast, such suggestions and student rationales were rarely evident in the protocols of novice demonstrators.

Knowledge of the Demonstration System

Experienced demonstrators often discussed the complexity of the videotaped demonstrations. These comments frequently became the rationale for suggesting simpler variations of chemical demonstrations when performing demonstrations with middle school students. The following quotes illustrate this understanding of the complexity of chemical demonstrations held by experienced demonstrators. The quotes are taken from critiques of the Density Column demonstration. They contain both direct and indirect references to the demonstration's complexity. (Additional discourses may be found in Appendix X).

E1 (Direct): Weakness. ... Other than maybe being a little bit too complicated for middle school. ... There are too many things involved with this demonstration that needs to be watered down a little bit. (VT #4, I. 4)

E2 (Indirect): He could make a point with a simple [density column] demonstration and use that as a focal point for quite a while. ... You see so many people set up maybe four or five [demonstrations]; they do this, this, and this: this big impact stuff. (VT #3, I. 5)

E3 (Indirect): There are several demonstrations that can be used to illustrate the concept of density ... although with the demonstration he did [perform, i.e., the density column demonstration], he did a good job with, but there are other ones which I would probably start off with in a classroom setting if you had total choice. (VT #3, I. 9)

E5 (Direct): It's very confusing when you start mixing ideas together. It wasn't clear cut. ... Maybe at the end of the lesson he could show a more complicated situation and ask students to explain it. (VT #3, I. 9)

Each of these comments reveals that experienced chemical demonstrators were familiar with the complexities of the videotaped demonstration. These subjects saw the density column as a complicated
chemical system for teaching the concept of density to middle school students. Because of this awareness, these demonstrators were cognizant of the demonstration’s potential for hindering, rather than fostering, the learning of the density concept.

Experienced demonstrators discussed multiple aspects of a demonstration’s complexity. For example, with the density column demonstration, they considered the number of materials used in the demonstration as a major source of complexity. This demonstration typically calls for (1) four to five liquids layered one on top of the other and (2) several different solids: one resting at each of the interfaces, one floating on top, and another sitting on the bottom.

The experienced demonstrators also discussed the complexity of the Density Column demonstration in terms of the number of chemical concepts that need to be addressed in order to fully explain the density column system. The experienced demonstrators were aware that the column formed not only because of the density of the liquids, but also because adjacent liquids were insoluble in each other. Finally, these demonstrators also considered tangential issues, such as explanations for how the four liquids in the column were colored, as further adding to the conceptual complexity of the demonstration.

Because of the perceived complexity of the density column demonstration, one experienced demonstrator suggested that this demonstration would be inappropriate to use as an introductory lesson on density. Only one novice made any reference to either the simplicity or complexity of the density column system as a rationale for accepting or modifying the videotaped presentation.
Discourses on the complexity of the Collapsing Aluminum Can demonstration were generally indirect. Experienced demonstrators usually discussed the issue of complex demonstration systems in terms of sources of student misunderstandings (see previous subsection).

Subject-Matter Knowledge

A taxonomic analysis and content analysis of the descriptive knowledge domain (domain b) has already shown that only the experienced chemical demonstrators identified incorrect science propositions mentioned by the videotaped models (see pp. 143-146). The rationales that supported their unfavorable judgments of these critical incidents were clearly tied to their knowledge of chemistry.

Subject-matter knowledge also played an important role in experienced demonstrators' critique of critical incidents involving the application of density and air pressure to students' lives.

Subject-matter rationales are illustrated in the following critiques.

E3 (Density column): And then lastly, what I hoped she would subsequently [do], if not at this point, is to draw from students other applications of density so it becomes a real concept for them and not just something. I mean, 'So what. You know water floats on top of corn syrup. Who cares about that?' So it would have some application to their lives. ... The concept of density applies in hundreds of applications in day to day living that could be drawn in, and everything from (1) submarines to (2) fish swimming to (3) density of battery acids to many, many, many applications of density. (VT #4, I. 5; VT #3, I. 9)

E5 (Collapsing aluminum can): I like relating that [demonstration] to the steam engine. As a first treatment on a steam engine, spraying water into the [engine's] cylinder, that’s the same as water going inside the tin (aluminum) can. (VT #2, I. 8)

These experienced chemical demonstrators possessed ample knowledge of the application of chemistry to students' lives. This
knowledge of concept applications is a form of pedagogical content knowledge because it is discussed in the context of teaching chemistry to middle school students. In a non-teaching context, it would be considered a form of subject-matter knowledge. In either case, this specialized knowledge permitted the experienced demonstrators to make evaluative judgments and suggestions for improving the videotaped demonstrations not observed among novice demonstrators.

Knowledge of Teaching Strategies

Experienced and novice chemical demonstrators evaluated and discussed many critical incidents based on their knowledge of fundamental principles of effective pedagogy and educational psychology. This body of knowledge provided these demonstrators with some justification for the judgments they rendered. A taxonomic analysis of the protocols showed that many critical-stop discourses on effective and ineffective chemical demonstration teaching were supported by statements related to the importance of motivational strategies, wait time, feedback, reinforcement, instructional pace, visual learning, and questioning. Demonstrators also made frequent reference to the value of using analogies, modeling behaviors for students, building on students' prior knowledge, engaging students in discovery learning and other learning strategies as contributing to an effective chemical demonstration presentation. The following quotes illustrate how two demonstrators discussed the value of probing students' prior knowledge and using motivational strategies to help contribute to an effective chemical demonstration performance at the middle school level.
N1 (Prior knowledge): And the fact that he is asking them about their past experience, what it is they know already, so he has a clearer idea of where to start with them, instead of assuming that they all know it (the concept "density") or assuming that they don't know it. He's really getting a hold on, at least, where a few people in the class are [with those questions]. (VT #3; S:3)

E1 (Motivational strategy): That was also good. He didn't tell them what he had in the [density] column. Instead, he suggested, that I'm not going to tell you what is here. So it set up some mystery in their (the students') mind and probably made them sit up and take a little bit of notice. (VT #3; S:15)

Principles of effective pedagogy and educational psychology also provided demonstrators with rationales to support their suggestions of how to improve the videotaped chemical demonstrations. Experienced and novice demonstrators both made frequent reference to these educational psychology rationales in their think-aloud discourses. Differences between experienced and novice demonstrators were difficult to discern based on a taxonomic analysis alone. A detailed content analysis was not conducted in domain c (Category 4: Knowledge of Teaching Strategies) because resources were not available to train a fourth coder. Such an analysis may have detected subtle quantitative differences in the number of teaching strategy rationales mentioned by the two groups of demonstrators.

Competing Rationales and Evaluative Judgments

A small percent (approx. 4-5%) of the critical incidents discussed by two or more demonstrators revealed differences in opinion (i.e., evaluative judgment) regarding whether an observed teacher behavior contributed to or distracted from the chemical demonstration performance. Such divergent judgments were consistently accompanied by different rationales used to support their judgments. Exploring
these differences in teachers' thinking may shed some light on experienced and novice demonstrators' pedagogical judgments and decisions during preactive and interactive teaching. Differences that emerge may suggest potential areas of growth in science teachers' professional knowledge base. Consider the quotes from the following two subjects addressing the critical incident involving the appropriateness of using the term 'phenolphthalein' during a presentation of the Density Column demonstration at the middle school level.

N4 (favorable judgment): I think it's good to introduce them to things like phenolphthalein, even though they don't have to know about it, because they become familiar with the words that they'll hear later on if they have more chemistry. And yet, at the same time, he says, "You don't have to worry about it," so the pressure is off, but the information has been planted. So, I think that's an O.K. technique. (VT #3, S:85)

E3 (unfavorable judgment): Here he's telling them that he's dyed the water which has changed its visible properties. It is good that he's telling that. Telling them that it's a dye alone would probably be sufficient rather than saying its phenolphthalein which is just some other chemical name for people. And telling them that chemical name is not important. I would have preferred just saying to them that the water has been dyed and letting it go at that. By throwing in "phenolphthalein", is another word that the students now have to think about, even though he's told them it's not important. If you're going to use words, they are important; use simpler words that you don't have to define. (VT #3, S:82)

Comparing these two discourses, it is apparent that the novice demonstrator evaluated this critical incident favorably using a rationale based on a knowledge of the high school science curriculum. This teacher considered it beneficial to at least minimally familiarize middle school students with new terms they will encounter again in succeeding science courses. The experienced demonstrator, on
the other hand, rendered an unfavorable judgment of this incident and provided a supporting rationale based on a knowledge of how middle school students learn. This demonstrator considered the new term 'phenolphthalein' excessive because it places an additional cognitive demand on students that is unnecessary. The use of this term would, presumably, only interfere with the learning of the central concept, density. Such differences in evaluative judgments and supporting rationales were not only observed between experienced and novice demonstrators, but on occasion, competing rationales were also observed between subjects in the same group. The experienced subjects, however, appeared to show slightly greater agreement in their evaluative judgments and supporting rationales than novices.

The Pedagogical Knowledge System Probed by the Critical-Stop Task

A theme analysis (Spradley, 1980) was conducted on the protocols for two reasons: to further document experienced-novice chemical demonstrator differences and to examine the extent to which the verbal data obtained during the clinical interview reflected Shulman's (1986, 1987) two theoretical constructs, pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK).

The entries in Table 17 show that most (over 90%) of the comments made by the chemical demonstrators during the critical-stop task addressed pedagogical issues important to chemical demonstrating (PCK + GPK). About 2% of the critical-incident comments focused on subject matter knowledge issues (SM), i.e., incidents involving the conveyance of inaccurate chemistry content. The remaining comments focused on
issues that the coders could not readily classify (NC) into the three knowledge systems, PCK, GPK, and SM, using literature definitions provided in the coding instructions (Appendix P). The NC comments generally dealt with the manipulation of demonstration equipment and safety issues.

A quantitative theme analysis, summarized in Table 17, revealed a characteristic difference between experienced and novice chemical demonstrators in terms of the frequency with which the two pedagogical

Table 17
Theme Analysis of Critical-Stop Discourses According to Pedagogical Knowledge System

<table>
<thead>
<tr>
<th>Knowledge System or Theme</th>
<th>No. Critical Comments Made by Chemical Demonstrators</th>
<th>% TOTAL (per group)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVE. Novice</td>
<td>Exper.</td>
</tr>
<tr>
<td>Pedagogical Content Knowledge (PCK)</td>
<td>38.0</td>
<td>41.2</td>
</tr>
<tr>
<td>General Pedagogical Knowledge (GPK)</td>
<td>11.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Subject Matter (SM)</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>No Code (NC)</td>
<td>3.0</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Total</strong>:</td>
<td><strong>53.0</strong></td>
<td><strong>54.2</strong></td>
</tr>
</tbody>
</table>

Notes.

- a Totals that differ from Tables 7 and 11 reflect the additional coding of "neutral" critical incidents.
- * p = .125 between experienced and pre-workshop novice demonstrators.
- ** p = .0625 between experienced and pre-workshop novice demonstrators.
knowledge systems were evoked during the critical-stop task. In absolute terms, the experienced chemical demonstrators made one-and-a-half times more frequent mention of pedagogical content knowledge issues than novices during their critique of the four demonstration videotapes (57 vs 38 PCK comments, respectively). These differences reached a probability of .0625 using Wilcoxon’s matched-pairs, ranked-sign test. (Probabilities ≤ .187 are considered meaningful using this non-parametric test). Likewise, for general pedagogical knowledge, the experienced demonstrators made 1.4 times more frequent mention of general pedagogical issues than novices (15.5 and 11.0 GPK comments, respectively; p = .125).

In relative terms, the data in Table 17 show that about 70% of the comments made by experienced and novice chemical demonstrators critiquing the four demonstration videotapes reflected pedagogical content knowledge concerns. These data provide evidence that the critical-stop task used in this study effectively probed teachers’ pedagogical content knowledge. To a lesser extent (15-20% of the discourses), it also probed other forms of knowledge important to effective chemical demonstrating.

Coder agreement in classifying critical-incident discourses according to theme (PCK, GPK, or SM) was 87.2%. Scott’s pi was calculated to be 82.9% when adjusting for chance coding into these three knowledge categories and NC.

Several critical-stop discourses are examined next to illustrate the two forms of pedagogical knowledge evident in experienced chemical demonstrators’ discourses (i.e., PCK and GPK). Although many examples of PCK have already been provided in previous sections, prior
discussions did not explicitly tie demonstrators' discourses to any particular pedagogical knowledge system reported in the literature. An effort to associate demonstrators' discourses to a specific knowledge system is the goal of the discussion that follows.

The discourses selected to distinguish between PCK and GPK verbalizations come from the critique of Videotape #3, the Density Column demonstration. Selection of this tape to illustrate the findings was arbitrary. PCK and GPK discourses were equally evident in the think-aloud critiques of the other three videotapes, but in order to better compare discourses, this researcher decided to keep content and context similar and, therefore, use the critical-stop discourses of only one videotape. The decision to use only experienced demonstrator discourses in this section was based on the clarity of their comments for illustrating the nature of the two pedagogical knowledge systems.

Examples of Demonstrators' Pedagogical Content Knowledge, PCK

The following quotes reflect the nature of experienced chemical demonstrators' discourses that coded as pedagogical content knowledge (PCK) during the theme analysis.

PCK Example 1: Evaluating the density column demonstration

E5: This choice of a demonstration at this point is inappropriate. Certainly density is a difficult topic. You should not start with a complicated system where you have a mixture of different densities but you should make sure that [students] have an understanding of the comparisons between densities of single substances such as a rock and a piece of styrofoam the same size. (VT #3, S:15)
In this example, demonstrator E5 mentions that the density column demonstration would not be an appropriate introduction to density at the middle school level. To address this matter, demonstrator E5 offered a brief description of a more suitable demonstration to introduce students to the concept of density. The alternative involves the simple weighing of two different solids of the same size. (In the follow-up interview, this demonstrator suggested the use of an equal-arm balance to conduct this weighing). This alternative demonstration is much simpler to perform and it clearly illustrates Shulman's idea of pedagogical content knowledge, i.e., knowledge of how to teach specific topics, such as density.

PCK Example 2: Using visual aids.

E3: Here, ... he's identified these layers [in the density column]. It would be preferable if he had a physical drawing on the board or an overhead that indicated the different liquids relative to the actual set-up so people have a direct visual of it, rather than just his words that, "Well, water is here and methanol is here." (VT #3, S:90)

E5: And I think I would like to see some visual rather than abstract sketches [words] on the board. The thing he put on the board were pretty much words, whereas a few sketches of how equal masses of material might have varying volumes [would be instructive]. (VT #3, S:97)

PCK Example 2 contains two suggestions for improving the observed chemical demonstration by means of the supplemental use of blackboard visual aids. These suggestions include the use of the blackboard to (1) diagram the physical system on display and (2) to diagram various objects with equal masses occupying different volumes. These "visual" illustrations provide middle school students with additional
representations of the concept of density. They further exemplify Shulman’s conception of pedagogical content knowledge.

Other discourses coded as pedagogical content knowledge included critiques on the videotaped teachers’ use of new terms. Five types of "new term" discourses qualified as PCK codings. They included discourses in which the demonstrator (1) recognizes outstanding explanations of new terms provided by the videotaped teacher, (2) provides alternative explanations of new terms used in a demonstration, (3) suggests the deletion of certain new terms and their explanations, (4) suggests the substitution of simpler terms in place of the ones used, and (5) identifies the problem of the videotaped teacher focusing on irrelevant terms that detract from the central issue or concept being demonstrated. The following quotes illustrate the third, fourth, and fifth type of discourse coded as PCK, respectively. The quotes address the issue of using the scientific term "phenolphthalein" during a demonstration with middle school students. The quotes refer to a critical feature different from the phenolphthalein incident discussed on page 144 (a Knowledge Inaccuracy) but similar to the one discussed on page 155 (Pedagogical Enhancements) and 182-183 (Competing Rationales). Obtaining representative quotes that address the issue of new terms and that also illustrate demonstrators’ PCK understandings were difficult to find in the protocols, therefore, a phenolphthalein-related critical incident is presented again.

PCK Example 3: Explaining chemical terms.

E2 (Substituting simpler terms): I thought that was a strange comment, ["I added a dye called phenolphthalein, O.K. And we won’t worry about what phenolphthalein is used for right now"]. I mean, if you’re not going to
worry about it, why bring it up? Why don’t you say, "It’s coloring"? (VT #3, S:83)

El (Focusing on irrelevant terms; delete term): This was completely irrelevant. The [term] ‘phenolphthalein’ was something he shouldn’t even have mentioned because for some people that would have just taken them off into another direction. ... I’m going to stop [the videotape] again because he’s saying that he’s not going to talk about phenolphthalein, but this part of the demonstration is predominantly on phenolphthalein and what it does and does not do; and it really does not have much to do with the problem of density. (VT #3, S:81 & 86)

In the examples provided above, two demonstrators discuss the appropriateness of using the term ‘phenolphthalein’ ¹ with middle school students during a presentation of the Density Column demonstration. In the first quote given above, demonstrator E2 suggests the use of a simpler term for phenolphthalein, like ‘coloring’: a term which most students could readily comprehend. This suggestion reflects this demonstrators’ pedagogical content knowledge because it reveals her understanding of effective and ineffective explanations of chemical phenomena at the middle school level.

The comments of demonstrator El relate to the problem of focusing students’ attention on non-essential terms that detract from the central issue or concept being demonstrated. El’s comments suggest indirectly the inappropriateness of discussing ‘phenolphthalein’ with middle school students when the focus of the demonstration is on density. Such comments reflect demonstrator’s pedagogical content knowledge in a more indirect sense because they reveal a knowledge of “ineffective explanations” (the converse of Shulman’s definition).

¹ Phenolphthalein is a chemical used to make one of the liquid layers in the density column more visible.
These discourses reveal demonstrators' knowledge of the importance of avoiding the use of formal chemical names when teaching density to middle school students. This aspect of pedagogical content knowledge reflects an understanding of those explanations that interfere with the learning of a particular chemical concept.

Discourses on the day-to-day applications of density to students' lives also code as pedagogical content knowledge, as shown by the following critical-stop comments.

PCK Example 4: Applying density to student experiences

E3: This is real good here. He's tying this concept [density], which they've ... talked about in reference to this particular system [the density column], and now he is applying it to something that the students are more likely to know about, oil on water, [e.g., oil from a motor] boat in a lake situation. (VT #3, S:76)

E1: This is excellent. He's using the idea of the concept (density) and applying it to their lives. And again, I find myself listening a little closer. "Gee. Have I ever had this experience?" (VT #3, S:76)

The idea of applying basic chemical concepts to students' experiences, such as having students think about an experience similar to the one of seeing oil float on top of water at a marina, also reflects Shulman's construct of pedagogical content knowledge. In the discourses above, the critical incident discussed actually reflects the videotaped teachers' knowledge of a useful form of representing the density concept. Even though the videotaped teacher provided the content example, the experienced demonstrators' critique of this critical incident illustrates their recognition of the value of integrating such applications of density into a chemical demonstration performance. Critiques of this nature were also considered to be an indirect reflection of chemical demonstrators' pedagogical content.
knowledge because the demonstrator clearly recognized the value of the PCK representation supplied by the videotaped teacher. The evidence was indirect because the application elicited by the videotaped teacher may not have been part of demonstrator E1's and E3’s prior PCK representation of density and how to teach it. Both direct and indirect references to PCK comprise the tallies given in Table 17.

The quotes given above provide qualitative evidence that the critical-stop task prompts teachers to draw on and verbalize their pedagogical content knowledge. This knowledge was evident throughout demonstrators’ protocols in the form of useful examples, applications, explanations, and alternative demonstrations that are useful in the demonstration teaching of density to the middle school students.

Examples of Demonstrators’ General Pedagogical Knowledge, GPK

About 20% of the critical-stop discourses of experienced and novice demonstrators (see Table 17) reflected a second form of pedagogical knowledge Shulman (1986, 1987) calls general pedagogical knowledge (GPK). This suggests that experienced and novice chemical demonstrators both consider generic teaching skills as contributing in an important way to the demonstration teaching of specific chemical concepts.

Examples of this form of pedagogical knowledge are now provided with quotes taken from teachers’ critical-stop discourses. The quotes illustrate the range of contexts discussed by experienced chemical demonstrators that coded as general pedagogical knowledge and considered important to effective chemical demonstration teaching.
GPK Example 1: Presentation Style

E2: He gave a good introduction. Nice and clear. His volume is up. And he’s looking around like he is looking at every one in the class and not just talking to himself. (VT #3, S:2)

E4: Also, good interaction with the audience. He is making eye contact with the audience. He is looking at people. He is acknowledging them. He’s probably doing more so, of the tapes we viewed so far, and that’s good. He is addressing people. (VT #3, S:37)

In this example, two experienced demonstrators discuss the issue of the videotaped teachers possessing good volume and good eye contact while performing the density column demonstration. These comments reflect a knowledge of generic teaching skills that are applicable to both chemical demonstration teaching and to a variety of other non-chemical demonstration teaching settings. Discourses on the communication skills needed to conduct a chemical demonstration effectively are content-independent issues and therefore indicative of general pedagogical knowledge.

GPK Example 2: Organization of movement around the demonstration table

E1: It might be minor, but it affected me when he stopped and went around the table. It probably would have been better had he started back there if he was going to use the board. (VT #3, S:3)

E5: One of the weaknesses is that he seems to be continually walking from the front to the back of the bench and he was asking the questions and he knew he was going write them down. He probably should have stayed at the back. (VT #3, S:7)

Example 2 talks about an organizational issue related to the videotaped teacher’s excessive movement around a large demonstration table in the front of the room. Because these comments are not discipline-bound or tied to a knowledge of density, they also reflect
general pedagogical knowledge associated with chemical demonstration teaching.

GPK Example 3: Interactive, Participatory Style

E3: Here he's involving students. Rather than him just talking and showing, he's already asked students for their input [student observations on density column]. And in this case he is having one student be a recorder for him which makes the class more involved. (VT #3, S:24)

E4: O.K. Another good point. Realizing the set-up of the room makes him walk around that [demonstration] table. He decided that he was going to work with the audience and he was going to have somebody come up [to the blackboard] and take notes. And that's a good point, a strong point. (VT #3, S:26)

The comments in Example 3 refer to the videotaped teacher asking the class to make observations on the density column while using a student recorder to keep track of students’ observations. This strategy of using a student recorder during a demonstration also reflects general pedagogical knowledge because it can be applied in a variety of teaching contexts.

GPK Example 4: Questioning strategies

E2: He is good at accepting people's answers all the time. (VT #3, S:77)

The discourse in Example 4 talks about the need to be open to student responses to questions raised by the teacher. This too is a content-independent issue and reflects general pedagogical knowledge.

The four examples given above provide a sampling of some of the critical-stop comments made by experienced chemical demonstrators that coded as general pedagogical knowledge (GPK) during a theme analysis of the data. They show that many pedagogical issues related to effective chemical demonstration teaching are clearly content
independent. The quotes also provide qualitative evidence that the critical-stop task probes both teachers' general pedagogical knowledge (GPK) as well as their pedagogical content knowledge (PCK). The semi-structured interview that followed the think-aloud, critical-stop task also contained discourses representing the two pedagogical knowledge systems.

Coding Difficulties Presented by Some Critical- Incident Discourses

The reliability of coding teachers' critical-stop discourses into the two major themes, pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK), was calculated to be 87.2%. Correcting for chance agreement in coding pedagogical discourses into the two major coding categories, inter-coder reliability was calculated to be 74.4%. Most of the coding difficulties encountered during the theme analysis again involved discourses that would not easily code into one of the two pedagogical categories defined by Shulman (1986, 1987), but represented pedagogical verbalizations that could be coded either way depending on how well the coder understood the context of the discourse and whether inferences had to be made in the coding process.

The critical-stop discourses that presented coder disagreements during the theme analysis include those related to:

1. the effective manipulation of chemical demonstration equipment and safety issues,
2. the effective use of the blackboard and student volunteers during a demonstration,
3. the use of general communication skills (e.g., praise, encouragement) that promote class discussions on science terms, concepts, or processes, and
4. the use of wait time and fielding questions related to chemical terms, concepts, or procedures.
The following two critical-stop discourses, for example, did not easily code as PCK or GPK, and therefore yielded different codings by independent coders.

Example 1: Mechanics of Demo

E3: Here he - I don’t think it was intentional for him to have the cylinder sort of covered with his hand. I think it was just the way he was holding it. I don’t think it was a major problem but in terms of visibility, ideally he should have held it in such that they can see the whole thing unless he had a distinct purpose in hiding part of it. At least it is not obvious at this point that he did. (VT #3, S:45)

In Example 1, a demonstrator suggests the importance of handling the density column without hindering the visibility of the top of the cylinder which contains a liquid that is clear and colorless. Such a comment relates to procedural knowledge in conducting chemical demonstrations effectively. Procedural knowledge discourses were coded several ways during the theme analysis, either as PCK, GPK, or NC (No Code).

E3’s suggestion requires some science subject matter knowledge; knowledge that some colorless liquids are somewhat more difficult to see from a distance, and especially if they are partially obstructed. Thus, in a limited sense, this particular discourse relates to one of Wilson and Gudmundsdottir’s (1986) definition of PCK, namely, the "types of materials to use" to teach a given topic. Therefore, some coders would be inclined to code discourses on the effective or ineffective handling of demonstration equipment as pedagogical content knowledge (PCK). On the other hand, the issue of handling demonstration equipment so that it is visible to students could also
be coded as GPK by other coders who are inclined to think that visibility of teaching aids is a generic teaching issue.

Given the confusion in coding this particular discourse, it should probably be coded as NC. In fact, most of the NC tallies in Table 17 involved procedural discourses.

Occasionally, non-procedural discourses that contained little or no reference to subject matter content also presented coders with PCK or GPK coding difficulty. Thus, for a few discourses, the degree of specificity a demonstrator chose to provide in discussing a critical incident also influenced coder reliability during the theme analysis. The following critical-stop comments illustrate this dilemma. It corresponds to one of the density demonstration videotapes and relates to lesson closure.

Example 2: Closure

N3: O.K. He's doing the generalizing at that point. ['We could generalize a little bit about densities. Solids generally are more dense than liquids. Not all liquids have the same density." (S:90-92)] I think it might be effective to say, 'Seeing what we have seen, looking at this demonstration, what could you generalize? Can you come up with a generalization you might feel is valid? just to see if maybe they might. I think they could. (VT #3, S:91)

The quote provided in Example 2 pertains to the videotaped teacher summarizing observations and drawing conclusions at the end of the demonstration so students could share a common understanding of the concept presented. Because this discourse makes no reference to specific science terms or concepts, a coder may occasionally be inclined to think that these comments reflect a general teaching principle (closure) and, therefore, code it as GPK. However, the context of the discourse is made in direct reference to the videotaped
teacher's closing comments that solids are generally more dense than liquids and not all liquids have the same density. Given this context, the discourse better reflects this teachers' pedagogical content knowledge of how to present the subject matter to middle school students. It therefore codes as PCK, but was occasionally miscoded as GPK.

The discourse given above suggest that the level of specificity a demonstrator chooses to provide during a critical-stop discourse may, at times, influence coding and, thus, coder reliability. This is especially true if the coder is not thoroughly familiar with the context of the critique. Increased rater training and familiarization with the demonstration videotapes could minimize such differences.

Closing Comments on the Taxonomic and Theme Analysis Findings of Experienced and Novice Chemical Demonstrator Discourses

Research Question 2 asked about the major commonalities and differences in experienced and novice chemical demonstrator discourses on effective chemical demonstration teaching. A taxonomic, componential, theme, and content analysis revealed both quantitative and qualitative differences between the two groups of demonstrators in terms of their knowledge of how to demonstrate specific chemical concepts to middle school students.

Having presented the major differences between experience and novice demonstrators' pedagogical knowledge discourses, attention is now turned towards the findings that pertain to the influence of an intensive inservice workshop on fostering pedagogical knowledge growth (discourse change) among novice chemical demonstrators.
Influence of Intensive Inservicing on Novice Chemical Demonstrators' Knowledge of Chemical Demonstration Teaching

Novice chemical demonstrators pre- and post-workshop responses to the think-aloud task and follow-up questions were audiotaped and transcribed. The resulting protocols provided a written record of their interview verbalizations. Analysis of these protocols helped address Research Question 3 which seeks to understand the influence of an intensive inservice intervention on promoting pedagogical knowledge growth among novice chemical demonstrators.

A domain analysis, taxonomic analysis, componential analysis, theme analysis, and content analysis were used to analyze the pre- and post-workshop protocols. These five methods of analyses helped highlight the commonalities and differences in novices' pre- and post-workshop verbalizations on chemical demonstration teaching of two chemical concepts.

Changes in Novices' Evaluative Judgments

A taxonomic analysis of the evaluative judgment domain showed that post-workshop novices continued to critique the four videotaped demonstrators using three forms of evaluative judgment. Most evaluative statements contained some form of "strength" or "weakness" evaluation. A small percentage of discourses contained an "acceptable-but-could-be-better" judgment.

A content analysis within the evaluative judgment domain showed that the inservice workshop intervention did not produce a meaningful change in the total number of critical incidents evaluated by novice chemical demonstrators (see Table 7 presented earlier in this
chapter). A more detailed content analysis using the three taxonomic categories of the evaluative judgment domain showed that the overall consistency in critique frequency was accompanied by a small, but non-meaningful, increase in the number of strengths and acceptable judgments rendered and a correspondingly small, and also non-meaningful, decrease in the number of unfavorable judgments rendered as a result of participation in the workshop (Table 7). (Qualitative changes are addressed in the next section).

A comparison of the experienced chemical demonstrators with the post-workshop novices showed that the experienced demonstrators continued to critique more critical incidents during the think-aloud task than the workshop-trained novices (p = .0625, using the Wilcoxon matched-pairs, ranked-signs non-parametric test and n = 4 paired scores; Table 7). In terms of the average number of strengths identified, the experienced subjects continued to identify more critical incidents than post-workshop novices (26.8 and 21.2, respectively). The novices, however, did identify more critical strengths after the workshop than before the workshop. Their critiquing skill for identifying "strengths" appeared to be intermediate between the experienced demonstrators and their pre-workshop performance. This change suggests that the workshop had some effect on helping workshop participants become more cognizant of factors that contribute to effective chemical demonstrating at the middle school level.

The total number of "frequently-cited" critical features identified by novice demonstrators after receiving the workshop intervention increased slightly (i.e., from 20 to 25 frequently cited
features; see Table 10 presented earlier in this chapter). This post-workshop number more closely resembles the number of frequently cited critical features identified by experienced subjects (30). It suggests greater commonality (and decreased variance) in the focus of their think-aloud discourses. Frequently cited critical features continued to comprise a small percentage (13.7%) of the total number of features identified by post-workshop novices, rising only slightly from the pre-workshop levels of 11.3%.

Experienced demonstrators and post-workshop novices generally identified and discussed different sets of frequently cited critical incidents. Only 15% of the frequently cited critical incidents identified were mutually discussed by both groups of subjects (see Appendix R). Similar low levels of group agreement were observed between experienced demonstrators and pre-workshop novices (17% mutually discussed). Pre- and post-workshop novices also showed a similar low level of agreement in discussing identical critical incidents (16% mutual).

Changes in Novices' Descriptive Knowledge

A taxonomic analysis of the descriptive knowledge domain (domain b) showed that post-workshop novices addressed the same nine pedagogical issues they addressed during the pre-workshop interview. These issues included the effective use of inquiry, questioning strategies, new terms, quality of explanations, interaction, mechanics of the demonstration, visual aids, organization, and presentation style. They represent the same general issues addressed by experienced demonstrators during the critical-stop task. These
pedagogical issues were discussed as contributors to effective chemical demonstration teaching.

In quantitative terms, very little change occurred in the number of critiques made by post-workshop novices in eight out of the nine pedagogical categories discussed (Table 11, p. 127). Post-workshop subjects placed slightly greater emphasis ($p = .187$) on critiquing critical incidents related to the quality of explanations provided by the videotaped models. The top three issues discussed by novices after the workshop continued to be questioning strategies, quality of explanations, and overall organization.

The workshop produced a change in discourse focus, with novices giving less attention to issues pertaining to the use of new terms, the use of the blackboard and visual aids, and overall organization (pre-workshop concerns) and greater relative attention to the quality of explanations and questioning strategies (post-workshop concerns) (Table 12, p. 131).

The following discussion summarizes the findings of a componential analysis of novices' clinical interview discourses, highlighting pre-/post-workshop changes within the nine categories comprising the descriptive knowledge domain.

**Inquiry, Investigative Approach**

Prior to the workshop, novices made no direct reference to the term "inquiry" or "inquiry approach" in their analysis of the four demonstration videotapes; however, this situation changed during the post-workshop interview. Several of the novice chemical demonstrators began to make reference to the value of this instructional strategy when conducting chemical demonstrations with middle school students.
The following quotes taken from the post-workshop transcripts of novice demonstrators illustrate this particular focus.

N2: Sometimes he'll make the kids guess what's going on, and that's O.K. using the inquiry approach. But this approach is also good because they know how to direct their attention. He asks them questions (video script S:17,19,21,26). He is not giving them any answers but he is telling them how to direct their attention, which can be very helpful, especially with the middle school level. It reminds them that they are not just being entertained, that they're supposed to be thinking. (VT #1, S:30)

N3: She is so excited that something is working right, as we all are, you know, when something works, but there are so many opportunities for student interactions, an opportunity for students to use inquiry and it's not offered to them, which is a shame. (VT #4, S:95)

N7: I can't remember, who said something about the water condensing and causing the air pressure to decrease. Did he give that information? (Interviewer nods). I thought he supplied it. I would have given a little more inquiry. (VT #2, S:46)

A descriptive summary of the workshop staff presentations (Appendix G) shows that inquiry demonstrating was frequently modeled by workshop instructors. The term "inquiry" was also mentioned once and alluded to several times during the first staff presentation entitled, "What Makes an Effective Demo?" (See quotes in Appendix G).

Although novices became more cognizant of the compatibility of inquiry methods of instruction and chemical demonstration teaching, post-workshop novices did not show any significant change in the total number of critical incidents discussed that pertained to inquiry demonstrating (see Tables 11 and 12). In addition, the numbers continued to fall short of the number of inquiry incidents discussed by the experienced demonstrators. Within this category, the experienced subjects recognized and discussed more critical incidents than post-workshop novices on the importance of (1) having students
make basic site observations during a demonstration and on (2) avoiding forecasting demonstration observations and outcomes. The "error" of forecasting was addressed in participants' first workshop handout (Appendix H, Section III-B) and by at least one workshop instructor during the first staff presentation. "If you forecast ahead of time what is going to happen, you set yourself up for some fancy footwork when it (the demonstration) doesn't work that well. In general, you want to use a more investigative approach."

The critical-incident discourses of post-workshop novices continued to stress the importance of having students attempt to explain or generate hypotheses about the phenomenon demonstrated. The following quotes illustrate this emphasis. (Others are provided in Appendix S).

N3: O.K., again it would have been real tempting for him (the videotaped teacher) to explain to the audience what might have happened [to can] but he is doing a good job of leading questions, "Can someone explain what's happening?" (VT #1, S:33)

N1: O.K. Good questioning ["What force did you use to crush that can?" "Do you think that there was possibly a force resisting your hand?"] He's leading them exactly down the track that he wants them to go, as far as the way he is asking the question. He is looking for specific answers [to how the can was crushed]. (VT #1, S:20)

No noticeable change occurred in the frequency or nature of novices' discourses regarding the forecasting of demonstration procedures, observations, and explanations.

**Questioning Strategies**

Novices showed no change in the number of critical incidents discussed pertaining to the identification of leading and poorly phrased content questions, or to the recognition of the value of
probing students' prior knowledge. Experienced demonstrators gave these issues particular emphasis during the clinical interview (see pages 139-142). A content analysis, however, did show that the post-workshop novices evaluated a few more critical incidents than pre-workshop novices regarding subject-matter questions asked by the videotaped demonstrators. These critiques focused on question clarity and appropriateness for middle school students. The following quotes exemplify these concerns.

N1: Of course, the way he phrases that question, "That the weight of the air, the pressure of the air in the room was greater after I put it in the water?" (S:62), really sort of throws them (the students) off because, obviously, the weight of the air pressure in the room has not changed. (VT #1, S:64)

N8: This is sort of a bad question. "[From your observations, what kind of observations can you make involving this cylinder?] ... It has something to do with density." That's his clue. I don't know how he can improve it but I think he needs to come up with better questions. Those questions are not something that are going to stimulate a student's mind. By now half of my kids would be asleep. (VT #3, S:17)

New Terms

Novice demonstrators showed little change in the number of critical incidents discussed regarding attention to new chemistry terms (Table 11). A componential analysis revealed little qualitative change, as well. The workshop did not give special attention to the effective use of new science terms when conducting a chemical demonstration (Appendix G).

Quality of Explanations

After the workshop, novices discussed more critical incidents related to the accuracy, clarity, and usefulness of concept
explanations provided by the videotaped demonstrator. The following two quotes illustrate this discourse focus. The quotes pertain to a critical incident involving an inappropriate density generalization presented to students by the videotaped teacher.

N7: Right there, ["Solids generally are more dense than liquids. Not all liquids have the same density." (S:91)], I didn’t—someone could have said, "Well, what about ice?" and that is just such an obvious everyday example. And that’s really going to confuse kids. I think he just—I don’t think he should make a generalization like that. I think he should just say, you know—. That just wasn’t necessary. (VT #3, S:92)

N8: Where he starts talking about solids being more dense than liquids, he should have had some examples of some solids that are not as dense as liquids and put them in the middle layers like we have seen. Put them in the interfaces of the liquids. That would spring more conversation, I think. (VT #3, S:92)

Post-workshop novices also focused more on critical incidents involving concept explanations, such as the applications of the concept to students’ lives and the effective use of science terms when presenting a chemical demonstration. (Additional quotes may be found in Appendix S).

N7 (Application): What he’s doing here I think is good. ["Have you ever had the experience of going out in a boat with an outboard motor and either filling or refilling or watching someone fill the engine with gasoline and the gasoline run off the engine into the water? (S:76)]. He’s bringing in everyday aspects into what density has to do with that [column of liquids], so that kinds of keys them a little bit as to why they’re observing what they’re observing. They’ve probably seen that [phenomenon] before but they’re not aware of it [relating to density]. (VT #3, S:76)

N1 (Weight/mass terminology): She is going to confuse them a little bit because she is using the ‘weight’ instead of using the word ‘mass’. She tried to clear that up in the beginning now she is fallen a little bit into the wrong lines as far as using that. That is something she would have to watch in the future. I think that is a pretty common mistake. (VT #4, S:22)
Given this discourse focus, novices discussed more critical incidents related to concept explanations in their post-workshop interviews ($p = .1875$, using a Wilcoxon non-parametric test; see also Table 11). Appendix M indicates that, during the demonstration workshop, novice demonstrators heard the concepts of density and air pressure addressed and explained several times by workshop instructors and workshop participants.

Interactive, Participatory Style

Little qualitative change was observed between pre- and post-workshop novices in their critical-stop discourses on the use of student participants during a chemical demonstration. Before and after the workshop, novices elicited comments very similar to those provided by experienced chemical demonstrators, albeit, fewer in number (Table 11, Category 5). Post-workshop novices identified a few more critical incidents involving student-teacher and student-student dialog, a feature frequently discussed by experienced demonstrators. Overall, however, the number of think-aloud discourses novices provided in this category did not appear to be greatly influenced by the workshop intervention even though the topic of effective use of student participants was one issue addressed during the first staff presentation "What Makes an Effective Demo?" (Appendix G and Appendix H, Section III-B). This teaching strategy was also modeled in several staff and participant demonstrations.

Mechanics of the Demonstration

Little change occurred in terms of novices identifying and discussing critical incidents related to the mechanics of the
demonstration (Table 11). Issues such as visibility and safety were discussed with about equal emphasis before and after the workshop.

One issue important to the experienced demonstrators, yet rarely addressed by pre- or post-workshop novices, included verification of procedural steps taken prior to the demonstration (see pp. 147-148). Novices, however, did become more cognizant of how the mechanics of the demonstration could hinder or promote concept learning among middle school students.

Use of Blackboard/Visual Aids

After the workshop, discourses on the importance of having physical drawings of complex demonstration systems on the blackboard, or other visual aids, became more evident among novices. The following quotes come from two novices who addressed this issue during the post-workshop interview. This issue was not addressed in their pre-workshop interviews.

N4: I think before he went on, it would have been a really good time for some diagrams on the board and to go into it a little more where a kid kept repeating that, "Air pressure." "Air pressure [caused the aluminum can to collapse]." (VT #1, S:60)

N3: There would have been - if she had a diagram [of the density column] for instance, and had a kid come up and label Corn syrup, where it was, and water, and mineral oil - it would have been clearer. I think that the students are probably confused at this point. I'm confused. I mean I know what should be there - I'm pretty sure. (VT #4, S:88)

The effective use of the blackboard and overhead illustrations during a chemical demonstration was frequently modeled during the workshop by both workshop instructors and workshop participants. This issue was briefly discussed during the first staff presentation
(Appendix G) and mentioned in the first workshop handout in terms of presenting a data collection table (Appendix H, Section III-A and B).

Overall Organization

After the workshop, novices began identifying and discussing a few more critical incidents related to the effective and efficient sequencing of demonstration tasks, an important organizational issue discussed by experienced chemical demonstrators (see p. 149). The following quotes illustrate novices’ post-workshop concerns for such issues. (Other quotes may be found in Appendix S).

N7  (Materials readily available): O.K., later on he does it, but he should have had the white background immediately because I couldn’t tell [what was in the density column]. He said, "There’s three different shades," and even seeing it on film I couldn’t tell there were three different shades until he put the white paper behind it. (VT #3, S:17)

N2  (Sequence in constructing a column): I’m glad she did it in that order so that students could see the displacement. I think that is very good because some people just build the column from the bottom up. And uh, I did that; I added the syrup after I had done everything else and watched it go to where it went [through the liquids to the bottom]. And I think that’s fun cause it’s good for the kids to see that. (VT #4, S:69)

Presentation Style

In terms of presentation style, the most apparent change observed in novices’ pre-/post-workshop critical-stop discourses involved more frequent reference to humor in a demonstration. This issue was also discussed by experienced demonstrators during the critical-stop task (p. 150).

N3: He has done an excellent job of getting his audience in the palm of his hand. He has a good humorous beginning, ... giving enough information to the audience to know why he selected Ed [as a student volunteer]. It’s a good intro. It really is. A good calm approach. (VT #1, S:9)
N2: He’s making good use of humor [with the title of his demo, "The Can-Man Can" lab]. (VT #1, S:3)

An examination of the descriptive summaries of the workshop staff presentations (Appendix G) shows that attention to humor was the focus of one of the scheduled staff presentations (see also Workshop Schedule, Appendix F).

Other issues related to presentation style, such as non-verbal gestures, courtesy, and rapport were addressed equally during the pre- and post-workshop interviews.

**Changes in Novices’ Knowledge of Alternatives**

The critical-stop task and semi-structured interview prompted both experienced and novice chemical demonstrators to discuss ways of improving critical incidents judged as a "weakness", or hindrance, to overall performance. These suggestions, called pedagogical enhancements (P), coded into the same nine pedagogical categories identified for discourses in the descriptive domain, i.e., Categories 1-9. Table 13 shows that novices made about the same number of suggestions for enhancing the videotaped demonstrations before and after receiving the workshop intervention. Post-workshop novices made a few more suggestions for improving the mechanics of the demonstration (Category 6) and slightly fewer suggestions for improving inquiry (Category 1), an interactive, participatory style (Category 5), use of the blackboard/visual aids (Category 7), and organizational issues (Category 8) (see Table 14, p. 153).

After viewing Videotape #3, post-workshop novices made several suggestions regarding ways in which the videotaped demonstrator could
improve the visibility of the Density Column demonstration. These suggestions included using larger graduated cylinders, a light board or light box, a display stand for the column, a white background, and food dyes in place of phenolphthalein. These suggestions were also evident in novices' post-workshop discourses. The issue of visibility was one that was consistently modeled during the workshop and stressed by workshop instructors (Appendix H, Section III-B and C). The following is representative of a post-workshop novice's discourse that stressed demonstration visibility. (Other quotes may be found in Appendix U.)

NS: At this point I think he could have used a larger cylinder and he could have used his lighting set which he had up there on the table which would have lit it up. Maybe a white background instead of having to stand there and everything. I think what he did do worked. Everybody saw what he was trying to go after but it just could have been a little cleaner. A little more visual. (VT #3, S:15)

Variations on the Observed Demonstration

The data presented in Tables 18 and 19 show that novices were able to discuss more variations (V) on the Density Column demonstration and Collapsing Aluminum Can demonstration after having participated in the chemical demonstration workshop (p < .05, using the independent t-test and more conservative non-parametric U-test). The variations discussed represented both simplified and more advanced presentations of the videotaped chemical demonstrations. The following quote represents a variation on the Density Column demonstration discussed by one post-workshop novice. (Others examples are provided in Appendix U).
Table 18

Frequency of AIR PRESSURE Demonstrations Cited by Pre- and Post-Workshop Novice Chemical Demonstrators

<table>
<thead>
<tr>
<th>Type of Demonstration Citation</th>
<th>Pre-Workshop Novices</th>
<th>Post-Workshop Novices</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  SD</td>
<td>Mean  SD</td>
<td></td>
</tr>
<tr>
<td>Variation (V)</td>
<td>0.5 0.8</td>
<td>1.6 1.2</td>
<td>2.26 *</td>
</tr>
<tr>
<td>Demonstration (D)</td>
<td>0.8 1.2</td>
<td>2.9 1.4</td>
<td>2.99 **</td>
</tr>
<tr>
<td>Demonstration Variation (DV)</td>
<td>0.0 0.0</td>
<td>0.0 0.0 a</td>
<td>-</td>
</tr>
<tr>
<td>Extraneous Examples, Total (XTOT)</td>
<td>0.6 0.7</td>
<td>0.9 1.0</td>
<td>0.57</td>
</tr>
<tr>
<td>Extraneous Examples, Positive (XPOS)</td>
<td>0.1 0.4</td>
<td>0.4 0.5</td>
<td>1.13</td>
</tr>
<tr>
<td>Extraneous Negative (XNEG)</td>
<td>0.4 0.5</td>
<td>0.5 0.8</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Notes:

* Indicates scores are significantly different from experienced demonstrators at the p < .05 level.
** Indicates scores are significantly different from experienced demonstrators at the p < .01 level.

* p < .05; ** p < .01

N5 (Density Column variation): That column can be enhanced. You can do a lot with relative densities given a bunch of knowns in the column and then peg an unknown with your knowns. That is the main variation on that one that I’ve have seen. ... If you peg the known densities of the liquids then he could start dropping unknowns in that would float or sink to various levels and people could peg the densities of those and maybe even a handout with densities on it that would match up with various knowns. Get people thinking about how density could be use to single out an unknown. (VT #3, I. 8)

A similar pattern showing novices providing more frequent discussion on variations of the Collapsing Aluminum Can were also observed during the post-workshop interviews. The following quotes...
Table 19
Frequency of DENSITY Demonstrations Cited by Pre- and Post-Workshop Novice Chemical Demonstrators

<table>
<thead>
<tr>
<th>Type of Demonstration Citation</th>
<th>Pre-Workshop Novices</th>
<th>Post-Workshop Novices</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Variation (V)</td>
<td>0.4</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Demonstration (D)</td>
<td>1.2</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Demonstration Variation (DV)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Extraneous Examples, Total (XTOT)</td>
<td>1.8</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Extraneous Examples, Positive (XPOS)</td>
<td>1.0</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Extraneous Negative (XNEG)</td>
<td>0.9</td>
<td>0.8</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Notes.
- a Difference between experienced demonstrators and post-workshop novices is significant at the p < .001 level.
- *p < .05;  **p < .001;

represent the demonstration variations discussed by one novice, N7.
(Quotes from other post-workshop novices are provided in Appendix U.)

N7 (Vacuum Pump variation): And the one where you take what the vacuum - you create the vacuum on a vacuum pump and you crush the can. (VT #3, I. 8)

N7 (Ditto Fluid Can variation): Or where you just heat it up and cap it and then watch it crush slowly through the hour. (VT #3, I. 8)

N7 (No Water in Al Can variation): Variation or twist on that one. Well, what they (some workshop participants) did with one (can) is [perform the demonstration] without water inside it to determine the differences, if it was really the water that was making a difference; and it does to a point. (VT #3, I. 8)
N7 (Different Types of Cans variation): That is the only variation - or you could use different types of cans to see if maybe - you could even run that into an experiment. You could give students two types of cans. I thought this was cute. I started thinking about this. You could take a Pepsi can and a Coke can and you could say, you know, "Americas choice. Which one do you think is better?" and you could use it as a demo. You could do that. You could take a vote of the class and see which one is going to be stronger. And you could maybe find a thicker heavier aluminum can or a real light one and see if it makes a difference as to, you know; and you time everything so it’s exactly the same. So you could turn it into a more of an experiment than it is. (VT #3, I. 8)

A few variations of the Collapsing Aluminum Can demonstration were publicly performed by workshop participants. Others were discussed in the workshop sourcebook (Appendix K; Sarquis & Sarquis, 1987) and by the workshop staff. These training components appeared to influence novices’ post-workshop response to the interview question regarding demonstration variations (Appendix I, Question I. 8).

Alternative Chemical Demonstrations and Extraneous Examples

Similarly, novices were also able to discuss more alternative chemical demonstrations (D) on air pressure and density as a result of the chemical demonstration workshop experience (p < .01 and .001, for the two concepts, respectively) (Tables 18 and 19). Prior to the workshop, novices generally discussed one other alternative chemical demonstration on the targeted concepts. After the workshop, they could discuss and critique three or four alternative chemical demonstrations on each of the targeted concepts. The following quotes illustrate the new pedagogical content knowledge acquired by subject N5 on the concept of air pressure. Prior to the workshop, novice demonstrator N5 provided one pedagogically unsound chemical demonstration on air pressure. After the workshop, this individual
freely discussed five different demonstrations that suitably illustrated the concept of air pressure. His post-workshop discourses are quoted below. (Additional quotes by other novice demonstrators, N1-N8, are provided in Appendix U. A complete list of the chemical demonstrations and demonstration variations discussed by experienced and novice subjects is provided in Appendices V and W).

N5 (Balloon Inverted in a Flask): Balloons, though – all kinds of air pressure things you can do with balloons. Like the one that John did where he heated up the flask and blew the balloon up and then he cooled the flask down and the balloon got sucked into the flask. That was kind of neat. And he showed both the effects of heat and the spreading out of molecules and the contraction will cool them off again. (VT #2, I. 8)

N5 (Egg in the Bottle): The egg being pulled into a flask. ... The egg in the bottle is a classic. (VT #2, I. 8)

N5 (Vacuum Chamber): The balloon and the belljar and the vacuum chamber was a reverse of what was going on there which I thought was kind of neat. God, there is just a zillion. I mean you can go on and on with those. (VT #2, I. 8)

N5 (Cartesian Diver): The Cartesian diver for the density. I forgot about that one. That was a good one. Also, the Cartesian diver fits in with this [i.e., air pressure] to a certain extent, although, I probably wouldn't use it for that just because that is kind of a confusing model. A tough one. (VT #2, I. 8)

N5 (Not on the Level/U-tube Barometer): Well, the U-tube is another fairly classic one that shows air pressure. You have that U-shaped tube and if you have a liquid with all the same density it remains at the same level and there is air pressure on both sides maintaining an equilibrium on the two ends. Then you can do things with that. You can cap off one end if you want to and do some stuff with the other end. I don’t know. There is a bunch of things you can do with it. I am trying to think of how you can tie that in exactly though. I suppose you could hook one end up to a hand pump, vacuum pump to show what happens when you start decreasing the air pressure on one side of the U-tube and the liquid is going to go up into the vacuum tube. You are going to have to figure out some way to keep the water from getting up in your pump. That is all I can think of off the top of my head. There is a bunch though. (VT #2, I. 8)
After participating in the intensive chemical demonstration workshop, novices also discussed fewer extraneous examples (XPOS and XNEG) of how to demonstrate the targeted chemical concepts (see Tables 18 and 19). When this researcher probed novices for additional demonstrations and variations, they made fewer references to laboratory and seatwork activities, and fewer references to class discussions of natural phenomena involving air pressure and density (XPOS). These novices also made fewer references to nebulous, erroneous, and pedagogically unsound demonstrations related to the targeted chemical concepts (XNEG), although, a few persisted (see Appendix U for examples). In general, they provided legitimate alternative chemical demonstrations on the targeted concepts (D).

An example of a pedagogically unsound/erroneous air pressure demonstration that persisted after the workshop with at least one novice subject, included the following.

**N2 (Inflating a Balloon):** You can also illustrate it (air pressure) by heating a balloon and blowing it up with (a heated Erlenmeyer) flask. That is better. (VT #1, I. 8)

This demonstration actually illustrates the thermal expansion of gases much better than it illustrates the influence of ambient air pressure on flexible objects such as balloons or aluminum cans. Although the suggested demonstration does deal with air pressure in some form (e.g., an increase in the internal air pressure of the balloon through heating), it is somewhat removed from the objective demonstrated on videotape which the novices were asked to address. Although such misrepresentations were not directly addressed during the workshop by workshop instructors, they were somewhat less prevalent in novices' post-workshop protocols.
The data in Table 20 summarizes the number of variations, alternative demonstrations, and extraneous demonstrations on density and air pressure discussed by experienced chemical demonstrators and pre- and post-workshop novices during the clinical interviews. The table shows that the intensive workshop intervention had a definite impact on helping novice chemical demonstrators increase the number of chemical demonstrations they could discuss on concepts that are basic to chemistry and the physical sciences (p < .01). Although the number of demonstrations discussed by novices increased substantially, these

<table>
<thead>
<tr>
<th>Type of Demonstration Citation</th>
<th>Pre-Workshop Novices</th>
<th>Post-Workshop Novices</th>
<th>Experienced Demonstrators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean SD</td>
<td>Mean SD p&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Mean SD p&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Variation (V)</td>
<td>1.0 0.9</td>
<td>2.8 1.1 **</td>
<td>5.2 1.7 ***</td>
</tr>
<tr>
<td>Demonstration (D)</td>
<td>2.0 1.6</td>
<td>6.9 2.7 ***</td>
<td>10.4 4.2 **</td>
</tr>
<tr>
<td>Demonstration Variation (DV)</td>
<td>0.0 0.0</td>
<td>0.5 0.8</td>
<td>3.0 2.3 *</td>
</tr>
<tr>
<td>Extraneous Examples, Total (XTOT)</td>
<td>2.4 1.8</td>
<td>1.9 2.3</td>
<td>0.4 0.6 *</td>
</tr>
<tr>
<td>Extraneous Negative (XNEG)</td>
<td>1.4 1.2</td>
<td>1.0 1.0</td>
<td>0.2 0.4</td>
</tr>
<tr>
<td>Extraneous Positive (XPOS)</td>
<td>1.0 1.1</td>
<td>0.9 1.8</td>
<td>0.2 0.4</td>
</tr>
</tbody>
</table>

Notes. *All probabilities in comparison to pre-workshop novice scores.*

*<p < .05;  **p < .01;  ***p < .001
numbers were still less than the number of chemical demonstrations discussed by experienced chemical demonstrators on the respective concepts.

**Changes in Novices' Rationales**

Post-workshop novices also provided rationales to support their evaluative judgments and suggestions for improving observed chemical demonstrations. Their rationales were coded according to their knowledge of the learner, the demonstration system, the subject matter, and teaching strategies.

When comparing novices' post-workshop protocols to their pre-workshop protocols, post-workshop protocols contained several more statements on the complexity of the observed chemical demonstration system and how this complexity may foster confusion and misconceptions among middle school students. Such discourses resemble the concerns that experienced demonstrators voiced in their critique of the videotaped demonstrations (see pages 178-180). The following discourses on the Collapsing Aluminum Can demonstration illustrate novices' post-workshop perceptions of this demonstration, in particular the confusion they believed this demonstration could generate with middle school students trying to understand the phenomenon of the can's sudden collapse.

N1 (Students' reasoning): After we have seen that [aluminum can] demonstration once or twice, a bunch of us got to talking, and I think someone has gone into the fact that water gets into it (the can). And that brings in another variable which can really confuse kids. (VT #1; I. 8)

N5 (Students' reasoning): I think this is a really effective demonstration but I hate the use of those big honking tongs. Because it steals something out of it. People (students)
think that maybe you are crushing it (the can) with those tongs.  (VT #2; S:25)

N8 (Students’ reasoning): O.K. I think, what I saw some other people do, is that they dropped it. They dropped the can into the cold water, and that way the students wouldn’t be falsely led to think that maybe the tongs, crunching down on the can, made it bend. (VT #2; S:29)

These post-workshop novice demonstrators recognized the difficulties middle school students may have in focusing on the variable that accounts for the can’s collapse. They realized that students may think that it was the cold water or the large tongs that actually caused the can to collapse, rather than the atmospheric pressure surrounding the can. The novices, much like the experienced demonstrators, realized that the complexity of the demonstration system may lead students to focus on the wrong variables and, thus, lead them away from the intended conclusion that air pressure was at work. These demonstration concerns were discussed during the workshop by the workshop staff after this demonstration was publicly performed by one of the workshop participants.

After the ICE demonstration workshop, novice demonstrators made more comments regarding effective solutions to working with inherently complex demonstration systems. (Other quotes may be found in Appendix X).

N1: One thing that was mentioned which I thought was a good variation, and we already have seen, is when you heat up the can, the larger [ditto fluid] can, and then you seal off the top, and you don’t put it into the water. ...
I think that [is] the one that Jim [a workshop participant] did, where you just heat up the can and seal it off, is just a very simple system. It cools by itself and there, all you are dealing with is really the air pressure. You don’t have the pressure of the water around the can. God knows if that is a variable! He (Jim) didn’t even spray water on the flippin thing. He just set it out there and it crushed all by itself. I think that is probably the best variation, if
that is the concept they are trying to get across. (VT #1; I. 8)

N5: And so I fiddled around in the lab with it and you can actually drop it from a foot and a half and as long as the top hits the water it creates enough of a vacuum in there so that it just goes, "Boom!" and it crushes all by itself. So you can drop it from a long ways if you want to, [and] it is very effective because you don’t have any tongs holding on to it (the can) anymore. When it hits the water it goes "Fwittt"; it does it’s thing (collapses). If nothing else, you can see that there is no tongs or anything messing with it. Those tongs are a little bit formidable looking. They look like they could crush that can just as easily as the change in air pressure. (VT #2; S:25)

After the workshop, most novices were able to discuss several ways of simplifying or adapting a complex demonstration so that students could more clearly see the influence of air pressure acting on the can. Such critiques were not evident in novices’ pre-workshop protocols.

Changes in Novices’ Theme Focus

The inservice workshop fostered a slight, though non-meaningful, increase in novices’ emphasis on pedagogical content knowledge issues during the critical-stop task (see Table 17). About 76\% of the issues discussed by novices after the workshop dealt with PCK, whereas, prior to the workshop the levels were closer to 71.7\%. In absolute terms, the experienced demonstrators discussed considerably more critical incidents than either pre- or post-workshop novices regarding chemical demonstration teaching and PCK issues (p = .0625, Wilcoxon non-parametric test). They also discussed considerably more generic teaching issues relevant to effective chemical demonstration teaching (p = .125).
Summary of Changes in Novices' Clinical Interview Discourses Following the Workshop Intervention

A comparison of novices' pre- and post-workshop protocols showed that post-workshop novices began to focus their demonstration teaching discourses on similar issues (exemplified by an increase in number of frequently cited critical incidents discussed). They could think of more alternative chemical demonstrations on the targeted concepts as well as more variations in conducting a given demonstration in order to increase or decrease its complexity to challenge or promote student understanding. Novices post-workshop discourses also contained a few more references in terms of the value of inquiry demonstrating and the quality of explanations provided by the videotaped teachers. A small, but non-significant, decrease in the number of extraneous demonstrations on the targeted concepts was observed.

Chapter Summary

This chapter has presented the findings associated with a domain analysis, taxonomic analysis, componential analysis, theme analysis, and content analysis associated with the verbal reports obtained from experienced chemical demonstrators and from pre- and post-workshop novices. In general, the clinical interview protocols showed both qualitative and quantitative differences between experienced and novice chemical demonstrators and between pre- and post-workshop novices regarding their discourses on effective chemical demonstration teaching. Novices' post-workshop discourses began to resemble the discourses of experienced chemical demonstrators as a result of their participation in a two-week chemical demonstration workshop. These
findings address the three research questions asked in this study on experienced and novice chemical demonstrator differences and the nature of science teachers' pedagogical content knowledge growth in an inservice setting.
CHAPTER 5
SUMMARY, DISCUSSION, AND RECOMMENDATIONS

Introduction

This study examined the cognitive differences between experienced and novice chemical demonstrators in terms of their pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK) of chemical demonstration teaching. The study further examined the influence of an intensive chemical demonstration workshop on fostering pedagogical knowledge growth among science teachers identified as novice chemical demonstrators.

Both independent and dependent measures (the ICE chemical demonstration workshop and Shulman's theoretical constructs PCK and GPK) are 'complex', each composed of multiple factors. In light of the complex nature of these variables, this researcher documented the major components of the workshop, used multi-method approaches to probe teachers' pedagogical knowledge, and employed several coding strategies to analyze the verbal data.

Two groups of chemical demonstrators possessing markedly different levels of experience in conducting chemical demonstrations participated in this study. The novice chemical demonstrators represented eight out of twenty-two science teachers selected to participate in an intensive, two-week chemical demonstration workshop partially funded by NSF. The novices represented the less experienced chemical demonstrators participating in the workshop. The five workshop instructors served as a group of experienced chemical demonstrators.
A clinical interview guide was developed to help assess the two groups of demonstrators' knowledge of effective demonstration teaching of two basic chemical concepts: density and air pressure. The clinical interview consisted of a critical-stop task (a think-aloud, critical incident task) and a semi-structured interview.

The verbal responses of the experienced and novice demonstrators were subjected to four methods of qualitative analysis described by Spradley (1980), namely: a domain analysis, taxonomic analysis, componential analysis, and theme analysis. A content analysis was also conducted to help quantify some of the verbal data.

A major assumption made in this study is that the verbalizations of chemical demonstrators discussing effective chemical demonstration teaching of targeted chemical concepts provide a general picture of their knowledge of how to demonstrate these selected concepts. This assumption is consistent with those made in other clinical interview studies that use verbal reports as valid and reliable indicators of teacher and student knowledge in specific content domains (Bussis, Chittenden, & Amarel, 1976, Chap. 1; Ericsson & Simon, 1984; Finley, 1986; Posner & Gerzog, 1982).

Summary of Major Observations

The major findings of this study, as they relate to the three research questions stated in Chapter 1, are now summarized. The first two research questions examined experienced-novice chemical demonstrator differences. The third question examined the influence of a two-week chemical demonstration workshop.
Research Question #1:

What are the domains of knowledge that characterize experienced and novice chemical demonstrators' pedagogical discourses on effective chemical demonstration teaching?

The major findings associated with this research question include the following:

1. The clinical interview comments of experienced and novice chemical demonstrators discussing effective chemical demonstration teaching coded into one of four major domains. These domains included descriptive knowledge, evaluative judgments, knowledge of alternatives, and rationales. About 95% of the clinical interview discourses coded into these four domains.

2. Discourses that coded as descriptive knowledge consisted of explicit verbal descriptions of demonstration teaching behaviors displayed by the videoetaped teachers. Demonstrators' descriptive knowledge discourses frequently included favorable and unfavorable evaluative judgments that reflected whether the observed behavior contributed to or hindered the chemical demonstration presentation. When demonstrators encountered unfavorable critical incidents, they frequently suggested alternative behaviors. Finally, demonstrators often provided rationales or reasons for their evaluative judgments and suggestions for improvement.

3. The four domains stated above characterized demonstrators' general pedagogical knowledge (GPK) and pedagogical content knowledge (PCK) discourses on effective chemical demonstration teaching.
Research Question #2:

What are the commonalities and distinguishing characteristics of experienced and novice chemical demonstrators' discourses (on effective chemical demonstration teaching) in each of the identified domains?

The major findings that describe experienced and novice chemical demonstrators' discourses on effective chemical demonstration teaching of fundamental concepts in chemistry are presented according to the four identified domains.

Evaluative Judgment Domain

1. Experienced chemical demonstrators evaluated and discussed more critical incidents pertaining to effective chemical demonstrating than novice demonstrators during their critique of the four chemical demonstration videotapes. The experienced chemical demonstrators observed and critiqued an average of 81 critical incidents across the four chemical demonstration videotapes, whereas, novices identified and critiqued an average of 48 (see Table 7). These quantitative differences in critique frequency were observed for critical incidents receiving favorable, unfavorable, and acceptable-but-could-be-better ratings.

2. Experienced chemical demonstrators evaluated and discussed more "frequently cited" critical incidents than novices during the clinical interview. Frequently cited critical incidents (i.e., critical incidents cited by at least half the experienced or novice demonstrators, and serves as an indicator of within-group agreement) comprised only a small percentage (approx. 10%) of the total number of critical incidents identified by subjects in each
Most critical incidents (approx. 70%) were discussed by only one subject.

3. The experienced chemical demonstrators collectively observed and critiqued a total of 274 critical incidents across the four chemical demonstration videotapes. Novices collectively identified about 177. For the experienced chemical demonstrators, these values translate to the identification of a total of 70 unique critical incidents in a typical 7-minute chemical demonstration videotape. Novices collectively identified about 45 unique critical incidents in a similar 7-minute demonstration videotape. These values were derived using the collective remarks of four subjects per group.

Descriptive Knowledge Domain

1. The think-aloud comments elicited by experienced and novice demonstrators reflected nine pedagogical issues that contribute to effective chemical demonstration teaching. These issues included the importance of inquiry, questioning, attention to new terms, clear explanations, attention to the mechanics of the demonstration, an interactive/participatory style, effective use of visual aids/blackboard, overall organization of the demonstration, and a suitable presentation style.

2. Experienced chemical demonstrators made more comments than novices in seven out of nine of these pedagogical categories - all except visual aids and overall organization.

3. The most frequently cited issues among experienced and novice demonstrators pertained to questioning strategies and the quality of explanations. The experienced demonstrators also placed
considerable emphasis on how the mechanics of the demonstration contributes to an effective performance. Novices placed greater relative emphasis on overall organization issues.

4. The experienced subjects frequently stressed the importance of inquiry and an investigative approach during chemical demonstration teaching. This emphasis was less evident among novices. Inquiry-related issues discussed by both groups included the importance of (1) having students provide supportive evidence for their hypotheses, predictions, and ideas, (2) avoiding leading questions that stifle inquiry, and (3) not forecasting demonstration observations, procedures, and explanations for students. The experienced demonstrators generally gave greater attention to each of these inquiry issues.

5. Experienced demonstrators, more so than novices, recognized the importance of probing prior knowledge while conducting a chemical demonstration. The experienced demonstrators were also more critical of the clarity and appropriateness of the questions asked by the videotaped demonstrators.

6. Experienced and novice demonstrators both discussed the importance of having new scientific terms defined when conducting chemical demonstrations with middle school students. Experienced demonstrators were more prone to suggest the use of simpler, generic terms in place of scientific terms to describe the demonstration system.

7. Experienced demonstrators were more skilled than novices in identifying knowledge inaccuracies presented by the videotaped demonstrator. Experienced demonstrators considered these
inaccuracies as contributing to ineffective chemical demonstration teaching. Novices did not recognize these knowledge inaccuracies.

8. No qualitative differences between experienced and novice demonstrators' discourses on using an interactive/participatory style was observed. The experienced subjects, however, did identify more critical incidents pertaining to good classroom interactions and incidents that inhibited student participation.

9. Experienced demonstrators considered the verification (i.e., repeating) of selected mechanical steps taken prior to the demonstration by the videotaped teacher as an important pedagogical procedure when demonstrating chemical concepts to middle school students. Novices generally did not address this issue of verification, or if they did address it, they relegated it much less importance.

10. Both experienced and novice chemical demonstrators discussed the importance of using the blackboard or overhead projector in conjunction with a chemical demonstration. The experienced demonstrators focused on using the blackboard to draw the physical system being demonstrated to illustrate relevant features and concepts associated with the demonstration system. Novices, on the other hand, stressed the importance of using the blackboard to record student observations.

11. Experienced demonstrators discussed critical incidents pertaining to the efficient sequencing of demonstration tasks more frequently than novices did. The experienced subjects appeared to be much more aware of how to optimally sequence content explanations,
demonstration procedures, and teacher questions when demonstrating basic chemical concepts at the middle school level.

12. Experienced and novice demonstrators both discussed issues related to the speech and gestures of the videotaped teacher during the critical-stop task. Only the experienced demonstrators, however, addressed the issue of humor, enthusiasm, and efficient movement around the demonstration table.

Knowledge of Alternatives

1. Experienced and novice demonstrators frequently suggested alternative approaches for improving the videotaped chemical demonstrations. These suggestions included discourses classified as (1) pedagogical enhancements (P's), (2) variations on the observed demonstrations (V's), (3) alternative density and air pressure demonstrations (D's), and (4) extraneous examples (X's) of how to demonstrate the targeted chemical concepts.

2. The experienced demonstrators provided more suggestions for improving the videotaped demonstrations than novices. The improvements corresponded to the nine pedagogical issues mentioned above, with the experienced subjects providing more suggestions than novices in terms of inquiry, new terms, and the mechanics of the demonstration.

3. The experienced chemical demonstrators verbalized five times more variations (p < .001) on the Collapsing Aluminum Can demonstration and the Density Column demonstrations than novices. Similarly, they verbalized approximately five times more alternative demonstrations on density and air pressure than novices (p < .01).
4. The experienced demonstrators provided fewer extraneous and erroneous examples of air pressure and density demonstrations than novices, (approx. 6 x’s less). When novice and experienced demonstrators were probed for additional density and air pressure demonstrations, novices provided more (approx 5 x’s more) examples of suitable labs, discussions, and student activities on air pressure and density than the experienced subjects. Novices also elicited more erroneous and pedagogically unsound demonstrations on density and air pressure than the experienced subjects, (approx. 7 x’s more). These erroneous examples were more evident with density demonstrations than with air pressure demonstrations.

Rationales

1. Four major rationales supported experienced and novice demonstrators’ evaluative judgments and suggestions for improving unfavorably rated critical incidents. These rationales included knowledge of the learner, the demonstration system, educational psychology, and teaching strategies.

2. Experienced demonstrators used the knowledge-of-the-learner rationale more frequently than novices to support their judgments and suggestions during the critical stop-task. The experienced demonstrators showed particular concern for how student misunderstandings and misconceptions could arise as a result of a given chemical demonstration performance.

3. Experienced demonstrators were more aware than novices of the complexity of some chemical demonstrations and how this complexity could interfere with learning. They also knew how to simplify complex systems to promote student learning of the demonstrated
chemical concepts. Novices rarely discussed demonstration complexity issues.

4. Experienced demonstrators critiqued more critical incidents than novices pertaining to knowledge inaccuracies mentioned by the videotaped teacher. They also critiqued more incidents involving the application of the targeted concept to students' lives.

5. Experienced and novice demonstrators both justified some of their evaluative judgments and suggestions for improving chemical demonstrations in terms of their knowledge of generic teaching strategies, such as, wait time, feedback, reinforcement, establishing rapport, building on students' prior knowledge, etc.

6. Experienced and novice subjects rendered opposing evaluative judgments on less than 5% of the critical incidents discussed. Differences in evaluative judgments were accompanied by different supporting rationales.

Major Pedagogical Themes

1. Experienced and novice demonstrators' verbalizations of effective chemical demonstration teaching reflected two forms of pedagogical knowledge: general pedagogical knowledge (GPK) and pedagogical content knowledge (PCK). During the critical-stop task, the experienced demonstrators made about one-and-a-half times more frequent mention of GPK and PCK issues associated with effective chemical demonstrating than novices did.

2. Approximately 70% of verbalizations provided by experienced and novice demonstrators related to pedagogical content knowledge (PCK) issues associated with effective chemical demonstrating. Generic teaching issues (GPK) comprised about 20% of their
discourses during the critical-stop task. The remaining comments coded as either "Subject Matter" or "No Code."

Research Question #3:

How does an intensive inservice chemical demonstration intervention alter novice chemical demonstrators' evaluative judgments and knowledge of effective chemical demonstration teaching of targeted chemical concepts?

Workshop Effects on Novices' Evaluative Judgments

1. Novices showed a small, but non-meaningful, increase in the number of critical incidents evaluated as a result of participating in the demonstration workshop.

2. Novices showed an increase in the number of frequently-cited critical incidents identified and critqued as a result of participating in the demonstration workshop.

3. Novices showed a small, though non-meaningful, increase in their use of more discriminating judgments (i.e., acceptable-but-could-be-better judgments) in their critique of videotaped chemical demonstrations.

Workshop Effects on Novices' Descriptive Knowledge

1. Novices showed a meaningful increase in the number of critical incidents discussed related to the quality of explanations provided by the videotaped teachers (Table 11). Novices also showed a slight, though non-meaningful, increase in the number of critical incidents discussed pertaining to questioning strategies and presentation style. This was accompanied by a small, though non-meaningful, decrease in the number of discourses related to new terms, use of visual aids, and overall organization. Novices
showed no change in the number of critical incidents discussed with respect to inquiry issues, interactive/participatory style, and the mechanics of the demonstration.

2. The workshop intervention lead to several qualitative changes in novices' discourses in the descriptive knowledge domain. Novices began to make more frequent reference to the value of inquiry strategies when conducting chemical demonstrations at the middle school level. However, no apparent change occurred in terms of their awareness of inquiry-teaching "errors", such as, the forecasting of demonstration procedures, observations, and explanations displayed by the videotaped teachers. After the workshop, novices gave greater attention to critical incidents that pertained to (1) question clarity and question appropriateness for middle school students, (2) the accuracy, clarity, and usefulness of concept explanations, (3) the applications of the concept to students' lives, (4) the proper use of terminology when presenting a chemical demonstration, (5) the importance of having physical drawings of complex demonstration systems on the blackboard, (6) the efficient sequencing of demonstration tasks, and (7) the use of humor in a demonstration. (Summarized in Table 11).

Workshop Effects on Novices' Knowledge of Alternatives

1. The workshop produced a meaningful (2.8 fold) increase in the number of demonstration variations cited by novices. The number cited, however, was still less than the number of variations cited by experienced demonstrators.
2. Novices showed a meaningful (3.5 fold) increase in the number of density and air pressure demonstrations cited as a result of the workshop intervention. However, experienced demonstrators continued to cite about 1.5 times more concept demonstrations than post-workshop novices, but this difference was not meaningfully significant. The demonstrations discussed pertained to the concepts of density and air pressure. These two concepts represented only two of over 30 major chemical concepts addressed by the workshop (Appendix E).

3. Novices showed no meaningful increase in the total number of pedagogical enhancements cited as a result of the workshop intervention. A closer examination showed that post-workshop novices made a few more suggestions for improving the mechanics of the videotaped demonstration, particularly the visibility of the demonstration system. Post-workshop novices made slightly fewer suggestions for improving the videotaped demonstrators’ (1) inquiry/investigative approach, (2) interactive and participatory style, (3) use of the blackboard and visual aids, (4) and organization. (See Table 14, Pedagogical Enhancements).

4. After the workshop, novices provided fewer extraneous examples of density demonstrations. They provided fewer references to density labs and seatwork activities and fewer references to erroneous and pedagogically unsound demonstrations on density. For the concept air pressure, there was little change in the number of pedagogically unsound demonstrations discussed, but the number of such citations was low initially.
Workshop Effects on Novices' Knowledge of Rationales

1. Post-workshop novices provided rationales, or reasons, for their evaluative judgments of critical incidents and suggestions for alternative chemical demonstrations based on their knowledge of the learner, the demonstration system, the subject matter, and teaching strategies. These categories of rationales were also evident in pre-workshop novices' and experienced chemical demonstrators' discourses.

2. After the workshop, novices began to recognize factors that contribute to a complex chemical demonstration and how such complexities could interfere with learning. Furthermore, the workshop-trained novices recognized several ways in which complex chemical demonstrations could be simplified in order to help middle school students learn basic chemical concepts.

Workshop Effects on Novices' Pedagogical Content Knowledge Focus

1. After the workshop intervention, novices gave greater attention to pedagogical content knowledge issues during the critical-stop task (Table 17). The increase, however, was not statistically meaningful ($p > .187$). Prior to the workshop, 71.7% of the critical incidents discussed related to pedagogical content knowledge issues. After the workshop, PCK emphasis increased to 76.0% of the critical incidents discussed.

Discussion

The findings of this study reveal several quantitative and qualitative differences between experienced and novice chemical
demonstrators in terms of their conceptualizations of effective chemical demonstration teaching. The findings further document knowledge growth in teaching among novice demonstrators receiving intensive inservice training. These findings support several recent studies contrasting experienced and novice teachers' thinking about teaching, students, and classroom events (reviewed by Calderhead, 1987; and by Clark & Peterson, 1986). They also add to the current research literature by providing data on the nature of science teachers' pedagogical content knowledge growth in an inservice setting. Finally, this study contributes to the growing body of literature examining the nature and development of pedagogical expertise (see Berliner, 1986, 1988; Carter et al., 1987; Leinhardt & Greeno, 1986).

The discussion that follows presents a synthesis and interpretation of the data obtained in this study. The discussion centers around five distinct areas that highlight the various characteristics of experienced chemical demonstrators' pedagogical content knowledge and factors that contribute to its growth among novices. The five areas of discussion center around demonstrators' (1) skill at critiquing content, (2) knowledge of concept-specific demonstrations, (3) knowledge of inquiry demonstrating, (4) knowledge of demonstration variations, and (5) skill at processing demonstration teaching information.

**Experienced and Novice Demonstrator Differences**

In the discussion that follows, all references to novices are to pre-workshop novices unless otherwise indicated.
Experienced and Novice Demonstrators' Skill at Critiquing Content

A componential analysis of the protocols revealed that experienced chemical demonstrators were considerably more skilled than novices at identifying erroneous and misleading propositions presented in the four videotapes. Shulman (1987) calls this skill "critical interpretation" of content. According to Shulman, this skill represents an important aspect of a teachers' PCK. The findings of this study suggest that this ability appears to be better developed among the experienced demonstrators than among the novices.

When teachers prepare a given topic for instruction, they must carefully scrutinize the teaching material and determine whether it is "fit to be taught." This process of critical interpretation includes (1) detecting and correcting errors of omission and commission in the curriculum texts, and (2) structuring and segmenting the text materials into forms more suitable for teaching. Although the demonstrators in this study were not given textual material to simulate this transformation activity, they performed a similar activity (the critical-stop task) in which they critiqued the teaching and content presentation of the videotaped demonstrators.

A close examination of the protocols showed that it was primarily the experienced high school chemical demonstrators, not the experienced middle school chemical demonstrators, that detected errors and misleading propositions presented by the videotaped teachers. This difference in error detection can be accounted for, in part, by the prior academic training these demonstrators received. The experienced high school demonstrators all had college degrees in chemistry, whereas the experienced middle school science teachers
completed two to seven semesters of college level chemistry (see Appendix C). These findings suggest that the very first step in the transformation process, critical interpretation, requires considerable knowledge of subject matter in order to identify content-matter statements that are erroneous or misleading and thus interfere with the learning of the targeted concept. In general, this detection skill was evident among experienced chemical demonstrators and, according to Shulman (1987), contributes to their pedagogical content knowledge by informing them of the content "most fit to be taught."

Novices did not examine the chemistry content presented in the videotapes as critically as the experienced demonstrators. Evidence for this claim comes primarily from what novices did not say during the critical-stop task, rather than from what they did say. For the most part, novices did not detect or discuss any of the knowledge inaccuracies mentioned during the videotaped presentations.

Structuring and segmenting constitutes another component of critical interpretation. Several critical-stop discourses, particularly those that coded as organizational issues (Table 10), reflected knowledge associated with this transformation subprocess. In this regard, the experienced chemical demonstrators readily identified and discussed critical incidents related to the sequencing of concepts and ideas in order to minimize student confusion about density and air pressure and to maximize the time available for instruction (see quotes provided on page 149-150). For the experienced subjects, the issue of structuring and segmenting extended beyond content matter organization, as discussed in Shulman's model, to include structuring and segmenting the manipulative tasks.
associated with the demonstration presentation. Furthermore, it included the interaction of structuring subject matter content with the manipulative tasks of the demonstration. The experienced chemical demonstrators considered the structuring and segmenting of content and handling of equipment as an important contributor to effective chemical demonstrating.

Novices' primary concern regarding the structure and sequence of content during a demonstration involved the issues of pacing, closure, and transitions. Novices did not identify and discuss critical issues related to the sequencing of key ideas and demonstration tasks to make the most of the limited time available for instruction. These findings, when contrasted with the discourse patterns observed among experienced demonstrators, suggest that novice demonstrators could continue to grow in their pedagogical content knowledge of how to optimally structure and sequence the content and demonstration tasks associated with chemical demonstrations.

Experienced and Novice Demonstrators' Knowledge of Concept-Specific Demonstrations

The verbal responses obtained from experienced chemical demonstrators revealed that these demonstrators possess a large body of knowledge on various chemical demonstrations that could illustrate the concepts of density and air pressure to middle school students. These demonstrators could recall several relevant demonstrations from memory and discuss them in detail. According to Shulman's (1987) model of pedagogical reasoning, these findings suggest that experienced chemical demonstrators possess multiple mental representations for demonstrating basic chemical concepts. This
multiplicity in representing basic science concepts reveals a particularly distinctive characteristic of experienced chemical demonstrators' pedagogical content knowledge. Given that density and air pressure represent only a small sampling of the concepts covered in chemistry (Appendix E) and that demonstration teaching represents only one of several ways of representing chemical concepts, the findings of this study suggest that experienced chemical demonstrators possess what Shulman (1986, p. 9) calls "a veritable armamentarium of alternative forms of representation."

By contrast, novice chemical demonstrators lacked the breadth and depth of pedagogical content knowledge exhibited by the experienced demonstrators of how to demonstrate basic chemical concepts to middle school students. It was apparent from the clinical interview discourses that novices could only think of and describe a small number of chemical demonstrations that would help students understand the concepts of density and air pressure. According to Shulman's model of pedagogical reasoning, this indicates that novices possess a limited representational repertoire for demonstrating basic chemical concepts at the middle school level. This finding is consistent with the self-report data gathered on these demonstrators who indicated they do not frequently use chemical demonstrations in their own science teaching (Appendix C).

Along with the representations that experienced demonstrators hold for demonstrating a given chemical concept, they possess an understanding of which representations, e.g., chemical demonstrations, are most suitable as concept introductions at the middle school level. During the clinical interview, the experienced chemical demonstrators
discussed the instructional value (i.e., the benefits and disadvantages) of the various representations without the prompting of the researcher. For these demonstrators this unsolicited information was integral to their evaluation of the videotaped demonstration presentations. Knowledge of which chemical demonstrations are most instructive for teaching a given concept and their placement in a given unit plan represents two other important characteristics of experienced chemical demonstrators' pedagogical content knowledge.

Novices, on the other hand, made very little reference to the appropriateness of the videotaped demonstrations for instruction at the middle school level. One novice who did verbalize discontent with the videotaped density demonstration suggested a density lab in place of the Density Column demonstration as a more suitable alternative for transforming the concept of density into a form students could understand. This response is not surprising given that many of the novices were probably more familiar with density labs than with density demonstrations (see Demonstration tallies in Table 16).

Another characteristic of novices' pedagogical content knowledge is that they often made reference to erroneous and pedagogically unsound chemical demonstrations for teaching density and air pressure. Some of the demonstrations novices discussed as suitable illustrations of the targeted chemical concepts were actually more appropriate for demonstrating related chemical concepts and principles, such as Archimedes Principle (water displacement), sedimentation rates, and Bernoulli's Principles (air flow). It appeared that some of the representations novices possessed were not optimally associated with the concept of interest. These findings further support the notion
that novices possess a limited and ill-developed representational repertoire for demonstrating basic chemical concepts.

**Experienced and Novice Demonstrators’ Knowledge of Inquiry Demonstrating**

During the clinical interview, the experienced chemical demonstrators made frequent mention of the importance of incorporating inquiry methods of instruction into the chemical demonstration. They recognized and discussed numerous critical incidents where the videotaped teacher hindered inquiry by forecasting the procedures, outcomes, and explanations of the phenomenon demonstrated. These comments reflect another aspect of content transformation called instructional selection (Shulman, 1987). During instructional selection, a teachers’ representation (e.g., the Density Column demonstration) is delivered to students with respect to some teaching strategy, such as lecture, Socratic dialog, discovery learning, silent presentation, seatwork, etc. In this study, the experienced chemical demonstrators frequently discussed issues related to instructional selection in terms of using inquiry methods of instruction when conducting chemical demonstrations. These inquiry discourses further depict the nature of experienced chemical demonstrator’s pedagogical content knowledge for demonstrating basic chemical concepts.

During the clinical interview, novices made no direct reference to the importance of using inquiry methods of instruction in a chemical demonstration. They also made little reference to some of the important components of inquiry instruction, such as, having students provide supportive evidence and conclusions during a demonstration (Trowbridge & Bybee, 1986). Novices did, however, make
reference to selected characteristics associated with good inquiry instruction, such as having students become involved in observing, measuring, predicting, describing, and inferring. Novices were also reasonably cognizant of how forecasting interferes with inquiry instruction, although novices discussed it in fewer critical incidents than did the experienced demonstrators. These findings, collectively, suggest that novices possess adequate knowledge of instructional selection (Shulman, 1987) in terms of presenting a chemical demonstration as a student-centered, inquiry-oriented presentation. However, if experienced demonstrators are used to establish desired standards of pedagogical knowledge and pedagogical reasoning, improvements in novices’ conceptualization of inquiry chemical demonstrating would be appropriate.

These findings, when interpreted in terms of schema theory (Rumelhart & Norman, 1978), suggest that experienced demonstrators’ schemata for inquiry teaching and their schemata for demonstration teaching appear to be better developed and interconnected than those of novice demonstrators. By better developed, we mean that the schemata of experienced demonstrators for inquiry teaching and for chemical demonstrating contain more detail and display more detail when verbally expressed. By interconnected we mean that the networks of knowledge associated with inquiry teaching and chemical demonstrating are more interrelated and that these relationships are more frequently and fluently expressed in verbal discourse among experienced subjects. Other studies, particularly those that have examined teachers’ thinking and decision-making among experienced and novice teachers, have noticed similar differences in teachers’
cognitive structures for teaching (Borko & Livingston, 1988; Leinhardt & Greeno, 1986; Peterson & Comeaux, 1987).

Experienced and Novice Demonstrators' Knowledge of Demonstration Variations

Experienced demonstrators were also quite knowledgeable of chemical demonstration variations. Their discourses revealed that the Density Column demonstration, the Collapsing Aluminum Can demonstration, and several other density and air pressure demonstrations could be performed in a variety of different ways. These variations usually involved adjustments in the kinds and number of materials that could be used in a demonstration and the sequence in which these materials could be handled or introduced to students. These findings suggest that experienced chemical demonstrators are quite capable of adaptation, i.e., fitting a given chemical demonstration to the characteristics of the learner (Shulman, 1987). This claim is based on the reasoning that knowledge of demonstration variations provides experienced demonstrators with several options for adapting a demonstration to student characteristics (e.g., their abilities and motivations).

Further evidence of experienced demonstrators' knowledge of adaptations emerged when they discussed the complexity of the videotaped chemical demonstrations. In their think-aloud discourses, the experienced demonstrators often identified sources of complexity in a demonstration and discussed ways of modifying a given demonstration to minimize student confusion and learning difficulties. Experienced demonstrators usually dealt with complex demonstrations by suggesting simpler variations of the demonstration that could help
students focus on the targeted concept rather than on extraneous or unrelated concepts. Shulman's model of pedagogical reasoning considers knowledge of what makes the learning of specific topics easy or difficult another aspect of adaptation. This feature reflects another dimension of experienced chemical demonstrators' pedagogical content knowledge (PCK).

Novices, by contrast, showed limited understanding of adaptation. The verbal reports indicate that novices possessed minimal knowledge of chemical demonstration variations (Tables 15 and 16), an indicator of their adaptational repertoire. Furthermore, they rarely recognized the complexity of the videotaped chemical demonstrations and situations where adaptation would be necessary, such as with concept introductions.

Collectively, critical interpretation, representation, selection, and adaptation represent four actions that permit teachers to transform subject matter content into a form that students can comprehend. The protocols of the experienced chemical demonstrators showed considerably greater evidence for each of these four actions, than the protocols of novice demonstrators. These actions characterize some of the distinctive commonalities and differences in experienced and novice chemical demonstrators' pedagogical content knowledge.

**Experienced and Novice Demonstrators' General Pedagogical Knowledge**

The critical-stop discourses of experienced and novice demonstrators included discussions of generic teaching issues that contribute to an effective chemical demonstration presentation. These verbalizations reflected demonstrators' general pedagogical knowledge,
GPK, (Shulman, 1987). This knowledge consisted of an awareness of the importance of integrating an array of generic teaching skills, such as encouraging student participation, promoting classroom discourse, determining prior knowledge, using advanced organizers, providing immediate feedback, using different levels of difficulty during questioning, using wait time, humor, and enthusiasm, and various classroom management skills when presenting a chemical demonstration to middle school students.

Although both experienced and novice demonstrators discussed many of these generic teaching issues during the critical-stop task, novices discussed them less frequently than experienced demonstrators.

**Experienced and Novice Demonstrators' Skill at Processing Pedagogical Information**

During the critical-stop task, experienced and novice chemical demonstrators discussed many critical incidents that reflected their pedagogical content knowledge and general pedagogical knowledge of chemical demonstration teaching. A taxonomic and componential analysis of these discourses revealed that the two groups of demonstrators critiqued a variety of different critical incidents. This pattern of varied response was also observed by Carter et al. (1988) in a similar think-aloud classroom analysis task. They, too, noticed that individual variance in response to visual materials (slides) presented to experienced and novice teachers sometimes appeared as great within groups as it was between groups. In the present study, the variance phenomenon can be accounted for, in part, by the fact that within a typical 7-minute demonstration teaching videotape, experienced demonstrators collectively noticed as many as
70 different critical incidents associated with effective and ineffective chemical demonstrating. This suggests that the variance observed may be partially attributed to the large number of critical incidents the demonstrators could choose to process and critique during the critical-stop task. This response variance, and the large number of critical incidents identified for the relatively brief videotaped demonstrations, lends support to Leinhardt and Greeno's (1986) notion that teaching, in general, is a cognitively complex task. With respect to chemical demonstration teaching, this complexity is suggested by the large number of critical teaching behaviors that chemical demonstrators need to organize and attend to within a limited span of time.

In spite of the variance in the data, the frequency with which the experienced chemical demonstrators discussed critical incidents observed on videotape suggests that they were able to process considerably more information pertaining to chemical demonstration teaching than novices. This information processing ability also suggests that experienced chemical demonstrators possess a well-defined knowledge structure or schemata for chemical demonstration teaching that is less-defined among novices (Berliner, 1987a; Carter et al, 1987; Gage & Berliner, 1984, pp. 317-319; Leinhardt, 1983; Leinhardt & Greeno, 1986; Rumelhart & Norman, 1978).

In summary, the verbal data can be interpreted to indicate that the experienced subjects had a much greater representational repertoire for demonstrating basic chemical concepts than novices. The experienced demonstrators also possessed greater knowledge and skill at critical interpretation, instructional selection, and at
adapting chemical demonstrations to match the level of the learner. These components of the transformation process indicate that experienced chemical demonstrators' pedagogical content knowledge and pedagogical reasoning (Shulman, 1986, 1987) is quantitatively greater, qualitatively richer in detail, and better integrated with other knowledge systems than that of novices.

Pedagogical Content Knowledge Growth Through Intensive Inservicing

Intensive inservicing produced observable levels of pedagogical content knowledge growth among science teachers identified as novice chemical demonstrators. This knowledge growth varied, however, with respect to the form of pedagogical knowledge/skill examined (e.g., skill at critiquing content, knowledge of concept-specific demonstrations, knowledge of inquiry demonstrating, knowledge of demonstration variations). In some pedagogical knowledge areas, novices experienced substantial knowledge growth; in other areas they experienced very little. Each area contributes to a teacher's pedagogical content knowledge.

Changes in Novices' Skill at Critiquing Content

During the pre- and post-workshop clinical interviews, novices did not identify any of the knowledge inaccuracies present in the videotaped demonstrations. This error detection skill associated with teachers' PCK, a skill Shulman (1987) calls critical interpretation of content, appeared to be unaltered by the workshop intervention as measured by the critical-stop task. The content errors presented to the novice demonstrators, however, were subtle in nature and were
presented very quickly during the videotape viewing task; thus, possibly eluding novices' attention.

Another process associated with the skill of critical interpretation of content is knowledge of how to structure and segment content-specific material for instructional purposes (Shulman, 1987). This skill also showed little development among novices engaged in the critical-stop task. During the pre- and post-workshop interviews, novices discussed content organizational issues, such as concept introduction and closure, with similar emphasis. Unlike the experienced demonstrators, however, pre- and post-workshop novices did not identify or discuss critical incidents pertaining to the organization of key ideas and demonstration tasks to aid learning, minimize student confusion, and maximize the time available for instruction.

Although the novice demonstrators were presented with chemistry content whenever they observed the experienced demonstrators (i.e., the workshop instructors) perform chemical demonstrations and whenever they observed peer presentations, the workshop did not include formal chemistry content lectures as a major component of its design. Instead, it sought to provide teachers with additional laboratory time to practice the numerous boxed demonstrations. The fact that novices showed no measurable change in terms of critical evaluation skills is consistent with the stated goals of the workshop. Both the NSF proposal and ICE brochures (Bell, 1987; Appendix B) make no direct mention of providing ICE Workshop B participants with skills that would allow them to critically examine chemistry content; although, it may have, nevertheless, been a hidden or secondary goal of the
workshop. The design and duration of the workshop may not have permitted the inclusion of this content goal as a major focus of the workshop. Thus, this study indicates that the critical interpretation dimension of pedagogical reasoning and pedagogical content knowledge, as measured by the critical-stop task, showed no observable change among novice chemical demonstrators receiving the workshop intervention.

Changes in Novices' Knowledge of Concept-Specific Demonstrations

Novices showed an increase in the number of chemical demonstrations on density and air pressure they could discuss and critique as a result of having participated in the workshop. This finding indicates that the workshop produced a significant (p < .01) increase in the representational repertoire of novice chemical demonstrators in terms of their knowledge of demonstrations that would illustrate basic chemical concepts to middle school students. Given the magnitude of the increase measured (about a 5-fold increase in the number of chemical demonstrations discussed, see Tables 15 and 16), and the number of concepts addressed during the workshop (over 30; see Appendix E), novices' knowledge growth in teaching basic chemical concepts may be considered substantial as a result of participating in the inservice workshop. These changes suggest that post-workshop novices began to develop a representational repertoire for demonstrating basic chemical concepts characteristic of experienced chemical demonstrators.

Cause and effect is difficult to attribute in a study such as this, but the increase in novices' representational repertoire for demonstrating specific chemical concepts may be attributable to a
number of workshop components including: modeling, observing, reading, practice, and feedback on these concept demonstrations performed by workshop instructors and workshop participants.

After the inservice workshop, novices elicited slightly fewer erroneous and pedagogical unsound demonstrations on the targeted concept, density. The decrease, although small and not statistically significant as determined by two statistical tests (a t-test and a non-parametric U-test), represents a 45% drop in the number of unsound concept representations discussed by novice chemical demonstrators on this concept (see Table 19). The small sample size available (e.g., eight pre- and post-workshop novices) may account, in part, for the lack of statistically significant change in the number of pedagogically unsound demonstrations novices discussed during the pre- and post-workshop interviews on the concept, density. No change was observed in terms of the number of unsound demonstrations a few novices discussed on air pressure. The numbers cited for this concept, however, were initially small.

To explain the decrease in the total number of extraneous examples discussed by novices during the clinical interview (see Table 20 showing frequency tallies summed across both concepts, and summed across negative and positive examples), one could hypothesize that as novices gained confidence in conducting and performing various density and air pressure demonstrations during the workshop, they relied less on brainstorming efforts and "survival responses" which previously lead to discussions of non-demonstration examples and pedagogically unsound demonstrations on the target concepts. The workshop, itself, did not directly address novices' unsound representations for
demonstrating specific chemical concepts. Their presence may reflect the existence of stable misrepresentations of how to demonstrate basic chemical concepts among novices.

As a result of participating in the demonstration workshop, novices became more cognizant of (1) the value of using physical drawings of complex demonstration systems on the blackboard, or other visual aid, to supplement the demonstration presentation and (2) strategies for increasing the visibility of demonstration systems when presented in a large classroom setting. Acquisition of these teaching representations can be attributed to various workshop factors, particularly, the modeling of these representations and direct instruction of their usefulness during the scheduled staff presentations. Learning may have also been reinforced as novices observed these representations modeled in many participant demonstrations.

After the workshop, novices discussed more critical incidents pertaining to the quality of the concept explanations provided by the videotaped teachers (Table 11). Novices, however, did not provide more suggestions for pedagogically enhancing the unacceptable explanations they critiqued (Table 14). These findings suggest that novices may have heard new representations for explaining abstract chemical concepts to middle school students as a result of the workshop intervention and, therefore, could identify effective and ineffective concept explanations more readily during the critical-stop task. These new concept explanations, however, may not have been sufficiently instantiated into teachers' existing schemata so as to assist them in providing more suitable concept explanations whenever
poor explanations were identified and discussed during the think-aloud task. The pedagogical content knowledge growth that novices did experience in terms of acquiring propositional knowledge for concept explanations may be attributed to the opportunities novice demonstrators had to hear these concepts explained and demonstrated by workshop instructors and the more experienced workshop participants (see Appendix M, Checklist of Density and Air Pressure Demonstrations Observed or Performed by Novices During the Workshop).

Changes in Novices' Knowledge of Inquiry Demonstrating

The workshop also appeared to help novices become more cognizant of the value of inquiry teaching when conducting chemical demonstrations. This instructional strategy was specifically mentioned by several novice demonstrators during their post-workshop interviews. This increased awareness of the value of inquiry demonstrating may be attributed to (1) the frequent modeling of this strategy by workshop instructors, (2) the references made concerning this instructional strategy during the first staff presentation (see Appendix G), (3) the descriptions of effective chemical demonstration teaching provided in the first workshop handout (see Appendix H), and (4) the "inquiry tips" participants occasionally received from workshop instructors as feedback to their public presentations. These factors contributed in various ways to novices' enhanced knowledge of instructional selection (Shulman, 1987), i.e., their increased awareness of an inquiry approach to conducting chemical demonstrations.

Although the inservice intervention provided novices with a greater realization of the value of inquiry demonstrating, it appeared
to be insufficient to assist novice demonstrators in recognizing a greater number of critical incidents (specific teaching behaviors) that hindered or promoted inquiry teaching of basic chemical concepts. Before and after the inservice workshop, novices generally identified and discussed similar inquiry-teaching critical incidents, such as:

1. the appropriateness of having students use their observation skills during a chemical demonstration and
2. the inappropriateness of having a demonstrator forecast demonstration procedures, observations, and explanations. By contrast, the experienced chemical demonstrators gave more frequent and more varied attention to inquiry issues than either pre- or post-workshop novices.

Changes in Novices’ Knowledge of Demonstration Variations

Knowledge of chemical demonstration variations provides demonstrators with options that allow them to fit the represented material to the characteristics of the students. For this reason, demonstration variations are viewed as the product of the adaptation process described in Shulman’s (1987) model of teaching.

After the workshop intervention, novices were able to discuss more variations on selected chemical demonstrations (p < .05). They also began to recognize the complexity of some chemical demonstrations and how these complex demonstrations could generate confusion among middle school students. This knowledge prompted novices to discuss ways of reducing the complexity of a chemical demonstration using simplified variations. This knowledge of complex chemical demonstrations, and suitable variations on such demonstrations, was acquired by novices partly through the workshop staff’s emphasis on simple demonstrations and how such variations potentially help
students focus on the central concept. Novices’ heightened awareness of demonstration variations can also be traced to some of the feedback workshop participants received immediately after performing a demonstration before their peers. The workshop sourcebook also provided several suggestions for performing variations on chemical demonstrations (see Appendix K for Sourcebook examples). The variations discussed during the workshop and those described in the sourcebook ranged from simpler to more complex approaches for demonstrating the original demonstration.

Changes in Novices’ General Pedagogical Knowledge

General pedagogical knowledge growth among novice chemical demonstrators during the two-week demonstration workshop was more difficult to detect. Data obtained from the critical-stop task revealed no significant increase in the total number of critical incidents discussed involving generic teaching behaviors important to chemical demonstrating (Table 17). This lack of change may be accounted for, in part, by the information processing skills that novices possessed for analyzing demonstration teaching episodes. (A further discussion of this issue is provided in the section that follows).

Issues pertaining to wait time, feedback, and building rapport with students continued to occupy post-workshop novices’ attention of general pedagogical issues during the critical-stop task. These issues were not given special attention during the scheduled staff presentations; however, they were addressed in various ways during the public and private feedback sessions that followed the public presentations given by the workshop participants.
Novices did give special attention to issues pertaining to the effective use of humor while thinking aloud about effective chemical demonstration teaching (pp. 209-210). These discourses appeared more frequently in their post-workshop discourses than in their pre-workshop discourses. This apparent change in general pedagogical knowledge associated with chemical demonstration teaching may be attributed to one of the workshop staff presentations that specifically gave attention to the use of humor in teaching (see Appendices F and G). This staff presentation may have influenced novice demonstrators in their post-workshop critiques of the four chemical demonstration videotapes.

Changes in Novices' Skill in Processing Demonstration Teaching Information

The protocols obtained from pre- and post-workshop novices reflected both general pedagogical knowledge and pedagogical content knowledge. The findings associated with several content analyses performed on this data (e.g., Tables 7, 10, and 11) suggest that novices' information processing skills may not have been substantially enhanced during the course of the workshop. Given that critical incidents were presented to the research subjects at a rate of one every ten seconds, the critical-stop task apparently requires a well-developed knowledge structures (schemata) for chemical demonstration teaching and well-developed cognitive processing skills to effectively perform the think-aloud task of (i) storing and encoding the verbal and visual cues presented via the demonstration videotapes, (ii) processing the information in terms of existing knowledge structures, and (iii) retrieving the processed information
to yield an appropriate verbal response (Gage & Berliner, 1984), i.e., evaluations of rapidly-occurring critical incidents.

Although novices continued to process information provided by the videotaped demonstrations at the same rate before and after the inservice workshop (Tables 7 and 17), there did appear to be a slight shift in critical-incident focus from generic issues, such as use of the blackboard and selected organizational issues (Categories 7 and 8 in Table 11), to content-bound issues, such as the quality of explanations and teacher-directed questions (Categories 2 and 4).

In summary, the verbal data can be interpreted to indicate that the two-week chemical demonstration workshop had an observable impact on promoting pedagogical content knowledge growth among novice chemical demonstrators. This growth, however, was most evident with respect to novices acquiring multiple representations for demonstrating basic chemical concepts and in terms of adapting demonstrations to fit the characteristics of the learner. Little pedagogical content knowledge growth was observed in terms of structuring content materials (critical evaluation) and using inquiry strategies (instructional selection) during a chemical demonstration. In addition, generic concerns associated with chemical demonstration teaching gave way to more content-bound concerns as a result of the workshop intervention.

The findings of this study support the literature that expertise in virtually any complex enterprise, including teaching, takes considerable time to develop (Bloom, 1985). Intensive inservice for two weeks, for example, on one science teaching strategy (demonstration teaching) in one subject matter discipline (chemistry)
does not suddenly transform novice chemical demonstrators into highly experienced or expert chemical demonstrators. It does, however, produce substantial knowledge growth in teaching that allows teachers to more readily progress through the five hypothesized stages of progression from novice to expert teacher (Berliner, 1988; Dreyfus & Dreyfus, 1986). Evidence for continued professional growth among ICE participants after the workshop comes from O'Brien’s (1987) follow-up study of another group of ICE Workshop B participants. This study documented increased classroom use of chemical demonstrations as a result of the workshop intervention, a factor that is likely to help perpetuate teachers’ continued pedagogical content knowledge growth long after the intensive chemical demonstration workshop experience.

Validity Considerations

Questions about a qualitative study’s internal validity center around how well rival hypotheses have been ruled out as alternative explanations for observed phenomena. In this study, this translates to a search for alternative explanations that could account for (1) experienced-novice demonstrator differences and (2) novices’ pre-/post-workshop changes in interview responses. Questions about a qualitative study’s external validity center around how well the findings of a study apply to other subjects and settings (Bogden & Biklen, 1982; Krathwohl, 1985; Goetz & LeCompte, 1984).

Internal validity

Response effects and selection present potential threats to the internal validity of this study. These two effects provide plausible
rival hypotheses for explaining the observed differences in experienced and novice chemical demonstrator discourses during the clinical interview. Response effects refer to those factors that influence a respondent (a demonstrator) to provide incomplete or inaccurate data (Borg & Gall, p. 438, 1983). One such response factor includes the predisposition of the interviewer, sometimes referred to as an interviewer effect.

To help minimize errors attributed to interviewer effects, the researcher developed an interview guide (Appendix I) which he used and adhered to closely during each clinical interview. This interview guide followed established techniques for conducting interviews (Borg & Gall, 1983; Novak & Gowin, 1984). This researcher also implemented many of the strategies for conducting effective clinical interviews recommended by Novak and Gowin (1984). Furthermore, this researcher piloted the interview guide and recommended interview procedures with four science education graduate students and again with eight ICE workshop participants during the first summer session of the workshop. Given that the interviewer conducted this study using recommended clinical interview procedures and after receiving training and feedback in interviewing science teachers, it would be unreasonable to believe that the observed differences between the two groups of demonstrators were artifacts of the interviewer's skills and biases. Furthermore, it would be unreasonable to expect that these interviewer effects would surface on so many of the variables examined in this study (D, V, XTOT, 9 Categories, Strengths/Weaknesses, etc.). Thus, prior chemical demonstration teaching experience, rather than
interviewer effects, provides the more plausible explanation for the observed differences in the two groups' interview responses.

Another response effect that could bias the interview data is the predispositions of the respondents. This effect suggests that the two groups of subjects could be differentially predisposed in their motivation to cooperate with the researcher or in their desire to present themselves in favorable terms. Such a possibility needs to be addressed in light of the fact that this researcher had professional interactions with all the experienced demonstrators and only one of the novice demonstrators prior to the study. One could argue that these differences could account for different predispositions of the respondents and, consequently, generate major differences in interview responses.

To help minimize this validity threat, this researcher made every attempt to build a satisfactory rapport with the novice demonstrators prior to the interview and during the first few minutes of the interview. Novices were contacted by mail requesting their voluntary participation (Appendix D). This letter was written so as to give these subjects some favorable, pre-workshop contact with this investigator. Local participants were also contacted by phone after having received the contact letter. The fact that all the contacted subjects volunteered to participate in this study suggests that a favorable rapport had been initiated. Furthermore, those novices that arrived a day before the workshop began, appeared to be eager to schedule time to view and critique the chemical demonstration videotapes and respond to a few follow-up questions.
Further attempts to build rapport with the novice subjects occurred during the beginning of the clinical interview when the interviewer introduced the study, described his role at the workshop, and asked a few non-threatening, warm-up questions. Prior to beginning the critical-stop task, novices indicated that they had a clear idea of what they had to do and were ready to begin. During the interview, the researcher made an effort to relate to the respondents in a non-threatening fashion, accepting their responses as given and providing a conversational style that communicated trust, confidence, and ease among respondents—conditions necessary for yielding valid data from informants (Goetz & LeCompte, 1984). Thus, with a satisfactory rapport established between the interviewer and respondents, there is sufficient reason to believe that both groups of demonstrators were favorably predisposed to the interview tasks and that group differences reflected prior knowledge of chemical demonstration teaching. Hence, the threat of differences in respondent predispositions can be ruled out as a plausible hypothesis for explaining experienced/novice chemical demonstrator differences.

Piloting this study also permitted a reduction in a third form of response effect that could account for group differences, namely the procedures used in conducting the study. Sources of error in this category include the place where the interview is held, the length of the interview, the quality of the questions, and the instructions presented to the subjects. Although the experienced subjects were probably more familiar with the workshop setting, took longer to complete the interview, and were more familiar with terms like "variations" than the novice subjects, the researcher made an effort
to minimize interview differences. This researcher conducted the interviews for both groups of demonstrators in rooms that afforded privacy and comfort, kept the interviews to within 50 minutes, yet allowed sufficient time for complete responses, and interacted with the respondents so they could clearly understand all terms, questions, and instructions. During the pilot phase of this study, respondents were also asked to supply their perceptions, feelings, and recommendations regarding the clinical interview to assist this researcher in reducing procedural errors in the actual study. Therefore, errors in interview procedures are hardly likely to account for the many differences in experienced and novice chemical demonstrator performance during the clinical interview.

Selection represents another major threat to the internal validity of a qualitative study. In one sense, it was absolutely necessary to identify and select chemical demonstrators who differed considerably in terms of chemical demonstration experience so that pedagogical content knowledge differences could be documented. On the other hand, bias in group composition (Borg & Gall, p. 141, 1983) could further accentuate or distort these findings. The greatest concerns of this type include differential representation within the two groups regarding the demonstrators' teaching grade level, prior experience in critiquing videotaped teaching episodes, content background, and the ability to verbalize thoughts about chemical demonstrating.

The experienced and novice group of chemical demonstrators both consisted of a mix of elementary, middle school, and high school teachers. These similarities are offset slightly by the fact that the
experienced group included a community college chemistry instructor who had some high school teaching experience. The novice group had no community college representative. The experienced group also had a slightly higher proportion of high school teachers (3/5), the novice group a slightly higher proportion of middle school teachers (5/8). One could argue that these teaching level differences could account for, or skew, group differences in interview response. Although the demonstrators in the two groups were not optimally matched in terms of grade level, this research study operationally defined "novice chemical demonstrators" in terms of self-reported teaching information gathered on the workshop participants. Thus, if another researcher were to replicate this study, similarities and differences could be accounted for in terms of the operational definition given to the term "novice chemical demonstrator." In this study, bias in group composition was therefore "controlled" by gathering quantitative data on the demonstrators' attributes (e.g., grade level, confidence and weekly use in conducting chemical demonstrations, chemical demonstration workshop/outreach experience, college chemistry courses, etc.) that become part of the operational definitions for the labels "experienced and novice chemical demonstrators." The background information obtained from the research subjects also provided important data necessary to discuss the generalizability of this study's findings (see section on External Validity, below).

Another selection threat arises from the possibility that experienced chemical demonstrators are less able to articulate their thoughts on demonstration teaching than novices because a greater part of their teaching knowledge has become embedded in routine behaviors
(knowledge in action). Such factors, if operating, would generate biased data and, thus, distortions in describing the nature of experienced and novice chemical demonstrators' pedagogical content knowledge. This line of reasoning argues that experienced demonstrators possess more tacit knowledge on the subject of demonstration teaching than novices, a factor that would interfere with efforts at collecting valid data. Tacit knowledge refers to a person's knowledge that has never been verbalized and may not be communicable in verbal form (Calderhead, 1981b). Tacit knowledge becomes a particular problem with behaviors that have reached a level of routinization where behavior is engaged in unthinkingly, a situation that characterizes expertise.

In defense of this selection threat to the validity of this study, this researcher observed no striking difference between the two groups of teachers in terms of their loquaciousness in discussing common critical incidents. The experienced subjects, all of whom had experience at teaching chemical demonstrations to other teachers, appeared very capable of discussing their knowledge of chemical demonstration pedagogy while analyzing videotaped demonstration performances. Furthermore, as Shulman (1986) has stated, "Tacit knowledge among teachers is of limited value if the teachers are held responsible for explaining what they do and why they do it, to their students, their communities, and their peers." For this reason, this investigator was primarily interested in examining readily retrievable pedagogical knowledge, not thoughts which occurred at a low level of awareness among the informants.
Finally, one could argue that differences between experienced and novice subjects may be attributed to their prior experience in critiquing teaching or videotaped models of teaching. To help understand this influence, this researcher asked the research subjects (Appendix I) if they had ever critiqued someone else’s teaching as observed on videotape. Both groups generally indicated they engaged in a task similar to the critical-stop task where they would carefully critique someone else’s teaching on videotape on at least one or two other occasions in their careers. Unfortunately, no information was gathered on subjects’ history in supervising student teachers where such critiquing skills could be developed. In any case, it appears that this threat is minimal and that differences in group performance during the clinical interview is best accounted for in terms of prior chemical demonstration experience.

Other threats to internal validity emerge and need attention when accounting for pre-/post-workshop changes in novice demonstrator interview performance. These variables include testing (interview practice) and maturation (changing predispositions).

In this study, the threat of testing (interview practice) suggests that learning during the first interview promotes enhanced responses during the second interview. Evidence for the presence of this extraneous variable comes from a small number of comments elicited by a few subjects during the post-workshop interview where they referred to one of the pre-workshop videotapes.

This researcher made an effort to minimize learning effects during pre-testing by using a parallel set of videotapes (same demonstration, different performance quality) during the post-workshop
interviews. The length of time between the pre- and posttests (two weeks) may have also worked to this researcher's advantage in keeping this factor under control. It was not possible, however, for this researcher to control the possibility of the pre-workshop interview causing novice demonstrators to become sensitized to the workshop treatment, particularly to the two chemical demonstrations observed on videotape. The pre-workshop viewing of these videotapes may have piqued novice demonstrators' interest and motivation to learn more about these particular demonstrations and, even, to learn more about chemical demonstrations in general. Some of the novices did appear to be impressed or curious about the concept/phenomenon demonstrated on videotape. Thus, the influence of testing could have had considerable impact on novices' pedagogical content knowledge growth by sensitizing subjects to the observed demonstrations and to the workshop intervention. Because this factor could not be well controlled, given that this researcher did not have the personal resources to conduct clinical interviews with a control group of novices who receive only post-workshop interviews, it would be best to consider testing a part of the workshop treatment for the eight novice demonstrators who participated in the study. This pre-workshop treatment appeared to have a beneficial, rather than detrimental, effect on the workshop participants.

Viewed from another perspective, it is hardly likely that a control group of novice demonstrators receiving only the pre-workshop interview would perform as well on the post-workshop interview, i.e., show as much knowledge gain, as those novices who also experienced the two-week workshop intervention. Thus, the influence of the workshop
becomes the most plausible, empirically grounded explanation for novices pedagogical knowledge growth.

Another threat to the internal validity of this study that could influence changes in novices' interview responses is maturation. Given that the workshop was an intensive two-week intervention program, it is not surprising that a few participants appeared to show some signs of "training fatigue" in terms of being a bit more physically tired than when they arrived for the workshop. This is understandable given the summer temperatures, demanding eight-hour workshop schedule, several evening sessions, and occasional late nights studying or socializing. During the last two days of the workshop, when most of the post-workshop interviews were held, some of the subject were also beginning to mentally prepare for a long trip home, arrange social time with peers, and think about an upcoming summer vacation. These altered physiological and psychological states among post-workshop novices may have prevented these subjects from performing even better than they did during the post-workshop interview. It is conceivable that the lack of change in the total number of critical incidents cited by novices after the workshop may be partially attributable to these uncontrollable factors. Novices may have been less alert and less able to focus on the critical-stop task. If these extraneous variables actually operated during the post-workshop interviews, this would suggest that novices' pedagogical knowledge gains are actually even greater than those documented in this study.

Having discussed the various threats to the internal validity of this study, differences in experienced and novice chemical
demonstrator performance appears best accounted for in terms of their prior chemical demonstration teaching experience. Likewise, the observed growth in novice demonstrators' pedagogical content knowledge and general pedagogical knowledge of chemical demonstrating is best explained in terms of the workshop intervention.

External validity

External validity refers to the extent a study's findings are generalizable to other educational settings. In this study it refers to an assessment of the applicability of the present findings to other experienced/novice teacher comparisons and to other teacher inservice programs. The key characteristics describing the setting of this study include a group of motivated elementary, middle school, and high school science teachers with limited experience in conducting chemical demonstrations participating in an intensive, two-week chemical demonstration workshop conducted by experienced chemical demonstrators. The workshop was designed to provide direct instruction as well as help participants observe, practice, perform, and receive feedback on numerous chemical demonstrations covering a range of basic chemical concepts.

The findings that illustrate the nature of the two groups of chemical demonstrators' PCK are most generalizable to other elementary and secondary physical science teachers possessing either minimal or considerable experience in conducting chemical demonstrations. The findings of this study may also apply to experienced and novice demonstrators in other science disciplines, such as physics, biology, and earth science, where teachers' pedagogical content knowledge, when defined in terms of knowledge of demonstrating discipline-specific
concepts, could be expected to show similar differences in breadth and depth of knowledge.

The findings of this study are consistent with those obtained in other studies examining experienced and novice teacher differences. Previous studies have documented cognitive differences between experienced and novice teachers in terms of their knowledge of students and knowledge of managing routine classroom tasks. The findings in these studies indicate that experienced teachers had amassed and could process a large quantity of information about students and classroom learning environments that distinguishes them from their less experienced colleagues (Berliner, 1986; Carter, et al., 1987; Peterson & Comeaux, 1987; Calderhead, 1983; Leinhardt, 1983).

Moving from population validity to ecological validity, this study would be most generalizable to other ICE field centers across the country that deliver the same workshop to similar participants. Generalizability would also extend to workshop participants attending similar programs at new ICE field centers in the future. Besides these specific contexts, the findings of this study are expected to be applicable to other short term inservice programs that focus intensely on one teaching strategy applied to a single discipline.

Recommendations

Recommendations based on the findings of this study can be grouped according to research recommendations, methodological recommendations, and program-specific recommendations.
Recommendations for Further Research

1. Conduct follow-up studies on novice chemical demonstrators one year after the workshop to determine whether pedagogical content knowledge continues to grow after the inservice intervention. This could be implemented by having novices critique a set of chemical demonstration videotapes at their leisure and then having them send the audiotaped comments back to the researcher. Follow-up phone conversations using a structured or semi-structured interview could also be conducted to gather additional information on novices’ post-workshop pedagogical knowledge growth. Such studies would help assess whether the participants have acquired the skills and motivation that allow for continued growth of their pedagogical content knowledge in the realm of demonstrating basic chemical concepts. Local teachers could be contacted directly for a second post-workshop clinical interview. Such follow-up studies would help determine whether the novice participants have come closer to reaching the pedagogical content knowledge levels observed among experienced chemical demonstrators.

2. Determine whether pedagogical content knowledge growth during a workshop intervention interacts with specific teacher aptitudes, such as prior chemical demonstration experience or prior subject-matter knowledge. Such interaction studies, for example, would reveal whether pedagogical content knowledge growth during inservice is greater among demonstrators with extensive content knowledge or among demonstrators weak in content knowledge. Such findings would help determine whether intensive, skills-oriented workshops have markedly different impacts on participants’ knowledge growth in teaching.
Interaction effects, such as those described above, should be examined in future studies exploring teachers' pedagogical content knowledge growth resulting from short-term teacher education programs as well as year-long classroom teaching experiences. Such interaction studies would help teacher educators better understand the nature of knowledge growth in teaching science within various learning environments. Such studies would also help program implementors design demonstration workshops that address differences in aptitude among inservice participants.

3. Use the cognitive methods described in this study to take a closer look at the components of inservice training programs most responsible for science teachers' pedagogical content knowledge growth. Workshop components worth examining in an isolated context include PCK studies that focus on the impact of laboratory practice, microteaching, observing, peer and videotape feedback, and workshop sourcebooks on knowledge growth in teaching.

Methodological Recommendations

Several refinements and modifications could be considered for the critical-stop task and semi-structured interview as a probe of teachers' pedagogical content knowledge related to the demonstration teaching of basic chemical concepts.

1. Given that the pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK) associated with the effective demonstration teaching of density and air pressure constitute a rather extensive knowledge base, it is possible to probe the various characteristics of this knowledge base even in greater detail by focusing only on selected generic or pedagogical content knowledge
(PCK) issues. This could be accomplished by simplifying or shortening the critical-stop task and having subjects discuss researcher-identified, rather than subject identified, critical incidents associated with the two knowledge systems. For example, a researcher may seek to focus only on critical incidents related to inquiry demonstrating and Shulman's (1986) construct of instructional selection. By having experienced and novice demonstrators discuss their perceptions on only these demonstration teaching issues, it may be possible to obtain greater insights into experienced and novice demonstrators' conceptualizations of teaching, especially in areas not voluntarily discussed by subjects during the critical-stop task.

2. To help increase the power of the statistical tests used to assess quantitative differences in experienced and novice demonstrators' critical-stop task performance, larger sample sizes are recommended. This would permit more powerful parametric statistical tests (e.g., the independent t-test) to be run in place of the more conservative non-parametric statistical tests (e.g., the Wilcoxon Matched-pairs Ranked-signs test) where meaningful differences were established at the 0.187 level. The non-parametric tests used in this study were limited to a sample size of n = 4, i.e., four pair-wise comparisons between experienced and novice demonstrators with group scores for each of the four videotapes. Non-parametric tests were used in this study because (1) the four videotapes critiqued varied in length and number of critical incidents and (2) the counterbalanced design used in this study had pre-workshop novices randomly examine two out of the four available videotapes. With a larger sample size, one could consider using individual performance scores rather than
group scores for each videotape as a unit of analysis, and, thus, not be constrained in using a non-parametric test of significance as part of the content analysis. Larger sample sizes could be achieved by training one or two individuals to conduct the clinical interviews concurrently with the researcher. A single researcher could obtain a larger sample only if the inservice teachers live local to the research site.

A larger sample size would be beneficial to a study because it would generate more discourses from experienced and novice chemical demonstrators on infrequently cited critical incidents. With the critical-stop task, frequently cited critical incidents typically represented a small percentage of the total number of incidents critiqued (approx. 10%). To counteract this effect and, thus, increase "yield" in terms of the number of discourses addressing the same incident, a larger sample size is recommended.

An additional advantage of working with a larger sample size includes the possibility of conducting subgroup comparisons (e.g., between experienced and novice middle school chemical demonstrators or between experienced and novice high school chemical demonstrators) and in effect "control" for selected teacher attributes or background variables. A disadvantage in working with a larger sample size, however, involves the time-consuming nature of gathering and analyzing verbal reports obtained from individuals regarding their conceptualizations of effective chemical demonstration teaching.

3. Modify the interview guide (Appendix I) to specifically probe novices in knowledge areas only discussed by the experienced chemical
demonstrators. For example, it was primarily the experienced
demonstrators and post-workshop novices who volunteered information
on the complexity of the observed chemical demonstration, the
appropriateness of the chemical demonstration for middle school
students, and the potential for the demonstration to generate student
confusion or misconceptions. A future interview guide may include a
series of structured and open-ended questions that specifically probe
topics rarely addressed by pre-workshop novices. This would require
the deletion of other questions less central to teachers’ PCK (e.g.,
I.3 and I.10) in order to help keep the clinical interview under 50
minutes.

Program-Specific Recommendations

Recommendations for the design and evaluation of this and other
skills-oriented chemical demonstration workshops include the
following:

1. The pedagogical content knowledge growth observed among
novice chemical demonstrators during the two-week workshop suggests
the importance of continued NSF support of summer institutes that
focus on science teaching skills. The pedagogical content knowledge
growth observed in the present study of a NSF-supported chemical
demonstration workshop appeared to be more extensive than that
reported in non-inservice settings (Mason, 1988; Shulman, 1987;
Wilson, Shulman, & Richert, 1987). NSF should therefore continue to
support, and even expand, their support of workshops that focus on
science teaching skills (e.g., computer-based laboratories,
demonstration teaching, science-technology-society, scientific
instrumentation, etc.) for each of the major scientific disciplines.
2. Although substantial pedagogical knowledge gains were observed among novice chemical demonstrators, they did not achieve the levels observed among experienced demonstrators. Although such levels of attainment were not expected for the workshop-trained novices, this finding suggests the importance of providing effective follow-up of workshop participants in the form of newsletters, demonstration materials, and other forms of encouragement that would promote increased use of chemical demonstrations in the classroom and involvement in conducting chemical demonstration workshops. Funding agencies should also consider supporting an "advanced" or "second year" chemical demonstration workshop to help more science teachers achieve the much-publicized need for excellence and expertise in science teaching (National Commission on Excellence in Education, 1983; Penick & Krajcik, 1984a, 1984b; Penick & Lunetta, 1984; Yankwich, 1984). The advanced workshop could help teachers develop more interconnections between the knowledge systems responsible for the growth and development of PCK.

3. Place greater emphasis on issues pertaining to inquiry approaches to chemical demonstrating. The inclusion of this goal is recommended to help bring novice chemical demonstrators further along or up to the knowledge level of experienced demonstrators in this important teaching strategy. The implementation of such a workshop objective would help foster the development of teachers' pedagogical content knowledge in the area of instructional selection, a subprocess in Shulman's (1987) model of pedagogical reasoning.
Summary

This study has accomplished several objectives. It has (1) provided rich descriptions of the nature of experienced and novice chemical demonstrators’ pedagogical content knowledge system, (2) provided empirical evidence that teachers’ pedagogical content knowledge can be enhanced through intensive, short-term inservice workshops, (3) garnered support for the usefulness of cognitive methods for evaluating a skills-oriented workshop, and (4) generated a set of recommendations for future inservice programs designed to produce professional growth in science teachers’ knowledge and skill in demonstrating basic chemical concepts.

This study addressed an important issue in science education, namely, the goal of achieving excellence in science teaching. This study has demonstrated that the growth and development of pedagogical content knowledge in science teaching can be substantially promoted through highly focused, short-term, inservice interventions. The results of this study strongly suggests the importance of inservice programs in enhancing science teachers’ pedagogical repertoire and thus, the quality of science instruction in this country.
Institute for Chemical Education

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Pending commitment of funds by the National Science Foundation and others, ICE will pay fees, expenses, and stipends for participating teachers.

Chemistry Challenges

1. Without opening unlabeled 12-ounce cans of diet and regular soda, how can you tell which is which?

2. Crush an unflavored Ex-Lax® tablet with 10-15 ml (2-3 tsp.) rubbing alcohol. Add 4 drops of this test solution to 5 ml each of ammonia, vinegar, citrus juice, solutions of baking soda, detergent, and other household substances; record your observations. What patterns can you see?

If you try these activities, let us know how they worked for you.
Institute for Chemical Education  
1987 Summer Workshops  
Application for Participation and Financial Support

Name: ___________________________  

Social Security # ___________________________  

Home Address ___________________________  

Home Phone (_____ ) ___________________________  

School ___________________________  

Work Address ___________________________  

Work Phone (_____ ) ___________________________  

Indicate the address to be used for correspondence: Home ______ Work ______  

Please rank the workshops you would consider attending, indicating your first choice with the number 1. (In selecting the field center, please remember that compensation for travel expenses may be limited to $250.)

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* This session is three weeks, others are two weeks.  
** This session is open only to Colorado Science Coordinators.

Upon your acceptance, we will contact your Superintendent of Schools and Principal, or their counterparts, to ask them to assist you in obtaining local public or private funds for your support. Please provide their names and addresses.

Superintendent ___________________________  

District ___________________________  

Address ___________________________  

Phone (_____ ) ___________________________  

Principal ___________________________  

School ___________________________  

Address ___________________________  

Phone (_____ ) ___________________________  

Summarize your college/university education.  

School ___________________________  

City and State ___________________________  

Degree ___________________________ Date ___________________________  

Major _________________  

Minor(s) ___________________________  

School ___________________________  

City and State ___________________________  

Degree ___________________________ Date ___________________________  

Major _________________  

Minor(s) ___________________________  

Current and projected teaching assignments:  

Course title ___________________________  

Number of sections ___________________________ Enrollment ___________________________  

Is this a current assignment? ___________________________  

Do you expect it in '87-'88? ___________________________  

Course title ___________________________  

Number of sections ___________________________ Enrollment ___________________________  

Is this a current assignment? ___________________________  

Do you expect it in '87-'88? ___________________________  

Course title ___________________________  

Number of sections ___________________________ Enrollment ___________________________  

Is this a current assignment? ___________________________  

Do you expect it in '87-'88? ___________________________  

Course title ___________________________  

Number of sections ___________________________ Enrollment ___________________________  

Is this a current assignment? ___________________________  

Do you expect it in '87-'88? ___________________________  

Professional Activities (NSTA, ACS, etc.) ___________________________
Describe your present style of teaching science, including the extent to which you use experiments, demonstrations, and hands-on science activities.

Briefly describe any experiences you have had that will help you in presenting outreach programs. Mention any programs you have helped to present, or educational materials or activities you have developed.

What are your professional goals? How can the workshops and outreach activities further those goals?
In addition, please submit the following information:

- A list of the titles and dates of natural science and mathematics courses you have taken.

- A list of any workshops, summer institutes and similar programs in which you have participated. Please include dates.
A resume of your teaching and science-related professional experience. Please indicate the schools at which you have taught, dates, and teaching responsibilities at each.

Signature

The application deadline to assure consideration for the 1987 Summer Workshops is March 23, 1987. Space is limited, so please apply early.

Please send your completed application to:
Institute for Chemical Education
Department of Chemistry
University of Wisconsin–Madison
1101 University Avenue
Madison, WI 53706

Applications will be forwarded to the appropriate center for review.

Please note: Once accepted by ICE, participants must complete additional forms to enroll in the summer program of the host university.
APPENDIX B

Participant Information Form (PIF)

Name: ________________________________ Social Security No. ________________________________

PARTICIPANT INFORMATION FORM

TOTAL NUMBER OF YEARS OF TEACHING EXPERIENCE: _______

TOTAL NUMBER OF COLLEGE CHEMISTRY COURSES COMPLETED: _______

WHY DID YOU DECIDE TO PARTICIPATE IN THIS WORKSHOP? (circle response)

<table>
<thead>
<tr>
<th>Importance</th>
<th>LOW</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>To meet other teachers and exchange ideas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>To travel to another part of the country</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>To explore the possibility of graduate studies</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>To learn additional chemistry content</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>To enhance teaching skills</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>To obtain financial remuneration</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>To learn how to conduct outreach programs</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>To earn academic credit</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

HOW CONFIDENT ARE YOU IN ... (circle your response to each)

<table>
<thead>
<tr>
<th>Importance</th>
<th>LOW</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>USING CHEMICAL DEMONSTRATIONS?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>USING OTHER SCIENCE DEMONSTRATIONS?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>YOUR ABILITY TO CONDUCT OUTREACH PROGRAMS USING CHEMICAL DEMONSTRATIONS?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

OVER A TYPICAL WEEK OF TEACHING, HOW MANY DIFFERENT... (circle response)

| CHEMICAL DEMONSTRATIONS DO YOU USE? | <1 | 1 | 2 | 3 | 4 | 5 | >5 |
| OTHER SCIENCE DEMONSTRATIONS DO YOU USE? | <1 | 1 | 2 | 3 | 4 | 5 | >5 |

DURING THE PAST YEAR, HOW MANY OUTREACH PROGRAMS INVOLVING CHEMICAL DEMONSTRATIONS HAVE YOU DELIVERED TO... (circle your response to each)

| STUDENTS OUTSIDE YOUR CLASSROOM? | <1 | 1 | 2 | 3 | 4 | 5 | >5 |
|OTHER TEACHERS? | <1 | 1 | 2 | 3 | 4 | 5 | >5 |

Note: the symbol < means "less than" and > means "more than"

TURN OVER
FOR WHAT PURPOSES SHOULD CHEMICAL DEMONSTRATIONS BE USED IN TEACHING?
(Rank Order on a 1 - 7 scale (using each number only once) with:
1 = most important purpose 7 = least important purpose)

Entertaining change of pace to the regular class format
Substituting for expensive/dangerous labs
Illustrating scientific concepts
Training students to make careful observations
Arousing curiosity when introducing new ideas
Stimulating student thought
Modeling good laboratory techniques & attitudes

WHAT LIMITS THE FREQUENCY OR QUALITY OF CHEMICAL DEMONSTRATIONS
IN YOUR TEACHING? (circle your response for each factor)

<table>
<thead>
<tr>
<th>IMPORTANCE OF FACTOR</th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of good demonstration ideas</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lack of demonstrating skills</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lack of confidence that demonstrations will work</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lack of time for preparation and cleanup</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lack of equipment and/or supplies</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lack of time in an overcrowded curriculum</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Inadequate teaching facilities</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Classroom management considerations</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Safety considerations</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Personal &quot;inertia&quot;</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Other:</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

DO YOU KNOW ABOUT THESE PUBLICATIONS ON DEMONSTRATIONS?

<table>
<thead>
<tr>
<th>Sources of Chemical Demonstration Ideas</th>
<th>Am Not Aware of</th>
<th>Am Aware of</th>
<th>Have Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tested Demonstrations in Chemistry (Hubert Alyea &amp; Frank Dutton)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entertaining Science Experiments with Everyday Objects (Martin Gardner)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Wizard's 400 Experiments in Science (Don Herbert)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Elementary&quot; Chemical Demonstrations (Linus Pauling)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Demonstrations (Bassam Shakhashiri)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Demonstrations: A Sourcebook for Teachers (Lee Summerlin &amp; James Ealy)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea Bank Collation (Irwin Talesnick)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea Bank (a feature of NSTA publication: The Science Teacher)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tested Demonstrations (a feature of The Journal of Chemical Education)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THANK YOU
## APPENDIX C

### Pre-Workshop Grouping of Participants

<table>
<thead>
<tr>
<th>Participant</th>
<th>Confidence (Chem/Other science)</th>
<th>Use (Chem/Other)</th>
<th>No. Chem Course/Years Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>More Experienced</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MA</td>
<td>5/4</td>
<td>5/1</td>
<td>7/13</td>
</tr>
<tr>
<td>LK</td>
<td>5/4</td>
<td>2/1</td>
<td>17/30</td>
</tr>
<tr>
<td>BB</td>
<td>4/4</td>
<td>4/2</td>
<td>3/10</td>
</tr>
<tr>
<td>JW</td>
<td>4/4</td>
<td>3/1</td>
<td>22/22</td>
</tr>
<tr>
<td>KM</td>
<td>4/4</td>
<td>2/2</td>
<td>2/13</td>
</tr>
<tr>
<td>JE</td>
<td>4/4</td>
<td>1/1</td>
<td>7/15</td>
</tr>
<tr>
<td>AH</td>
<td>3/5</td>
<td>2/3</td>
<td>3/3</td>
</tr>
<tr>
<td>GJ</td>
<td>3/3</td>
<td>2/1</td>
<td>7/1</td>
</tr>
<tr>
<td>SY</td>
<td>3/3</td>
<td>2/2</td>
<td>4/15</td>
</tr>
<tr>
<td>IW</td>
<td>2/4</td>
<td>3/4</td>
<td>1/12</td>
</tr>
<tr>
<td>JO</td>
<td>2/3</td>
<td>3/3</td>
<td>0/24</td>
</tr>
<tr>
<td><strong>n = 11</strong></td>
<td><strong>4.2 / 4</strong></td>
<td><strong>2.7 / 1.8</strong></td>
<td><strong>6.6/14</strong></td>
</tr>
<tr>
<td><strong>Less Experienced (Novices)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>3/4</td>
<td>&lt;1/3</td>
<td>5/1</td>
</tr>
<tr>
<td>N2</td>
<td>2/3</td>
<td>&lt;1/1</td>
<td>2/12</td>
</tr>
<tr>
<td>N3</td>
<td>2/3</td>
<td>&lt;1/2</td>
<td>0/15</td>
</tr>
<tr>
<td>N4</td>
<td>2/5</td>
<td>&lt;1/3</td>
<td>0/16</td>
</tr>
<tr>
<td>N5</td>
<td>4/4</td>
<td>1/3</td>
<td>6/2</td>
</tr>
<tr>
<td>N6</td>
<td>3/4</td>
<td>2/2</td>
<td>2/3</td>
</tr>
<tr>
<td>N7</td>
<td>2/4</td>
<td>1/2</td>
<td>6/1</td>
</tr>
<tr>
<td>N8</td>
<td>1/3</td>
<td>&lt;1/2</td>
<td>4/7</td>
</tr>
<tr>
<td><strong>N1 - N8</strong></td>
<td><strong>2.4 / 3.8</strong></td>
<td><strong>0.5 / 2.2</strong></td>
<td><strong>2.8/7</strong></td>
</tr>
<tr>
<td>SD</td>
<td>3/4</td>
<td>1/3</td>
<td>2/8</td>
</tr>
<tr>
<td>LA</td>
<td>2/4</td>
<td>&lt;1/3</td>
<td>1/26</td>
</tr>
<tr>
<td>BC</td>
<td>2/2</td>
<td>&lt;1/&lt;1</td>
<td>6/9</td>
</tr>
<tr>
<td>JA</td>
<td>1/1</td>
<td>&lt;1/1</td>
<td>0/9</td>
</tr>
<tr>
<td><strong>n = 12</strong></td>
<td><strong>2.2 / 3.4</strong></td>
<td>&lt;0.4 / 2.0</td>
<td><strong>2.3/9</strong></td>
</tr>
</tbody>
</table>
### Scale 1 - 5: Confidence, (Low - High)  Use, (0 - 5+ times/week)

<table>
<thead>
<tr>
<th>Participant</th>
<th>Confidence (Chem/Other science)</th>
<th>Use (Chem/Other)</th>
<th>No. Chem Course/ Years Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experienced Demonstrators, Trainers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>4/4</td>
<td>3/3</td>
<td>2/15</td>
</tr>
<tr>
<td>E2</td>
<td>5/5</td>
<td>3/-</td>
<td>7/11</td>
</tr>
<tr>
<td>E3</td>
<td>5/5</td>
<td>5/5</td>
<td>19/4+5</td>
</tr>
<tr>
<td>E4</td>
<td>5/5</td>
<td>&gt;5/&gt;5</td>
<td>&gt;18/22</td>
</tr>
<tr>
<td>E5</td>
<td>5/5</td>
<td>5/-</td>
<td>&gt;12/&gt;20</td>
</tr>
</tbody>
</table>

| E1 - E5             | 4.8/4.8                        | >4.2 / >4.3     | >11.6 / >15.4                   |
APPENDIX D
Letter to Novice Participants

Dear ________,

The staff of this summer's University of Maryland I.C.E. Demonstration Workshop is completing their final preparations for the NSF-sponsored program you and 23 other teachers from around the country will be attending. As part of the I.C.E. associate staff, I share with them the excitement of the upcoming events that are planned. I will be serving you in the chemistry labs where you will be given opportunities to practice and perform numerous chemical demonstrations.

In conjunction with the summer workshop, I will be conducting a special exploratory research project designed to assess science methods workshops. You are invited to participate by evaluating two videotaped chemical demonstrations in the beginning and end of the workshop. The videotape viewing will be done on a purely voluntary basis.

If you would be willing to view and comment on the two videotaped presentations of popular chemical demonstrations on Sunday any time after you have checked-in, simply return the enclosed response card. Sending the card in no way obligates you once you arrive. It will inform me, however, of participants' general intentions. If you decide to participate when you arrive, we would be most happy to accommodate you.

The videotape viewing will be held in a room adjacent to the lobby area of LaPlata Hall dormitory where you will be arriving. The staff members at the check-in table can direct you to the lobby area where you can view and comment on the videotaped demonstrations. Signs to direct you the videotape equipment room will also be posted. The videotaped demonstrations are each about five minutes long and the entire session lasts about 50 minutes. The viewing room will be conveniently set up on Sunday afternoon as well as Sunday evening, after the official check-in.
I hope you may find the occasion to participate in this optional viewing session and research study. I would also like to wish you safe travels on your way to the University of Maryland. The entire staff look forward to your arrival. We hope the workshop will be a most pleasant and highly rewarding experience for you.

Respectfully yours,

Chris Clermont
APPENDIX E

List of 50 Boxed Chemical Demonstrations
Set Up for the Workshop

<table>
<thead>
<tr>
<th>Concept</th>
<th>Demonstration, Demo #</th>
<th>Number of Subjects Practicing Boxed Demonstration During Workshop 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Air Pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balloon Inverted in a Flask</td>
<td>#2</td>
<td>12</td>
</tr>
<tr>
<td>The Collapsing Aluminum Can</td>
<td>#21</td>
<td>9</td>
</tr>
<tr>
<td>Egg into the Bottle</td>
<td>#38</td>
<td>(2)</td>
</tr>
<tr>
<td>2. Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density Bobbing</td>
<td>#31</td>
<td>9</td>
</tr>
<tr>
<td>Density Column</td>
<td>#32</td>
<td>4</td>
</tr>
<tr>
<td>Density: &quot;Sink or Swim&quot;</td>
<td>#35</td>
<td>11</td>
</tr>
<tr>
<td>Density: Not on the Level</td>
<td>#34</td>
<td>7</td>
</tr>
<tr>
<td>Mouth-to-Mouth Bottles</td>
<td>#57</td>
<td>2</td>
</tr>
<tr>
<td>Water Fountain</td>
<td>#83</td>
<td></td>
</tr>
<tr>
<td>3. Gases and Their Properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide - Three Activities</td>
<td>#8</td>
<td>4</td>
</tr>
<tr>
<td>Carbon Dioxide Rocket Launch</td>
<td>#11</td>
<td>9</td>
</tr>
<tr>
<td>Density Bobbing</td>
<td>#31</td>
<td>9</td>
</tr>
<tr>
<td>Mouth-to-Mouth Bottles</td>
<td>#57</td>
<td>7</td>
</tr>
<tr>
<td>Production of Hydrogen Via the Oxidation of Aluminum</td>
<td>#67</td>
<td>2</td>
</tr>
<tr>
<td>4. Acids and Bases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage Patch Detective</td>
<td>#7</td>
<td>8</td>
</tr>
<tr>
<td>Red Cabbage Juice as Acid Base Indicator</td>
<td>#72</td>
<td>5</td>
</tr>
<tr>
<td>Mouth-to-Mouth Bottles</td>
<td>#57</td>
<td>7</td>
</tr>
<tr>
<td>A Tornado Show</td>
<td>#80</td>
<td>1</td>
</tr>
<tr>
<td>5. Boiling Point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiling Water at Low Temperatures</td>
<td>#5</td>
<td>5</td>
</tr>
<tr>
<td>6. Capillary Action</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromatography and Capillary Action-Paper and Chalk</td>
<td>#17</td>
<td>12</td>
</tr>
</tbody>
</table>

1 Total number of workshop participants is 22, with about half being novices.
7. Catalysis

Blue Bottle #4
Rate of a Chemical Reaction #69
Oxidation of a Tartrate Salt #64

8. Chemical Reaction

Blue Bottle #4
Carbon Dioxide - Three Activities #8
Carbon Dioxide Rocket Launch #11
Change in Oder (Esters) #12
Changing Hard Water to Fire Water (Sterno) #13
Dehydration of Sugar #29
Density Bobbing #31
Egg into the Bottle #38
Endothermic Reaction Ba(OH) 8H O and NH Cl #40
Evidence for Chemical Reactions #41
An Experiment in Alchemy - "A Penny for Your Thoughts" #42
Production of Hydrogen Via the Oxidation of Aluminum #67
Rate of a Chemical Reaction #69
A Tornado Show #80
Lemonade or Grape Juice #52
Oxidation of a Tartrate Salt #64
Reaction of Zinc and Tidine #71

9. Chemical Substances

Carbohydrates:
Dehydration of Sugar #29

Carbon Dioxide:
Carbon Dioxide - Three Activities #8
Carbon Dioxide Rocket Launch #11

Esters:
Change in Oder (Esters) #12

Metals:
An Experiment in Alchemy - "A Penny for Your Thoughts" #42
Flame Test #44

Proteins:
Coagulation of Milk With Rennin #20

Polymers:
An Amazing Pin Cushion #1

Soaps:
Surface Tension, Waterproofing and Soap #77
10. Colloids
   Changing Hard Water to Fire Water (Sterno) #13
   Coagulation of Milk With Rennin #20

11. Color Changes
   Cabbage Patch Detective #7
   Red Cabbage Juice as Acid Base Indicator #72
   Flame Test #44
   Lemonade or Grape Juice #52
   Magic Signs #54

12. Combustion
   Cloud in a Jar #19
   Investigating the Burning Candle #50
   Non-burning Towel #58
   Ripple Your Chips

13. Complex Ion Formation
   Magic Signs #54

14. Condensation
   Cloud in a Jar #19

15. Crystals
   Crystallization from Supersaturated Solutions of Sodium Acetate #27

16. Dehydration
   Dehydration of Sugar #29

17. Discrepant Events
   An Amazing Pin Cushion #1
   Corn Starch Putty #24
   Mini-Tornado #55

18. Endothermic/Exothermic
   Endothermic Reaction Ba(OH)₂H₂O and NH₄Cl #40
   Dehydration of Sugar (Exothermic) #29
   Reaction of Zinc and Iodine (Exothermic) #71

19. Energy
   Changing Hard Water to Fire Water (Sterno) #13
   Dehydration of Sugar #29
Endothermic Reaction Ba(OH) \(_8\) H \(_2\) O and NH Cl \(#40\)
Non-burning Towel \(#58\) \(_10\)
Reaction of Zinc and Iodine \(#71\) \(_1\)
Investigating the Burning Candle \(#50\) \(_3\)

20. Heat/Kindling Temperature
Changing Hard Water to Fire Water (Sterno) \(#13\) \(_11\)
Dehydration of Sugar \(#29\) \(_5\)
Investigating the Burning Candle \(#50\) \(_3\)
The Paper Pot (Kindling Temperature) \(#65\) \(_5\)

21. Foods
Cabbage Patch Detective \(#7\) \(_5\)
Red Cabbage Juice as Acid Base Indicator \(#72\) \(_5\)
Coagulation of Milk With Rennin \(#20\) \(_10\)

22. Indicators
Cabbage Patch Detective, Red Cabbage Juice as Acid Base Indicator \(#7, 72\) \(_5\)
Changing Hard Water to Fire Water (Sterno) \(#13\) \(_11\)
Magic Signs \(#54\) \(_1\)
Mouth-to-Mouth Bottles \(#57\) \(_7\)
A Tornado Show \(#80\) \(_1\)

23. Kinetics & Reaction Rates
Blue Bottle \(#4\) \(_13\)
Coagulation of Milk With Rennin \(#20\) \(_10\)
Rate of a Chemical Reaction \(#69\) \(_1\)
Oxidation of a Tartrate Salt \(#64\) \(_2\)

24. Mixing and Mixtures
Chromatography and Capillary Action-Paper and Chalk \(#17\) \(_12\)
Density: Not on the Level" \(#34\) \(_11\)
A Tornado Show \(#80\) \(_1\)

25. Odors
Change in Oder (Esters) \(#12\) \(_5\)

26. Phase Change
Balloon Inverted in a Flask \(#2\) \(_12\)
Boiling Water at Low Temperatures \(#5\) \(_5\)
The Collapsing Aluminum Can \(#21\) \(_9\)
The Paper Pot \(#65\) \(_5\)
Which Will Evaporate First \(#85\) \(_3\)
27. Physical Properties and Physical Changes

An Amazing Pin Cushion #1 12
Boiling Water at Low Temperatures #5 5
Corn Starch Putty #24 13
Density Column #32 9
Density: Not on the Level" #34 11
Density: "Sink or Swim" #35 4
Egg into the Bottle #38 2
Flame Test #44 9
Mini-Tornado #55 9
Water Fountain #83 2
Which Will Evaporate First #85 3

28. Polarity

Surface Tension, Waterproofing and Soap #77 3

29. Reaction Mechanisms

Blue Bottle #4 13

30. Redox (Oxidation-Reduction Reactions)

Production of Hydrogen Via the Oxidation of Aluminum #67 2

31. Scientific Reasoning

An Amazing Pin Cushion #1 12

32. Separation Techniques

Chromatography and Capillary Action-Paper and Chalk #17 12

33. Solid State Reactions

Endothermic Reaction Ba(OH)₂ 8H₂O and NH₄Cl #40 5
Evidence for Chemical Reactions #41 5

34. Sublimation

Reaction of Zinc and Iodine #71 1

35. Solubility

Crystallization from Supersaturated Solutions of Sodium Acetate #27 6
Evidence for Chemical Reactions #41 5
Mouth-to-Mouth Bottles #57 7
36. Surface Tension

Surface Tension, Waterproofing and Soap #77

37. Suspensions **

Corn Starch Putty #24

38. Tornados

Mini-Tornado #55
A Tornado Show #80

39. Vacuum

Balloon Inverted in a Flask #2
The Collapsing Aluminum Can #21

Production of a Chemical Foam A-23
* Rate of a Chemical Reaction #69
* Oxidation of a Tartrate Salt #64
* Which Will Evaporate First #85
* Reaction of Zinc and Iodine #71
* Investigating the Burning Candle #50
* Water Fountain #83
* Lemonade or Grape Juice #52
* Flame Test #44
* An Experiment in Alchemy - "A Penny for Your Thoughts" #42
* The Paper Pot #65
* Evidence for Chemical Reactions #41
? Genie in a Bottle
* Endothermic Reaction Ba(OH)₂H₂O and NH₄Cl #40

* Density: "Sink or Swim" #35
* Density: Not on the Level" #34
* Ripple Your Chips
* Surface Tension, Waterproofing and Soap #77
* Density Column #32
* Dehydration of Sugar #29
* Density Bobbing #31
* Crystallization from Supersaturated Solutions of Sodium Acetate #27
* Corn Starch Putty #24
* The Collapsing Aluminum Can #21
* Coagulation of Milk With Rennin #20
* Cloud in a Jar #19
* Chromatography and Capillary Action-Paper and Chalk #17
* Carbon Dioxide Rocket Launch #11
* Change in Oder (Esters) #12
* Changing Hard Water to Fire Water (Sterno) #13
* Carbon Dioxide - Three Activities #8
* Cabbage Patch Detective, Red Cabbage Juice as Acid Base
| Indicator #7, 72 | 5 |
| Boiling Water at Low Temperatures #5 | 5 |
| Blue Bottle #4 | 13 |
| Balloon Inverted in a Flask #2 | 12 |
| An Amazing Pin Cushion #1 | 12 |
| Magic Signs #54 | 1 |
| Dehydration of sugar by Sulfuric Acid #29 | 7 |

Unnamed Demo 1 (Crushing Cans Reversibly, #25) | 3 |
Unnamed Demo 2 (The Water Exchange: An Equilibrium Model #32) | 2 |
Unnamed Demo 3 | 2 |
Unnamed Demo 4 | 6 |
Unnamed Demo 5 | 4 |

| Egg into the Bottle #38 | (2) |
| Non-burning Towel #58 | 10 |
| Mouth-to-Mouth Bottles #57 | 7 |
| Mini-Tornado #55 | (9) |
# APPENDIX F

## Two-Week Workshop Schedule

### WEEK 1/ICE WORKSHOP B/SESSION 2/JULY 13 - JULY 17

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00</td>
<td>&lt;-------- Breakfast (7:00 - 8:00)--------&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:30</td>
<td>Participant/Staff</td>
<td>What Makes an Effective Show with a Swap Shop</td>
<td>Cost, Time, &amp; Individual Other</td>
<td></td>
</tr>
<tr>
<td>9:00</td>
<td>Intros. and Demo?</td>
<td>Course</td>
<td>Theme</td>
<td>Videotape</td>
</tr>
<tr>
<td>9:30</td>
<td>Registrations</td>
<td>C-3219</td>
<td>C-3219</td>
<td>C-3219</td>
</tr>
<tr>
<td>10:00</td>
<td>Intro to</td>
<td>C-3219</td>
<td>C-3219</td>
<td>C-3219</td>
</tr>
<tr>
<td>10:30</td>
<td>Demonstrations</td>
<td>Demo Practice Camp</td>
<td>Demo Practice in Labs</td>
<td>Demo Practice in Labs</td>
</tr>
<tr>
<td>11:00</td>
<td>C-1208/1228</td>
<td>C-1208/1228</td>
<td>C-1208/1228</td>
<td>C-1208/1228</td>
</tr>
<tr>
<td>11:30</td>
<td>Expectations</td>
<td>C-3219</td>
<td>C-3219</td>
<td>C-3219</td>
</tr>
<tr>
<td>12:00</td>
<td>&lt;-------- Lunch (12:15 - 1:00)--------&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:40</td>
<td>Intro to Labs</td>
<td>Presenters</td>
<td>Public</td>
<td>Presenters</td>
</tr>
<tr>
<td>2:00</td>
<td>C-1208/1228</td>
<td>Gather supplies</td>
<td>Presentations of Assigned</td>
<td>Gather supplies</td>
</tr>
<tr>
<td>2:30</td>
<td>Demo Practice</td>
<td>Demonstrations</td>
<td>Monday Camp</td>
<td>Team Pilot</td>
</tr>
<tr>
<td>3:00</td>
<td>C-1208/1228</td>
<td>Presentations of Assigned</td>
<td>Their Demos</td>
<td>C-1402</td>
</tr>
<tr>
<td>3:30</td>
<td>C-1208/1228</td>
<td>12 participants</td>
<td>C-1402</td>
<td>C-1402</td>
</tr>
<tr>
<td>4:00</td>
<td>C-1402</td>
<td>Videotape (individually scheduled)</td>
<td>R. Perkins</td>
<td>Less Magic</td>
</tr>
<tr>
<td>4:30</td>
<td>Analysis</td>
<td>More Instruction</td>
<td>C-1402</td>
<td>C-1402</td>
</tr>
<tr>
<td>5:00</td>
<td>&lt;-------- Dinner (5:30 - 6:30)--------&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:00</td>
<td>Videotape</td>
<td>Chemistry Canl Guest Lecture</td>
<td>Analysis</td>
<td>Be Fun</td>
</tr>
<tr>
<td>7:30</td>
<td>(individually</td>
<td>B.Shakashiri</td>
<td>R. Perkins</td>
<td>(individually</td>
</tr>
<tr>
<td>8:00</td>
<td>Optional: Demo</td>
<td>C-1402</td>
<td>C-1402</td>
<td></td>
</tr>
<tr>
<td>8:30</td>
<td>Practice in Lab</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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INSTITUTE FOR CHEMICAL EDUCATION/FACULTY AND STAFF

Ann Benbow: Univ. of Maryland (Instructor/Chem Camp Director)
Mike Bellama: Univ. of Maryland (ICE Field Center Director)
Chris Clermont: Univ. of Maryland (Demonstration Assistant/Researcher)
Mary Hoy: Carroll Co. (MD) Schools (Instructor)
John Hudson: Montgomery Co. (MD) Schools (Instructor/Stockroom Contact)
Kathy Moser: Univ. of Maryland (Graduate Student Assistant)
Tom O'Brien: SUNY/Binghamton (Instructor/Program Director)
### WEEK 2 ICE WORKSHOP B/SESSION 2 JULY 20 – JULY 24

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00  I Breakfast (7:00 - 8:00) I --------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:30  I Humor in the Quickie, Cheap!</td>
<td>Split Session Quickie</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00  I Science Demos</td>
<td>Classroom Demos</td>
<td>C-3219 [Instructors]</td>
<td>C-3219 [Computer]</td>
<td></td>
</tr>
<tr>
<td>9:30  I Applications Midd/Secondary</td>
<td>Fri Camp Pilot/Ed Tech Center</td>
<td>C-3219 C-3219</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00 I Demo Practice or</td>
<td>Benjamin Bldg I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:30 I in Labs Demo Practice Library Time Demo Practice Cleanup</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11:00 I</td>
<td>Evaluation I &amp; Final</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:30 I Pilot Demos C-1208/1228 OPEN</td>
<td>C-1208/1228 Meeting C-3219 &amp; C-3219</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00 I Lunch (12:15 - 1:00) I Demo by Kids</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1:40 I Presenters gather supplies for Public Presentations</td>
<td>Public Presentations gathering supplies I Presenters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:00 I</td>
<td>Public Outreach I Demonstrations Public</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:30 I Public Presentations C-1402 Presentations</td>
<td></td>
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<tr>
<td>3:00 I</td>
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<tr>
<td>3:30 I C-1402 I</td>
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<tr>
<td>4:00 I Demos in the Dark (Instructors)</td>
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<tr>
<td>4:30 I</td>
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<tr>
<td>5:00 I</td>
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<tr>
<td>5:30 I Dinner (5:30 - 6:30) I</td>
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<tr>
<td>7:00 I Professional An ICE Demonstrators Outing/Dinner on Videotape Optional</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>8:00 I</td>
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<td></td>
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</tr>
<tr>
<td>8:30 I</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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APPENDIX G

Workshop Staff Presentations

Staff Presentation #1: Introduction to Chemical Demonstrations

This presentation introduced participants to the goals and purposes of the workshop. Several demonstrations were performed for the participants with discussions on the characteristics of effective demonstrations. A workshop handout summarizing these characteristics was provided (Appendix H).

Staff Presentation #2: What Makes an Effective Demo?

Workshop instructors further discussed the various types and purposes of chemical demonstrating, performed several inquiry-oriented demonstrations, and informed the participants of their expectations (summarized in a workshop handout, Appendix H).

The instructors informed and encouraged the workshop participants to present their public demonstrations in a manner similar to the investigative, inquiry approaches modeled for them. The term "investigative" came up frequently during the first staff presentation, the term "inquiry" was used once, as indicated by the following quotes.

Instructor: (The didactic mode of chemical demonstrating) is disastrous for two reasons. One, because it is not the least bit investigative ...

Instructor: In general, you want to use a more investigative approach with kids, with your demonstrations. And that is what we would like you to model in the ones (demonstrations) you do for us [publically]. Let the demo do the talking.

Instructor: Big ideas in science, we ought to teach in an inquiry mode.

The term "discovery approach" appeared in their first workshop handout (Appendix H, Section 3-B).

Staff Presentation #3: Demonstration Shows with a Theme

One of the workshop instructors shared an example of an Outreach Program with a theme (The "Hole" Theory of Matter). This presentation was followed by a discussion of points to consider in planning such a program. Participants were then assigned to work in small groups to prepare a written plan that included goals, target audience, and a list of demonstrations to be used for an assigned title/theme.
Participants were provided with tips on the management and logistics of delivering such outreach programs.

**Staff Presentation #4: Cost, Time, Safety, & Other "Limiting Reagents"**

Workshop instructors shared basic safety tips and resources with teachers. Demonstrated and discussed the feasibility of conducting effective demonstrations low-cost, readily available materials.

**Staff Presentation #5: Humor in the Science Classroom**

Participants received information on resources and ideas for integrating humor as a motivating instructional teaching strategy. Cartoons, puns, and AV examples were presented along with an extensive resource packet.

**Staff Presentation #6: Quickie, Cheap Demos**

Workshop instructors received guidelines and examples of demonstrations that could be done quickly (under 2 minutes) with students of various ages. Participants were provided with resources and ideas for performing Quickie demonstrations planned on the last day of the workshop.

**Staff Presentation #7: Computer Applications**

Participants were introduced to integrated software packages and their usefulness to teachers in managing student records and preparing lesson plans. An opportunity was also provided for teachers to "rummage" through an extensive software library housed at the University's Educational Technology Center.

**Staff Presentation #8: Split Session: Elem/Middle and Middle/Secondary**

*(History and Stories in Chemistry)*

Participants were provided with several amusing, historical anecdotes of "people and events in chemistry" that could be integrated into science teaching, in general, and demonstrations in particular. An extensive resource packet was provided to help guide teachers to useful texts and materials on the history of chemistry.
APPENDIX H

Expectations for Participants

INSTITUTE FOR CHEMICAL EDUCATION
WORKSHOP B/SESSION 2
UNIVERSITY OF MARYLAND - SUMMER 1987

EXPECTATIONS FOR PARTICIPANTS

Each participant is expected to:

1. Be present and active at all scheduled training sessions.

2. Perform a pre-Assigned Demonstration from the ICE Guidebook in front of your peers on the second or third day of the workshop. (See the Presentation Schedule for your time).
   a. The demonstration will be presented within a 5 minute time period with an additional 5 minutes for group discussion and instructors' comments.
   b. As part of the pre-demonstration setup, the participant should state his/her name, the demonstration title (and number), and the grade level at which it is being presented. Subsequent verbal interaction should be geared to this target audience.
   c. Presentations should aim to be interactive, participatory, and investigative. Accurate, concise, grade level appropriate explanations should evolve as part of the presentation. As much as possible, "Let the demonstration do the talking" - ask more, tell less. See the Demonstration Analysis Form and accompanying handout for specific points to consider.
   d. Presentations may include variations that increase the utility and applicability of the demonstration, but if they differ significantly from that described in the ICE Guidebook (other than shortening a demonstration series), they should be approved by one of the instructors.

Note: This demonstration, and all subsequent public presentations will be videotaped for later individual and instructor provided analysis. The intent is to provide both positive support and critical feedback to assist each individual presenter to a higher level of performance competency and conceptual understanding. All participants are expected to attend an individually scheduled evening videotape analysis session for this first public demonstration. Subsequent analysis sessions for other presentations will be optional.

3. Perform as many of the boxed demonstrations from the ICE Guidebook as possible given that for each demonstration you perform you should:
   a. Mark the Demonstration Log in each box to indicate you have completed it and can serve as a possible resource person
for others. A key ingredient to the anticipated success of the workshop is the willingness of participants to share their experience and knowledge with others.

b. Keep a written, personal record that includes:
   (1) several critical pre- and post-demo questions you would ask your class or audience
   (2) real-life applications or examples of the principle/concept being demonstrated
   (3) additional variations (optional)
   (4) suggestions for improvement (if these are necessary or highly desirable, please also leave a brief note in the boxed demonstration).

4. Work with your assigned team to develop a 30 minute Demonstration Program for the 5-8th grade youngsters attending the Chem Camp which runs concurrently with the teacher workshop during the mornings of the second week. A typed handout that describes at-home extensions, real-world applications, related questions or puzzles, etc., should also be prepared for distribution to the youngsters (these should be approved for use by the instructors one day prior to the actual program). As a trial run, each team will present their show to the other workshop participants for practice and critical analysis. (An overhead transparency should describe the theme and sequence of demonstrations.) Each team member should be actively involved in presenting at least one demonstration and each demonstration should be tied to a common group theme (this theme may or may not be tied to the laboratory activity that the students will be performing earlier the same day). OPTIONS:
   a. One or two members of the team may elect to assist the Chem Camp Director in monitoring the laboratory activity performed earlier in the morning by the youngsters. This would involve some pre-coordination with the Chem Camp Director and if desired, individuals who chose this option could elect to simply introduce the post-lab demonstration show for their team.
   b. While we strongly encourage/prefer you to choose from among the pre-boxed ICE demonstrations, demonstrations can be selected from other sources. If any demonstrations chosen are not from the ICE Guidebook, a Demonstration Approval Form must be turned in at least 24 hours before the anticipated practice trial run to allow time to assemble the necessary supplies and provide a quality check.

5. The Second Demonstration performed in public can be chosen from either pre-boxed ICE Guidebook demonstrations (if previously performed by another participant, a new variation/twist/grade level must be used), your own "favorite" demonstration you brought with you, or from other available demonstration sourcebooks. Again, if the demonstration setup is not already boxed, a Demonstration Approval Form must be turned in at least 24 hours before the anticipated trial run to allow time to assemble the necessary supplies (when possible.
participants are encouraged to gather their own household-type supplies) and to provide a quality check. Once approved, a formal writeup that matches the ICE guidebook style is required (in the case of a demonstration from the ICE Guidebook, a critical review will take the place of a formal writeup). You will be allotted 10 minutes to perform the demonstration with 5 minutes for group discussion and analysis. The final draft of the writeup will be due on Thursday morning, July 23 so that copies can be xeroxed for all workshop participants.

6. Develop and submit by Wednesday, July 22, an outline for a 1-hour Outreach Program to be carried out in one’s home district.

   a. Include: general theme, intended audience, goals, and the sequence of activities and demonstrations including titles and source citations (summarize this on an overhead transparency).

   b. One of these Outreach Program Demonstrations, (if the demonstration chosen has been previously performed by another participant, a new variation/twist/grade level must be used) will be presented on the Wednesday or Thursday afternoon of the second week. You will be allowed 10 minutes for presentation with 5 minutes for group discussion and analysis. (Note the previous comment about the Demonstration Approval Form if "new" demonstrations are used).

7. Present a "Quickie," attention grabbing Demonstration (less than 5 minute) on the last morning of the workshop which utilizes readily available chemicals and equipment that you were able to obtain from "garbage," grocery stores, etc. A brief (one-half to one page) writeup should be turned into an instructor by Thursday morning, July 23.

8. Help the ICE staff check the conditions of the pre-boxed demonstrations and complete evaluation materials before leaving the workshop to return home.

FRANK & ERNEST BOB THAVES

AH, THERE YOU ARE, WIMBLE --- I WANT YOU TO READ THIS PROPOSAL AND TELL ME IT'S A GREAT IDEA.

FRANK THAYES

302
DEMONSTRATIONS:
AN INTERACTIVE INSTRUCTIONAL STRATEGY FOR THE SCIENCE CLASSROOM

I Demonstrations - A Part of Science and A Part of Learning

The dictionary defines the word demonstrate as to manifest or reveal - to display, operate, and explain. In science instruction this occurs when the teacher manipulates models, chemicals, apparatus, etc in such a way as to introduce, illustrate, or challenge students' understanding of an important concept by engaging their ability to observe, question, and reason. This process is of course, the essence of science - science is not just a highly organized body of unalterable facts and theories to be memorized; it is also a method of inquiry, and a way of looking at the world.

In addition to reflecting the nature of the scientific enterprise, using demonstrations as an instructional strategy reflects what common sense and educational research tell us about the process of learning. Learning is an active process - the learner's mind must be engaged to operate on and transform sensory data into concepts and models within his/her own particular mental framework - knowledge can not be poured out (or injected under pressure) from the teacher's mind into the learner's. For learners who are still at a concrete operational stage with respect to science concepts (which includes most high school students according to a number of Piagetian type studies), words alone are not an adequate sensory experience to promote reasoning and understanding. Thus, if one's objective as a teacher is to promote more than "regurgitation" type learning, it is essential that you provide opportunities for your students to "see" science in action.

II Demonstrations vs Laboratory Experiments:

Not a Question of Either/Or, But Rather When

The Chinese proverb "A picture is worth a thousand words" is logically extended to another Chinese proverb: "I hear & I forget - I see & I remember - I do & I understand." Clearly, laboratory experiences should be an important part of science classes. Given this belief, why not just have student laboratory experiences and forget about demonstrations? Beyond the obvious fact that reliance on any single "right" instructional strategy is educationally unsound, demonstrations can open up new possibilities not available through direct student laboratory experiments.

Practical considerations such as safety, availability and/or expense of equipment/supplies, and time limit both the number and type of experiments students can perform within a given class. Also, teacher demonstrations provide an environment where:
(a) student ideas/hypotheses can be immediately tested (given advance planning & teacher understanding of possible safety threats) - most laboratory experiments are designed to carefully "limit" (or even eliminate) action on independent ideas,
(b) students can be taught "how to" observe, formulate questions, and reason about science, and (c) the teacher can demonstrate his/her love of and enthusiasm for science. Thus, demonstrations can complement and extend more direct laboratory experiences and provide a rich sensory data base for students to operate on in order to learn scientific concepts and principles.
III Presenting Effective Demonstrations

A Pre-Demonstration Planning

As with other instructional strategies, careful planning increases both the probability and potential degree of success. Several factors should be considered:

1. What is the purpose of the demonstration? What concept is it designed to illustrate? Would a laboratory experiment be preferable? Demonstrations should be timely—consider whether it is best to use the demonstration to introduce a new concept, illustrate a previously discussed concept, challenge a misconception, or to model good technique. They should also be appropriate to the abilities of the students and the conceptual level of understanding desired.

2. Given constraints of materials at hand and the specific "audience," what design would be most effective? In general, avoid the elaborate and nonessential "don't get out a cannon to shoot a fly." Extraneous equipment may cause students to "miss the forest for the trees." Also, the use of clearly marked household chemicals and/or "equipment" helps students to realize that science can be found everywhere and not just in test tubes and beakers.

3. While not all demonstrations need be spectacular, they should be "attention grabbers"—given certain student misconceptions, discrepant event type designs can be particularly effective. In addition to surprise, a bit of preplanned showmanship and humor can be powerful strategies.

4. What step(s) of the demonstration procedure should be carried out ahead of time? Minimally, reagents and apparatus should be prepared, labeled, and conveniently arranged to avoid wasting valuable class time. Also, if any steps in the demonstration are excessively long and not pertinent to the actual concept to be demonstrated, carry out these steps ahead of time. Be sure to, always pretest the demonstration for its pedagogical value, safety, visibility, etc.,—"prior practice prevents poor presentation."

5. What questions/practical applications will be appropriate to motivate and direct student observation and thought processes? What potential questions or experimental variations are students likely to pose?

6. If appropriate, a data collection table may be prepared for the blackboard or an overhead projector.

7. If available, consider delegating some of the preplanning responsibility to assistants? Also, consider how "volunteers from the audience" might be used as assistants during the demonstration itself.
B Presentation
Although the demonstrator should allow his/her natural personality to come out in the manner of the presentation (Be yourself - but try to be your best self!), there are some "rules" which are generally applicable:

1. Clear the demonstration table of clutter that presents a safety and/or visibility problem.

2. Provide a short, general introduction that connects the demonstration to previous discussion and helps to focus student attention, but "let nature do your talking for you" - "show, don't tell" - adopt a "let's see what happens" or discovery approach. If appropriate, ask students to predict the results but avoid forecasting the expected results yourself.

3. As you perform the demonstration check with your audience to be sure that they can see, hear, smell, etc., the phenomenon. Do not attempt to provide a lot of scientific verbiage at the time of the demonstration - allow sufficient time for the full sensory impact to be felt before eliciting student response. Encourage students to make careful observations of the system - you may wish to appoint a class "reporter" to record the results for subsequent discussion.

4. Ask probing questions and encourage similar questions from your students. If unsure, do not attempt to hide your lack of knowledge but do attempt to display scientific reasoning.

5. If the demonstration requires the use of special safety precautions, follow these precautions and warn your students not to attempt to duplicate your actions.

6. If the demonstration does not work out as planned, remember that "experiments never fail" - you may wish to invite your students to explain what did occur and/or consider this yourself and attempt to repeat the demonstration altering a perceived flaw. If after a second attempt, "success" is not achieved, avoid "desperate" attempts to salvage the "failure," be honest with your students.

IV Post Demonstration
After the students have experienced the phenomenon and been guided to an understanding of the corresponding concept, additional vocabulary, mathematical relationships, and activities/exercises may be appropriate to help ensure understanding and long-term retention. Also, if toxic chemicals are involved, these should be properly disposed of at this time.
APPENDIX I
Clinical Interview Guide

Method #1: Critical-Stop Method

Key:
I: = Interviewer comments
I #: = Interviewer questions
S: = Subject Response

A. Instructions to Subjects

1. Introduction

I: I would like to begin by briefly orienting you to this session. This session is being conducted in conjunction with the summer institute sponsored by ICE (the Institute for Chemical Education) as part of a PROGRAM assessment. We appreciate your voluntary participation.

During this session you will have the opportunity to examine two popular chemical demonstrations conducted by teachers in a simulated classroom setting. Based on your knowledge of science and science teaching you will be asked to comment on the effectiveness of the presentation. Your responses will be kept confidential and anonymous.

Before we proceed any further, we would like to know if we have your permission to audiotape your comments regarding the videotaped presentations?

S: (Response)
I: Thank you.

2. Warm-up question

I 1. Have you ever examined your own or someone else’s teaching on videotape? What setting was that in?

(If so): I see. So this won’t be anything new.

(If not): Well, then this will be a new experience for you!

3. General Instructions

I: Let me now provide you with some general instructions. There are two short videotaped demonstrations you will observe. The teachers who have been videotaped have agreed to let their
demonstration receive analysis during this workshop. You will have a chance to view each demonstration twice.

After viewing the first demonstration, I will rewind the tape so you can view it again. During the second viewing you will be asked to stop the videorecorder at critical points during the demonstration every time you notice a strength or weakness in the presentation. After you have stopped the tape, comment on the particular strength or weakness you noticed in the presentation and explain why you thought it contributed or hindered to effective teaching. After you’ve made all your critical stops, I will ask you a few follow-up questions. The entire session involves two different tapes and will take about 45-50 minutes.

B. Specific Instructions for Demo #3/#4 (Density):

1. Introduction

I: Let’s begin with the first demonstration which deals with a chemical concept covered in many physical science classes. This demonstration will run for about seven minutes. You can assume that the presentation represents an introductory lesson for middle school students.

In this first tape you’ll notice the teacher has a slight regional accent and at one point will very briefly slip out of the view of the screen. When he is not in view, just concentrate on what he is saying. Remember, during the first viewing you will simply watch the tape. After you have viewed the tape, I will rewind it and then show you how you can stop the videorecorder so that you can comment on all the critical points in the presentation. Are you ready to view the first tape?

S: (Response)
I: O.K., here it is!

I: (Once completed) Thank you!

Interviewer rewinds tape for subject.

2. Queries while rewinding videotape

I 2. Have you ever seen this demo before?
   Have you ever seen this principle demonstrated before?

I 3. Have you ever performed this demo before?
3. Critical Stop

The idea, once again, is to stop the tape at every critical point in which you notice one or several strengths or weaknesses in the presentation. You can stop the tape by pushing the PAUSE button here and then make your comments. You can resume the tape by pressing the PAUSE button a second time. Do you have any questions concerning this procedure?

S: (Response)
I: Remember to assume that the presentation is geared to middle school students. Go ahead and proceed. (I starts tape for S).

4. Follow-up Interview

I: Thank you. I'd like to continue with a few follow-up questions.

Then proceed with Interview Questions I 4 - I 10, below.

C. Specific Instructions for Demo #1 & 2 (Air Pressure):

I: The second demonstration presentation will take about seven/four minutes. We will follow the same procedure as we did with the first. We'll watch it through once, then, during the second viewing you will stop the tape at critical points whenever you observe a strength or weakness in the presentation. Assume this lesson is part of an introduction to a middle school science lesson. Are you ready?

S: (Response)
I: O.K., go ahead!

I: (Once completed) Thank you!

Then proceed with Interview Questions I 4 - I 10, below.
Method #2: Semi-Structured Interview

Key:

I #. = Interviewer questions

A. Instructions to Subjects

After the critical stop method has been completed, the Interviewer will proceed with the following questions:

1. Pedagogical Queries:

I 4. Are there any other specific strong or weak points in the presentation you haven't already mentioned? What are they?

Anything else?

I 5. So, how would you summarize the major strengths of the presentation?

How would you summarize the major weaknesses of the presentation?

I 6. What would be your overall reaction to the performance if you had to evaluate it on a scale of 1 to 5, with 1 being terrible, 2 poor, 3 fair, 4 good, and 5 excellent? (Show card with scale).

I 7. What do you think was the intended lesson objective?

I 8. Do you know of any variation, twist, or extension of this particular demonstration that could be performed? What would it be?

Any other variation or twist on this particular demonstration that could be performed?

Any other?
9. Do you know of any other demonstration that, Demo (A): shows the effects of air pressure, Demo (B): shows the concept of density? What would it be? Any other demonstrations? Any others?

2. Conceptual Queries

10. Air Pressure Demo: Please explain, step-by-step, the physical principles that are involved in this demonstration? Do you know what is happening at the molecular level in this demonstration? Density Demo: What principles of density can be drawn from this demonstration? At the molecular level, do you know what influences the density of a substance? Anything else?

I: Thank you for your participation in this program assessment.
APPENDIX J

Scripts for Videotapes #1 - #4

Key:

D = Demonstrator
A = Audience
# = Statement Number

Videotape # 1:  Air Pressure (Favorable Model, +)

(7 minutes)

Scripts:

D stands behind demonstration table with following information on board: Can Man Can Demo

D states:

1 "Actually, what I'm going to do today is try to answer or at least attempt to answer two questions. Now the first question I want to answer is,

D walks to blackboard to uncover question.

3 'Can a Real Man crush an aluminum can'?; I call this the Can Man Can lab".

4 "Before we got here this afternoon, I took a survey among all the people in the class to see who the only Real Man was, and guess what? Ed, you came in as the unanimous choice. Would you come on down please?"

7 A: "Ed, Ed, he's our man, if he can't do it nobody can!"
A: (Laughter from class).

9 "Ed, this is an aluminum can. Nothing fancy about it. Just a regular aluminum can. Could you crush that for me?"

Student thoroughly crushes can with his hands.

13 A: Incident generates class laughter and approval.

14 "What force did you use to crush that can? What forces are responsible for crushing that can?"

16 A: "The muscles in my wrist and hand."
"Do you think that there was possibly a force resisting your hand?"

A: "Possibly the tensile strength of the can."

"Could there have been anything else?"

A: "Uh, air pressure perhaps, but I think that it would be equal on the inside and the outside."

"So your saying that air itself or the fact that the can was filled with air, might be exerting some pressure against your hand?"

A: "Air can exert a pressure, yes."

"O.K., let's see. Thank you, Ed. Let's give Ed a big hand. A big hand for a Real Man!"

D walks to blackboard and uncovers second question.

"The second part of the demonstration involves the second question right here. That's assuming of course we had a Real Man in the first place. 'Can the air crush an aluminum can?'"

"And to help answer that question possibly, I've taken an aluminum can here that I have water in. It's partially filled up with water. And I'm going to heat the can. Can somebody possibly describe for us what's happening inside the can while it's being heated?"

A: "Water's evaporating."

"Could that cause some other changes inside the can?"

A: "The air is warming up."

"O.K."

A: "Air is pushed out."

"Excuse me."

A: "Air is being pushed out by the steam inside there, by the water vapor inside."

"Is there pressure on the outside pushing back in possibly, also?"

A: "Yes."

A: "But they're not equal anymore. Air's coming up or the water vapor's coming up and pushing the air out."

A: "But they are equal now."
"Is there any evidence to support that?"

A: "They look equal to me. The can is not changing shape, so they look equal to me."

"O.K. that's a good observation. Right now the water inside is boiling. I can feel it boiling and perhaps you can hear it boiling, and in just a second or two possibly we'll see some vapors forming there. They are beginning to form on the outside. So what I'm going to do is to take the can, with the boiling water inside and invert it in this container of water over here."

D grabs container and inverts it into a pool of cool water. One hears a loud POP! D lifts can out of water bath.

"And as a result of this you can say that the can itself was crushed. Now we agree unanimously, first of all, that Ed is a Real Man, and we agree too that Ed was able to crush the can with the force of his tremendous musculature that crushed the can. Well, what force then could possibly be responsible for crushing the can in the second demonstration?"

A: "Were you squeezing on the tongs?"

"No mam."

A: "The air pressure."

"Air pressure? Are you saying then that the pressure was greater outside after I heated the can as opposed to before?"

A: "It was greater after you put the can in the water."

"That the weight of the air, the pressure of the air in the room was greater after I put it in the water?"

A: "No."

A: "There was no opposing pressure."

A: "The differential was greater."

"Hum. I'm impressed!"

"Let's look at the problem from a little bit different standpoint. Same situation: aluminum can, I'm going to heat it up over the flame, except this time, instead of having a tiny bit of water inside the can, this can is empty, essentially. Now somebody make some predictions as to what they might think now that the can only contains air."

A: "It's still going to crush."

A: "I see a lot of steam coming out."
"That's because I'm burning the can. You say you think it's still going to be crushed, due to the change in pressure, the pressure inside this?"

D inverts second can into pool of water which is followed by a sizzling sound. D then pulls it out of the water and then right back in.

"O.K., essentially, no crushing at all in that case, maybe a little bit along the exterior there where I overheated it, but in this particular case, the can more or less remained intact. Why the difference? Why the collapsing can in the second part of the demonstration where we had water in it and not so in the third part? Can any one explain that?"

A: "Density of the steam in the first can could have taken up less space."

"And the last one?"

A: "The air..."
A: "There probably is some difference in air pressure but maybe not enough in this case."

"Do you agree then that the air outside both of the cans, or the pressure or weight of the air outside both of them was the same in both cases?"

A: "Yes."

"So what was the principle difference then in these two?"

A: "As the steam condensed it left behind a partial vacuum inside the can that contained water."
A: "In the other one you weren't able to drive out all the air."
A: "You didn't change the state of the air either, you just cooled it, the air down, but didn't change the state."

"O.K. so what we agree then, certainly on the first one, that Ed is a real man and could crush the can. And we can agree that it was the air that crushed the can the second time."

A: "I think you should do it again with..."
Videotape #2: Collapsing Aluminum Can  (Unfavorable Model, -)  
(3.5 minutes)  

Script:

D stands behind demonstration table and states:

1 "We're on this planet earth and, of course, we live on the surface of the earth. And living on the surface of the earth we're at the bottom of this ocean of air. Being at the bottom of this ocean of air, therefore, we must be receiving the total pressure of this atmosphere."

4 "Now we have instruments that measure this. There are instruments such as the barometer, OK. And an alternative to the barometer would be an altimeter which is used in airplanes which utilize the atmospheric pressure."

7 "And so there's atmospheric pressure. You deal with this and yet I can't feel it. I don't feel any pressure on me at the moment. Certainly, if this pressure is coming on me ..."

D places hands on shoulders.

11 "... well why aren't I being crushed? And well, let's see what would happen. Is there air pressure on this can?"

D picks up can and holds it in hand.

13 "You know - the can appears to be in pretty good shape. And well, what would happen if we eliminated the pressure inside the can? Well, why don't we take a look?"

D ignites Bunsen burner.

16 "O.K., I'm going to heat this can for a few minutes and while we're heating it - if anyone happens to notice - there's a little bit of water in the bottom of this can. And if any of you happen to see steam, please let me know."

D picks up tongs, holds it in hand, and continues to talk.

18 "O.K., at this point - of course, what's happening? OK, what's happening to the air inside this can, for example? It should be something obvious."

21 A: "It's getting warmer."
"OK, this air is going to get hotter. Then we're going to cool this air very, very rapidly in this small pool of ice water that I have here."

D grabs can with tongs and holds it secure.

"I'm going to take this can and of course since the air inside the can is hot, so is the can, I have to use tongs. I am going to take this and..."

D inverts can into tub of water. You hear a sudden popping noise. D turns off Bunsen Burner.

"OK, it doesn't take any genius to see what happened, but I'll ask anyway."

D grabs can with hand and displays it.

"What happened anyway?"

A: "The can collapsed" (Multiple response)

"All right. Any guesses as to why?"

A: "Air pressure on the outside of the can was greater."

""

"Air pressure on the outside, O.K. Greater than what?"

A: "Air pressure on the inside."

"Air pressure on the inside of the can. O.K., well how did this occur? What causes air pressure on the inside to suddenly be decreased?"

A: "I have a question. If it's just air pressure in there why is it filled with water? Why put water there in the first place?"

"The um - the water, O.K., caused steam. What did the steam do? It forced the air out. And as the air was put out, what happened when we started to cool?"

The steam inside condensed. Now you suddenly have a vacuum which would decrease the air pressure. Any other questions?"

("OK, I think I'm going to end at this point. You would then proceed into a lesson about the atmosphere, and so forth.")
Script:

D stands before class and states:

1. "We have two ideas or concepts that we’d like to talk about today. One of those concepts involves density. And from your previous experience with density, I’d like to find out what you know about density and then perhaps we can build upon that."

D walks around front desk to the blackboard and writes the word "Density".

4. "OK, could I get a volunteer to tell me something that they know about density?

D recognizes a student and says,

5. "Yes."

6. A: "Density is how much a given volume of something weighs."

7. (Slight pause, then) "All right."

D recognizes another student and says,

8. "Yes, Dee."


10. "Mass per unit volume. (Slight pause). O.K. I can’t argue with that. I think the textbook would agree with that type of a definition."

D puts formula on board: ‘Density = mass/volume’.

14. "And perhaps mass per unit volume is a little bit difficult to conceptualize."

D reaches for graduated cylinder and displays it to the class.

15. "I have one little demo here, and I’m not going to tell you what the contents of this cylinder are, but I’ll show you what I have and I’d like you to make careful observations. I’ll give you a hint that this cylinder has something to do with density.

17. From your observations, what kind of observations can you make involving this cylinder? Perhaps if I hold something white behind it."

D holds white paper behind 100-mL cylinder.
A: "It’s darker at the bottom."
A: "It has three shades in it."
A: "It has four substances."
(Other simultaneous responses)

"O.K. Boy, I’m getting all kinds of good observations here very rapidly. I think I’d like a secretary to keep track.

Dee, would you help me and perhaps put some of these things on the board for me please. O.K., let’s start over again. Let’s start over here to my right."

A: "I said it’s darker on the bottom."

"It’s darker on the bottom. All right."

A: "There’s an object at the bottom."

"I beg your pardon."

A: "There’s an object on the bottom."

"There is an object in the bottom. (Slight pause) O.K."

A: "Three colors. There would be three distinct colors ranges there."

"Three distinct colors." (Slight pause). "Let’s slow down so Dee can catch up with us." (Silence for 22 seconds as secretary records).

"O.K. Any other observations that we could add to the three that are up there?"

A: "The interface between the bottom layer and the middle layer is not as clearly defined as between the middle layer and the top layer."

(Some students begin to converse with each other.)

O.K. (Slight pause). My hand’s covering the top. How about if I move it to the bottom.

A: (Choral response form class) "Ohhh! Ahhh!"

"I was disguising part of it! Sorry about that." (Slight pause) "O.K. From your knowledge of density perhaps, where do you think the material is that’s most dense; at the top or at the bottom?"

A: "At the bottom (choral response). "

"At the bottom."

"O.K., you indicated that...; what form of matter is the object at the bottom? What form of matter does it appear to be?"

A: "Solid."
"And indeed it is a solid form. I’ll shake this a little bit so you can tell. Can you tell above the solid object, can you tell whether we’re dealing with solid, liquid, or gas above it?

A: "Looks like a liquid."
A: "Liquid." (Multiple response).

"And indeed you’re right. It is liquid. In fact, if I were to be really honest with you there are actually three liquids above the solid. And one of the students in class told us that there’s an interface, a separation layer, apparently here as well as here.

We actually have one liquid here, a second liquid here, and a third liquid on top. Each of the liquids having a different density. Do you have any guesses as to what the liquids might possibly be?"

A: "Looks like oil."
A: "Top one looks like oil." (Plus other simultaneous responses).

"And what sort of experience have you had that might tell you that oil would be less dense?"

A: "It don’t mix."
A: "It doesn’t mix with oil."

A: "Like in salad dressing; you shake it, it doesn’t mix."

"All right."

A: "And the oil floats to the top."

"All right. Have you ever had the experience of going out in a boat with an outboard motor and either filling or refilling or watching someone fill the engine with gasoline and the gasoline run off the engine into the water? Would you say gasoline mixes with water?"

A: "No; uh uh". (Choral response).

"No. It sits on top. And part of the reason for that is the difference in densities. Oil, like gasoline has a density less than that of water. There is actually water in this container. [Liquid?] down here is colored. O.K., and I did that on purpose, and I added a dye called phenolphthalein, O.K.

D picks up cylinder.

And we won’t worry about what phenolphthalein is used for right now. But there’s actually water in this portion.

The middle layer is methyl alcohol. It turns out that phenolphthalein is actually, it’s more soluble in water.
than it is in the alcohol. And as you can see there's no pink
coloration in the glass [ ]. Apparently, phenolphthalein
is not soluble in oil."

"What's on the bottom? Chalk."

"Basically what I wanted you to see is that each form of matter
has - we could generalize a little bit about densities.
Solids generally are more dense than liquids. Not all liquids
have the same density.

Uhh, then the question is - this is something we really deal
with, something we can really see when we use liquids and solids.
The problem we're going to deal with today involves, is densities
of gases. The problem that we have with gases is that they're
very difficult to see. So I wanted to start out with something
that was visible."

"Now there is a second idea that we're going to deal with
involving these gases..."
Script:

D stands behind demonstration table with following information on board:

D states:

1 "O.K., today's lesson is on density. Can anybody tell me what density means? Do you remember hearing that term before?"

4 A: "How heavy something is for its size."

5 "O.K., that's very good. The density means how heavy it is for its size, the way Jean put it. Or the way that a scientist would say, it has to do with its mass, which is related to its heaviness. We think in terms of weight, but as you remember the long discussion we had before about the difference between the weight and the mass. So the scientist uses the more technical term - the mass per unit volume, meaning that for a given volume, it's the amount of weight that that volume will have is the density. So given the set of units ...

D proceeds to write out the definition of density on the board. that the, 'Density is the mass per unit volume'."

11 "What units do we usually talk about - do the scientists usually use for mass?"

12 A: "Grams."

13 "Grams, O.K. And volume, you remember we talked about several different ways of telling about the volume. The scientist often will use the milliliter, but they also use something called a cubic centimeter, meaning they take a centimeter, I mean a cube, that's one centimeter in each direction. That's a cubic centimeter. So the density would be how much, how many grams does one cubic centimeter of a substance weigh. Water, each substance has a characteristic density, meaning that each one will weigh a certain amount given the same conditions, no matter whether you take that cubic centimeter of water here, or one cubic centimeter over in Europe, it's still going to have the same density. O.K., so water, the characteristic density of water is...

D writes density of water on board.
one gram per cubic centimeter. So if you have one cubic centimeter of water, it’s going to weigh one gram. Rubber, on the other hand, has a density of 1.2 grams per cubic centimeter (written on board). So that means if you have the same size of a cube, it’s going to weigh 1.2 grams. So which one would you say has the higher density?"

A: "Rubber."
A: "Yeh, it looks like the rubber."

"Rubber, O.K. It has the larger density. So what does that mean? What does that mean that it has the larger density? We’ll find out in a minute."

"O.K., alcohol has a density of .8 grams per centimeter - cubic centimeters. So alcohol has a greater or less density than water?"

A: "Less."

"Less, a smaller density. So what happens - what would happen if I put a piece of rubber in water? What will happen to that rubber - to that piece of rubber?"

A: "Would it sink?"

"Yeh, that’s very good. And why would it sink? The rubber would sink in the water, why would it sink?"

A: "It has a higher density."
A: "It’s more dense."

"It’s more dense. O.K., so that the weight of that piece of rubber, that small piece of rubber is heavier than water so it will go down through the water. O.K. what will happen if you put the rubber in alcohol?"

A: "It will still sink."

"It will still sink because it’s denser. O.K., I have a number of substances here. Let’s see what happens. This is the water. I put a little yellow food coloring in it, just so you can see it better. And I’ll take the rubber cork and drop it in, and what did we say would happen?"

A: "It will sink."

"It will sink."

D drops rubber cork into beaker of water.

"Tah dah, sure enough, it does. O.K., now I’m going to pour this water in the cylinder - graduated cylinder. And I have another
substance. This is called Caro corn syrup. And again, I put
food coloring in so you can see it. This you can just buy in the
grocery store. Folks use it for cooking and in the kitchen. Now
if I pour this in here, what’s going to happen?"

A: "Well, if it’s denser, it will sink to the bottom. If
it’s lighter, it will float."

D pours Caro corn syrup into graduated cylinder.

"Very good. And what did it do, Jean?"

A: "It sank to the bottom."

"So what does that mean?"

A: "It must be denser than the water."

"O.K., so the corn syrup is denser than the water. The water’s
on top, the corn syrup is underneath. "O.K., and I also have
some mineral oil. And this is just colorless.

D adds another liquid, (mineral oil).

"Ooh. So what happened?"

A: "The corn syrup is on top."

"The corn syrup’s on top. So that means - is it more or less
dense than the corn syrup - the mineral oil?"

A: "It’s gotta be less."

"It’s gotta be less."

"Why’s that?"

A: "It probably has a density less than one.

"Less than one?"

A: "Less than water."

"O.K. water has a density of one; it’s floating on top of the
water. What about the - how do we know that it’s lighter than
this?"

A: "Because that’s lighter than the water."

"O.K. so this is the heaviest and this is less dense than the
corn syrup, and this is less than the water so therefore this
must be less dense than that. O.K. here I have some alcohol. And I again, I put blue food coloring in it just so you can see it better."

D transfers alcohol to cylinder.

"So now we have corn syrup, water, mineral oil, and alcohol. O.K., now, what about a penny? Do you think a penny is heavier than water?"

A: "Yeah."

"You think it’s heavier than water? Do you think it’s heavier than corn syrup? Let’s drop it and see."

D drops penny into cylinder.

"Oops, all the way to the bottom. It’s sitting on the bottom now. You saw it fall, didn’t you see it fall? Anybody want to come up and verify it you may. O.K., what about rubber? What do we know about rubber?"

D holds up rubber stopper.

A: "It should go below the water."

"It should go below the water? Do you think it will go all the way to the bottom like the penny? Do you think it’s as dense as the penny?"

A: "Uh-Uh."

"You don’t think it’s as dense as the penny? It could still be not as dense as the penny and still sink to the bottom, right, if the penny is a lot denser than the corn syrup."

D drops rubber stopper into cylinder.

"Where is it sitting? Where did it come to rest?"

A: "It’s on top of the corn syrup."

"O.K., it’s on top of the corn syrup so it’s denser than the water because it went all the way through the water, but it’s not much denser than the corn syrup. O.K., and we have one more substance. We have a cork. And what do you think the cork will do? We have the density - we don’t have the density of the cork, but you know how just from working with it, it will float."

A: "It will float on water."
"It will float on water. O.K. but we have two substances above the water. We have oil, and we have alcohol. Let's drop it and find out."

D drops in the cork.

"Oop. It's lighter even than the alcohol. O.K. I'm going to give you - I'm going to erase these, and give you a list of densities."

D writes additional density values on the board.

"O.K., these are all in grams per centimeter cubed. Write these all on your paper. Write this list and the list that I'm writing down. O.K., now what I want you to do is I want you to match up the density of the substance, the name of the substance with the density of the substance. We already know that water is one, right? We've already got that. You should be able to tell which go with which by where it is in the column. So why don't you start working on that right now."
APPENDIX K

ICE Sourcebook Instructions for Demonstrations A and B
(Collapsing Aluminum Can and Density Column)

DRAFT COPY
From the forthcoming GUIDEBOOK OF CHEMISTRY
ACTIVITIES FOR PREHIGH SCHOOL CLASSES,
Produced by the Institute of Chemical Education, University of
Wisconsin, Madison, WI; edited by Mickey and Jerry Sarquis

air pressure, vacuum, phase change

Title: The Collapsing Aluminum Can

Purpose: To promote creative thinking and develop problem solving
skills.

Intended Audience: General audiences, all ages.

Presentation: This may be done as a demonstration or as a hands-on activity,
depending on the age group and previously covered material.

Time required: 10 minutes for the entire activity.

Materials: (per lab group or demonstration)
2 aluminum soda pop cans, clean and empty
heat source (bunsen burner, hot plate, or even a candle)
1 pair of tongs or beaker tongs
large bowl filled with about 3-5 inches of cold water (ice
water can be used for a more dramatic effect), a fish bowl,
or a tall-form beaker (approx. 400-600 mL size)

Safety and disposal. The can and heat source will be hot. Care should be taken when
handling hot objects.
No special disposal precautions required.

Procedure: 1. Put a small amount (about 5 mL) of water into the aluminum
can.
2. Heat the can until the water is boiling and steam is clearly
escaping. This takes about 30 seconds. Do not boil till dry.
3. Using tongs, quickly invert the can into the cold water. The
can will crush with a bang.
Variations: 1. The classic version of this demonstration is to boil water in a thoroughly rinsed empty, duplicating can. Once boiling of the small quantity of water has filled the can with steam, it is removed from the heat and capped with a rubber stopper. The can is then either allowed to slowly cool to room temperature or cooled by running water.

2. Plastic 2 L soda bottles or plastic 1/2-1 gallon milk jugs can also be used for a similar effect. Half fill with hot water and allow to sit for one minute. Pour the water out and immediately screw on the cap.

3. Try:
   A. inverting the can to different depths in the water;
   B. heating an empty can and inverting it into water;
   C. doing the experiment with cans of different sizes and shapes or made from different materials
   D. doing the experiment with different temperatures of water in the beaker/fish bowl.

Explanation: When the water in the can is heated, it changes from the liquid state to the vapor state. The vapor produced drives the air out of the can. When the can is cooled, the vapor changes back into a liquid. Since the water in the dish seals off the opening of the can, a partial vacuum is created. The outside air pressure (which has a greater pressure than the partial vacuum) pushes in on the sides of the can and on the water causing the can to collapse and the water to be pushed into the can.

You can use a hammer hitting a sheet of aluminum (flatten out a can) to show how great a force it takes to dent the can. Hold up a sheet of aluminum and ask the class what particles are hitting it? (air) Is the air hitting with equal force on both sides? (yes) Then get a hammer and hit one side of the metal. What happens? (It caves in on the side that the hammer hits.) Why? (There are more particles hitting the aluminum on one side than the other.)

You may also wish to allow students to see if they can duplicate the effects by simply squeezing the A1 can with tongs. This should dispel any doubts about trickery on your part.
Curriculum Integration: Air pressure, weather (atmospheric pressure), particle theory, or as a thought provoking exercise.


Reviewer: Tom O'Brien, University of Maryland, College Park, MD 20742.
Title: Density "Density Column"

Purpose: To show the relative densities of substances by observing what fluids they sink through (substance density > fluid).

Intended Audience: Kindergarten through adult.

Presentation: Each of these demonstration/experiments must be seen so volumes may need to be adjusted for audience size.

Time Required: Takes less than 15 minutes to set-up if the materials are readily available. Demonstration and discussion time will depend upon grade level and complexity of explanation/discussion. Clean-up time is usually under 5 minutes.

Materials:
- 1 -100 mL or larger cylinder
- 10 to 20 mL each of these liquids:
  - mercury (optional)
  - glycerin
  - water (with optional food coloring)
  - cooking oil or mineral oil
  - alcohol (isopropyl or ethanol)
- samples of these solids sized to fit into the cylinder:
  - lead sinker or steel bolt
  - rubber stopper
  - piece of plastic
  - piece of oak or other substance with a density between 0.9 and 0.8 g/cc.
  - cork

NOTE: You may want to try other materials such as corn syrup, motor oil, saturated salt solution, ditto fluid, aluminum, brass, rocks or chalk.
Safety and Disposal:

Mercury is extremely toxic and should be handled with care to avoid prolonged or repeated exposure to the liquid or vapor. Continued exposure to the vapor may result in severe nervous disturbance, insomnia, and depression. Continued skin contact also can cause these effects as well as dermatitis and kidney damage. Mercury should be handled only in well-ventilated areas. Mercury spills should be cleaned up immediately by using a capillary attached to a trap and an aspirator. Small amounts of mercury in inaccessible places should be treated with zinc dust to form a nonvolatile amalgam.

The density column may be kept for months if handled carefully. A separatory funnel might be used to reclaim the mercury when the density column is dismantled. DO NOT DISCARD MERCURY! Save for reuse or collect cleaning!

Procedure:

1. Place the liquids in the cylinder. If immiscible liquids are used the order of addition is not important. Miscible liquids will require addition in the order of densities from the greatest to the smallest (See Figure 1). Caution should be used when pouring mercury (See Figure 2).

2. Add one or more of the solids and note where they come to rest.

3. Students note the relative densities of each substance.

4. If given a list of the names of the substances and a list of the densities represented, they can match the substances, in order, with their densities.

Explanation:

All materials have characteristic densities. This demonstration allows for a discussion of relative densities. The less dense materials float above the more dense. Each substance sinks into another fluid until it displaces its own weight (Archimedes principle). For example, a lead sinker, which has a mass of 11.3 grams, would displace only 1 gram of water. This is because lead atoms weigh about 11 times as much as water molecules. We see that water cannot support the lead sinker because 11.3 grams of water cannot be displaced as the sinker sinks into the water.
When the lead sinker reaches the mercury, however, it sinks until about 80% of its volume is in the mercury. At that point the sinker has displaced 11.3 grams of mercury and is supported by the mercury.

Curriculum Integration:
This study is part of the characteristics of matter unit or in a density unit.

References:


Contributors:
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Jane Kotlewski, Custer High School, Milwaukee, WI 53209.

Don Morton, Kellogg High School, Little Canada, MN 55117.

Reviewer:
APPENDIX L

Chemical Demonstration Log

DEMONSTRATION LOG

DEMONSTRATION TITLE/#:

Please place a check mark behind your name indicating that you have completed the demonstration and can possibly serve as a resource person for another participant working on the same demonstration.

NAME CHECK WHEN COMPLETED PERSONAL RATING OF DEMO (optional)

(1=Poor 2=Fair 3=Average 4=Good 5=Excellent)

Michael Abramam
Lloyd Allen
Julia Alsobrook
Shannon Cde Baca
Barbara Bannister
Paula Borinsky
Leslie Chatak
William Christie
Jeff Decker
Joy Elliot
Ann Horn
Gayle Jackson
Leon Kauffman
Karen Minihan
Dixie Moore
Mary Jo O'Connor
Judith Ostrowski
Elizabeth Palmer
Scott Record
Ellen Small
Ilene Wagner
Sheryl Weeks
John White
Sandra Young
## Checklist of Density and Air Pressure Demonstrations

### Density

<table>
<thead>
<tr>
<th>Attempted</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10 Carbon Dioxide: Dancing Raisins</td>
<td></td>
</tr>
<tr>
<td>#31 Density &quot;Bobbing&quot;</td>
<td></td>
</tr>
<tr>
<td>#32 Density &quot;Density Column&quot;</td>
<td></td>
</tr>
<tr>
<td>#34 Density &quot;Not on Level&quot;</td>
<td></td>
</tr>
<tr>
<td>#35 Density &quot;Sink or Swim&quot;</td>
<td></td>
</tr>
<tr>
<td>#46 The Great Balloon Race</td>
<td></td>
</tr>
<tr>
<td>#57 &quot;Mouth to Mouth&quot; Bottles</td>
<td></td>
</tr>
<tr>
<td>#83 Water Fountain</td>
<td></td>
</tr>
</tbody>
</table>

### Air Pressure

<table>
<thead>
<tr>
<th>Attempted</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2 Balloon Inverted In a Flask</td>
<td></td>
</tr>
<tr>
<td>#14 The Chemical Fountain</td>
<td></td>
</tr>
<tr>
<td>#21 The Collapsing Aluminum Can</td>
<td></td>
</tr>
<tr>
<td>#25 Crushing Cans Reversibly</td>
<td></td>
</tr>
<tr>
<td>#38 Egg into the Bottle</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX N

Instructions to the Coder for Coding the Protocols of the Critical-Stop Task and Follow-up Interview

(Part I: Encoding Verbal Propositions into Domains)

Goal: As a coder for this study, you will be coding several protocols that reflect teachers’ pedagogical knowledge of chemical demonstration teaching. The protocols were obtained from two methods of probing teachers’ knowledge, namely, from a think-aloud critical-stop task and a follow-up interview. The protocols generated by each of the two methods have identical coding instructions.

A. General Instructions

To assist you in coding teachers’ think-aloud comments of effective and ineffective chemical demonstrating, you will first view a videotape of a science teacher conducting a chemical demonstration. The videotape will let you become familiar with what the research subjects (chemistry and physical science teachers) were critiquing. After viewing the videotape, you will be given protocols containing teachers’ critiques of the videotaped demonstration and their responses to several follow-up questions.

The objective in coding the protocols is to code teachers’ comments according to the types of semantic relationships that exist in their verbal statements. This strategy is designed to identify the major knowledge domains associated with teachers’ pedagogical comments. Here are some specific directions to assist you.

B. Instructions for Classifying Statements into Content Categories

1. Begin by viewing Videotapes #3 showing a science teacher performing the Density Column demonstration. You will be given a script of the videotaped demonstration to help you follow the teacher’s and students’ comments. Assume that this and all other videotaped demonstrations are geared towards the middle school student. Videotape #3 represents one of four videotapes the teachers critiqued.

2. After viewing the videotape, read through the critique associated with critical-stop #1 (CS 1.) on the protocol supplied to you by the researcher. This brief critique tells you what was said by one of the research subjects engaged in the critical-stop task. In this task the teacher discusses strengths and weaknesses he or she observes at critical points during the videotaped demonstration.

3. Each critical stop is identified with the abbreviation, CS, and a number. For instance, "CS. 3" stands for Critical Stop #3. The different critical features and suggestions for improvement
discussed during each critical stop have already been separated
for you by two independent coders and are indicated by paragraph
breaks in the verbatim transcripts. This is the only "prior
analysis" information provided in your transcripts.

4. The comments associated with each critical incident usually
contain one or more of the following evaluative elements:

1. Description of the critical incident.
2. Evaluative judgment, (good, poor, better, etc).
3. Suggestion for pedagogical enhancement,
   (A clearly-stated improvement).
4. Rationale or reason for the evaluative judgment or
   suggestion for improvement.

A more detailed explanation of each of these evaluative elements
(or semantic relationships) is provided in step 7, below.

5. A domain analysis (Spradley, 1980) of science teachers'
verbalizations carefully examines the relationship between words,
or terms, that form a meaningful proposition (a sentence with a
subject and a predicate). You will find that most propositions
(90-95%) reflect one of four basic semantic relationships. These
relationships parallel the evaluative elements discussed in step
4. Using Spradley's nomenclature, the four semantic relationships
have the following form:

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Descriptive</td>
<td>X is a behavior of Y.</td>
</tr>
<tr>
<td>2. Evaluative</td>
<td>X is an evaluation of Y.</td>
</tr>
<tr>
<td>3. Alternatives</td>
<td>X is another way to do Y.</td>
</tr>
<tr>
<td>4. Rationale</td>
<td>X is a reason for Y.</td>
</tr>
</tbody>
</table>

Consider the letters, X and Y, the subject and predicate,
respectively, of a given sentence or clause in the verbatim
transcript.

6. For each critical-stop discourse (e.g., CS. 7), read the critique
through once before coding. This will help you become familiar
with the context of the discourse. On second reading, separate
each proposition (or a sequence of similar propositions) with a
slash ("/"). You will typically find that slashes separate
clauses within sentences, sentences, and sentence clusters related
to the same domain. Code each proposition (or proposition
cluster) in the discourse into one of the four semantic
relationship categories mentioned in the previous step using the
numbers 1 - 4. After identifying the proper coding category,
place the code number directly above the proposition or in the
margins next to the proposition, whichever is most convenient and
legible.

Entering slashes and coding may be done simultaneously after
having some practice. Some coders find the use of colored pencils
a convenient method for entering slashes and code numbers, e.g.,
one color for each of the four coding domains. This strategy
effectively keeps slashes from getting mixed up when separating overlapping propositions. (See step 8 for coding overlapping propositions).

A small number of propositions (approx. 5-10%) may reflect one of the eight semantic relationships discussed in step 13. Most, however, will fall into one of the four domains already mentioned in step 5. The four major domains are now discussed in greater detail.

7. A detailed description of the four most prevalent semantic relationships (coding domains) you will come across in the verbatim transcripts is now provided. You may tear off the next two sheets as a reference guide to help you code the data.

1. **Descriptive**

   - **X is a behavior of Y.**
   - **X is an inferred feeling or thought of Y.**
   
   (where Y is the teacher, students, or observer).

   Descriptive propositions are those statements made by the research subjects, and recorded on your transcripts, that describe a general or specific behavior, X, of the videotaped teacher, Y. The videotaped behavior, Y, may be a verbal utterance or an action performed by the videotaped teacher at any time during the chemical demonstration.

   Descriptive comments include more than just teacher behaviors. They also include feelings or thoughts of the videotaped teacher that were inferred by the research subject. Important: Read such inferences carefully because they may also represent Rationales (Code 4; an example of this is provided below).

   Descriptions of student behaviors and inferred student feelings and thoughts also fit this linguistic pattern. These student descriptions are frequently encountered and need to be coded differently from teacher behaviors using subcode letter "s". Since the analysis of teacher demonstration behaviors are of central interest to this study, references to student behavior should be coded as "1-s" so they can be distinguished from teacher behaviors, given the code "l".

   Subjects reflecting on their own teaching behaviors or describing some of their behaviors, thoughts, or feelings while viewing the videotape should receive the code "1-o" ("o" for observer). For example, the comments, "I did that demo just last week"; "Now I see what he was getting at"; or "I had a feeling he would do that," would all receive codes 1-o.

   Descriptions of the videotaped demonstration receive the code "1-d".

2. **Evaluative**

   - **X is an evaluation of Y.**
   
   (where, X is a value-laden term, and Y is an action or statement made by the videotaped teacher or students)

   The evaluative judgments expressed by the research subjects critiquing the videotape contain a value term, X, such as:
"good, bad, poor, kind-of-neat, not such a hot idea, O.K.-but-could-be-better, it's more effective if, too often, easy to follow, nice approach, bothered me, missed his chance, etc." These terms are directed towards the value object, i.e., the behavior being evaluated. It also includes evaluative statements of uncertainty, such as, "I don't know," or "I'm not sure if that is good or not." The value object, Y, represents an action, words, inferred feeling, or inferred thought of the videotaped teacher or students.

Propositions that evaluate student behaviors should be coded "2-s". Code "2" is reserved for teachers. Code "2-d" is used when the demonstration set-up is being evaluated in a given proposition.

3. Alternatives X is another way to do Y.

(where Y is an action, words, or demo)

Alternatives refer to any statement that describes an overt action or verbal utterance that the videotaped teacher could have displayed or performed to improve the performance quality of the demonstration. For example, "He could have asked a student to define that term," codes as an Alternative (Code 3).

If a given sentence discusses an alternative as well as the observed behavior, the clause describing the alternative is coded one way, i.e., "Alternatives" (Code 3), while the clause describing the observed behavior is coded another way, i.e., "Descriptive" (Code 1).

A common confusion is to incorrectly code suggestions for improvements (code 3) as evaluative judgments (code 2). Consider the following proposition, "That idea of solubility should probably be left unmentioned." This proposition should be coded as an alternative (code 3) because a specific pedagogical suggestion to improve the demonstration is being advanced. One could also infer from this statement that a negative evaluative judgment (code 2) was rendered. However, it is important not to infer beyond the given text and force such statements to be evaluative. Rule of thumb: If a given statement codes one way without making any inference regarding its content (e.g., code 3) but also codes another way if a simple inference is made about the content (e.g., code 2), go with the face value, non-inference coding in your analysis (i.e., code 3).

Note that suggestions involving the omission of observed behaviors are also considered alternatives. For example, "Comments like that really should not be made with middle school students," received a code 3.

Alternatives may also contain evaluative terms, but consider them as part of the alternative proposition.
4. Rationale (where Y is an evaluation, behavior, or alternative demonstration)

A rationale refers to any statement in the protocols that supports the evaluative judgment or suggestion for improving the videotaped demonstration. Rationales may reflect knowledge of students (e.g., characteristics, thoughts), teacher (e.g., knowledge of teacher thinking, planning, and decision-making), educational research findings, a pedagogical belief system, personal experience (e.g., practical knowledge), or any other basis of justification. It includes propositions as simple as, "That's how I would do it."

Statements containing the comparative forms of adjectives and adverbs, (e.g., clearer, more visible) also reflect teachers' rationales. Therefore, do not code them as evaluative judgments. For example, consider the statement, "It could have been done more visually." This proposition contains explicit comparative terms (more visually) and therefore, by the aforementioned coding rule, represents a rationale. The emphasis here is on making some kind of improvement (code 3) for the purpose of making it more visual (code 4, Rationale). The coding of comparative propositions in the verbatim transcripts are generally easily spotted, especially when read in the context of the entire discourse.

Inferences regarding the videotaped teacher's thoughts and feelings (code 1, descriptive knowledge) may also be coded as Rationales (code 4) in some cases. For example, "He must feel awkward doing it that way." In this proposition, the research subject indicates that the rationale provided for not doing some aspect of the demonstration is because it simply would feel awkward (an inference regarding the teacher's feelings).

8. Frequently, propositions will overlap. In such cases, some of the terms in one proposition will also be part of a second semantic relationship. Consider, for example, the comment:

"That teacher did a very good job of asking several inquiry-oriented questions which got the students to actively use their senses and become more involved in the class discussion."

This sentence contains three overlapping propositions, or X - Y semantic relationships. Such sentences make the separation of a propositions using the slash notation difficult. Observe the overlap of X's and Y's in the following domain analysis.

Proposition 1: "That teacher did a very good job ..."  
(X is an evaluation of Y, the teacher).

Proposition 2: "That teacher ... ask[ed] several inquiry-oriented questions ..."  
(X is a behavior of Y, the teacher).

Proposition 3: "...ask[ed] several inquiry-oriented questions which got the students to actively use their senses and become more involved in the class discussion.
"
discussion."
(X is a rationale for Y).

Notice that the words designated as X in the second proposition is designated as Y in the third proposition. It is not crucial that each proposition be neatly separated by slashes and contain both X and Y terms. When you encounter such overlapping propositions, you will find that some slashes will only separate one of the terms in a semantic relationship, with the second term "near-by". The slashes are only designed to help simplify the coding process by breaking down large paragraphs so that major semantic relationships in a given discourse can be more easily identified. Thus, it is very appropriate to use the terms of a previous proposition and apply it to the next proposition if overlapping occurs. You may find underlining X and Y terms in a complex sentence to be a useful strategy in your analysis. After you have become more familiar with coding, you will be able to spot X and Y terms readily and you won't need to use these X and Y labels. In the case of very short propositions that contain evaluative terms, e.g., "He's got good volume," clearly codes as "2" even if there is some evidence of overlap, ("He has got ... volume", descriptive). Overlapping usually occurs with very long sentences. Use your best judgment in identifying overlapping propositions.

9. Occasionally, an X or Y term may not be explicitly stated in the protocol and must be inferred from the remaining text. In such cases, inferred cover terms are often given in brackets [ ]. These bracketed comments represent additional information provided by the researcher so that the coder will not have to spend hours searching the videotape scripts to understand the context of the critique.

10. Go ahead and try coding the following brief discourse as a check of what you have read so far. Enter your codes right above the identified propositions.

E2's Discourse on Critical Incident A:

She looks like she only has like a 100-ml cylinder there. I think if she had a liter cylinder it would have been much more effective. It's just difficult to see it. (VT #4)

You may check you work by reading the analysis below conducted by this researcher.

This critical incident discusses the size of a graduated cylinder being used for the demonstration. The discourse contains the semantic relationships 1, 2, 3, and 4.

1. Descriptive: "She looks like she only has a 100-ml cylinder there."
3. Alternative: "I think if she had a liter cylinder ..."

2. Evaluative: "it would have been much more effective."

4. Rationale: "It’s just difficult to see it."

This discourse represents a relatively easy discourse to code. Some critiques can be very complex and are therefore troublesome to code. Simply do the best you can with the information available to you. If you feel confident in using the first four coding categories you may now proceed to step 13 which describes how to code items that don’t fit the semantic forms, 1-4. A few more examples are provided below for you reference, if you like to see how other discourses have been coded by this researcher.

11. Here are two additional critical-stop discourses and a complete coding description.

a. E5’s Discourse on Critical Incident B:

One of the weaknesses is that he seems to be continually walking from the front to the back of the [demonstration] bench, and he was asking the questions and he knew he was going to write [the answers] down. He probably should stay at the back or if he wanted to have a secretary, one student act as a secretary, it would probably be better to get that arrangement out of the way at the very beginning before the demonstration starts because it’s distracting to arrange for that in the middle of the demonstration.

(VT #3, S:7)

Once again this discourse requires propositions, or clusters of similar propositions, to be separated by a slash, "/", to help simplify the coding task. Here is one way to divide up the critique according to the semantic relationships of the cover terms in the critique.

\[
\begin{align*}
2 & \quad 1 \\
\text{One of the weaknesses is that } / & \text{ he seems to be} \\
\text{continually walking from the front to the back of the} & \\
\text{[demonstration] bench, and he was asking the questions and} & \\
\text{he knew he was going to write [the answers] down. } / & \text{He} \\
\text{probably should stay at the back or if he wanted to have a} & \\
\text{secretary, one student act as a secretary, it would} & \\
\text{probably be better to get that arrangement out of the way} & \\
\text{at the very beginning before the demonstration starts } / & 
\end{align*}
\]
because it’s distracting to arrange for that in the middle of the demonstration. (VT #3, S:7)

Evaluative propositions:

The semantic relationship of the terms in the first proposition, [i.e., actually the first two lines of this critique], shows that experienced demonstrator E5 makes a negative, or unfavorable, judgment about the videotaped teacher’s distracting movements around the demonstration bench while performing the chemical demonstration. The value term "weaknesses" explicitly indicates that an evaluative judgment has been rendered with respect to a value object (the teacher’s behavior). The semantic relationship of the terms in the proposition is of the form: X is a judgment of Y. This type of comment is given code number 2.

Descriptive propositions:

The second proposition encountered in the above transcript also provides a brief description of the critical incident being critiqued, "...he seems to be continually walking from the front to the back of the [demonstration] bench, and he was asking the questions and he knew he was going to write [the answer] down." This statement describes an incident in Videotape #3 where the videotaped demonstrator walks back and forth around the demonstration table to get to the blackboard during the beginning of the demonstration (X is a behavior of Y). Both cover terms X and Y are explicitly provided by the research subject. Once again, the statement represents descriptive knowledge associated with chemical demonstration teaching, coding category 1.

Alternatives:

Experienced demonstrator E5 also provides a suggestion for dealing with the dilemma of confronting a large demonstration table that makes accessing the blackboard difficult. Subject E5 states, "... he probably should have stayed at the back [of the table]." This subject also indicated that the use of a student secretary at the blackboard could be enhanced by arranging for the selection of a student recorder at the beginning rather than during the middle of the demonstration [note the phrase, "...it probably would have been better to...]]. Both comments represent solutions to the "blackboard problem" and the task of coordinating the various components of effective chemical demonstration teaching. The semantic relationship of the terms in these two statements [X is another way to do Y] provide evidence for coding the comments as Knowledge of Alternatives, category 3.
Rationales:

Demonstrator E5 also provided a justification for the improvements he advanced. The remark, "... because it's distracting to arrange for that in the middle of the demonstration," represents a practical justification for why the observed teaching behavior (calling on a student recorder to keep track of the class' observations during the middle of the demonstration) is perceived to hinder effective demonstration teaching. This statement supports the evaluative judgment E5 rendered. The terms in this statement are characteristic of a rationale statement, and its presence provides support for the rationale category in the coding scheme. It receives the code number 4 which is entered into the margins of the transcript.

A second discourse is now subjected to a domain analysis.

b. E2's Discourse on Critical Incident C:

That's a really good thing to do, to get participation from everybody like that, [i.e., polling the class along a given criteria to select a student volunteer to hand-crush an aluminum can]. It makes it, not cutesy, but if he's working with middle school kids, then that particular technique is excellent 'cause they want as much involvement as they can and you can see that when we work with the little kids, as soon as you ask for a volunteer, everyone's hand goes up. So everyone wants to participate. (Videotape #1, S:4).

The first step in the coding task is to separate each identified proposition, or class of propositions, with a slash, (/). Remember, this is somewhat of an arbitrary process because some cover terms relate to two separate propositions. Here is one way to divide up the critique to help simplify the domain analysis.

That's a really good thing to do, / to get participation from everybody like that, [i.e., polling the class along a given criteria to select a student volunteer to hand-crush an aluminum can]. / It makes it, not cutesy, but if he's working with middle school kids, / then that particular technique is excellent / 'cause they want as much involvement as they can and you can see that when we work with the little kids, as soon as you ask for a volunteer, everyone's hand goes up. So everyone wants to participate. (Videotape #1, S:4).

Evaluative propositions:

The opening phrase, "That's a really good thing to do," identifies a proposition and shows that a positive evaluative judgment was made about a particular incident [polling students] that transpired early in the demonstration. This verbal proposition
contains the value term "really good" which indicates that the statement is characteristic of a value judgment. The semantic relationship among the terms in this opening statement is clearly evaluative \([X \text{ (a really good thing)} \text{ is an evaluation of } Y \text{ (polling students; also indicated by the pronoun, "That"})]\). Statements possessing this semantic form cluster neatly into the evaluative judgment domain. This statement, therefore, receives the code number "2" which is placed above the proposition or in the margins of the protocol next to the evaluative comment. The evaluative judgement is repeated later in the discourse with the term 'excellent'. It would also receive the code number 2.

Descriptive propositions:

The remaining portion of the first statement, "... [for him] to get participation from everybody like that, [i.e., polling the class along a given criteria to select a student volunteer to hand-crush an aluminum can] ...", represents a brief description of the particular critical incident observed on videotape #1 by subject E2 and represents another proposition. The description refers to the creative method used by the videotaped teacher for selecting a student to participate in the demonstration. The semantic relationship among the terms in this proposition is descriptive \([X \text{ is a behavior of } Y]\). \(Y\) needs to be inferred and represents the videotaped teacher. \(X\) is provided by the research subject with some added contextual information provided by the researcher. The proposition provides a basic description of a teaching behavior associated with effective chemical demonstrating. It therefore receives the code number "1".

Rationales:

The remaining comments in the above discourse represent a rationale for why chemical demonstrator E2 rated the observed critical feature as "really good." This demonstrator reasoned that the technique of calling on student volunteers is rather important for effective chemical demonstration teaching at the middle school level because students at that age have a strong tendency to enjoy and desire participation in classroom demonstrations, ["... 'cause they want as much involvement as they can..."]]. The semantic relationship of the terms in this proposition reflect the pattern: \(X\) is a reason for \(Y\). Such propositions represent knowledge of why specific teaching strategies are able to motivate and interest students to learn science and is indicative of the coding category called, rationales, coding category 4. The number "4" is therefore entered in the margins of the protocol next to the statement. The phrase, "It makes it, not cutesy, but if he's working with middle school kids, ...", would also be coded as a rationale. The critic considers the level of the learner an important reason for why the particular teaching strategy would be effective.

12. The two examples below serve as further illustrations of the coding scheme and your task as a coder.
E4's Discourse on Critical Incident D:

This was good. He said, "This [column] has something to do with density. O.K. Now tell me about it." And of course now he puts the paper behind it which is a strong point. You can make the difference [i.e., the different layers] show up to show that there is a dark area, a medium colored area in a sense, and what appeared to be on the screen, a colorless area. (VT #3)

The critical incident above discusses the use of a paper background to enhance visibility of the density column. A careful examination of the verbal critique shows that it contains three evaluative elements or semantic relationships 1, 2, and 4.

1. Descriptive: "He said, 'This has something to do with density. O.K., now tell me about it.'"
   Descriptive: "And of course now he puts the paper behind it..."

2. Evaluative: "This is good," and "...which is a strong point."

4. Rationale: "You can make the difference show up to show that there is a dark area, a medium colored area in a sense, and what appeared to be on the screen, a colorless area."

Codes 1, 2, and 4 are placed above the propositions or in the margins along side the discourse.

Coding is still possible even if the subject’s comment contains no more than a proposition expressing a knowledge of alternatives. The following comment exemplifies this type of response.

E2’s Discourse on Critical Incident E:

She should have had a kid do that. (VT #4)

This critical incident contains only one proposition which reflects a knowledge of alternatives, 3.

3. Alternatives: "She should have had a kid do that."

This comment suggests there is a way to enhance student participation in the demonstration, (see video script), and thus, the overall effectiveness of the presentation. The comment, therefore, suggests that the subject has identified a perceived "Weakness" in the videotaped model of chemical demonstrating. Although the weakness may be inferred from the critique, it is not coded as evaluative, 2, since there is no clear value term provided in the proposition.
13. In the case when a particular proposition cannot be easily coded into one of four domains discussed above, consider one of the following semantic relationships discussed by Spradley (1980). You will probably notice, as you review these extra domains/relationships, a few of the propositions you may code as 1, 2, 3, or 4, may also code into one of the "Other Knowledge" domains/relationships (5 - 12) stated below. In cases where multiple codings are possible, select the one most appropriate code in your analysis. To assist you with that function, codes 5-12 are available when codes 1-4 are not appropriate. In case of "ties", use codes 1-4 instead of 5-12.

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Form</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Cause-effect</td>
<td>X is the cause of Y.</td>
<td>The can didn't collapse because of a pinhole.</td>
</tr>
<tr>
<td>6. Function</td>
<td>X is used for Y.</td>
<td>The tongs allow you to manipulate a hot can.</td>
</tr>
<tr>
<td>7. Sequence</td>
<td>X is a step (stage) in Y.</td>
<td>Solids are added after the liquids are layered.</td>
</tr>
<tr>
<td>8. Means-end</td>
<td>X is a way to do Y.</td>
<td>One could heat the can by placing it over a lit Bunsen burner.</td>
</tr>
<tr>
<td>9. Location-for-action</td>
<td>X is a place for doing Y.</td>
<td>That is best done under a hood!</td>
</tr>
<tr>
<td>10. Spatial</td>
<td>X is a place in Y.</td>
<td>The coin is sitting on the bottom of the column.</td>
</tr>
<tr>
<td></td>
<td>X is a part of Y.</td>
<td></td>
</tr>
<tr>
<td>11. Strict inclusion</td>
<td>X is a kind of Y.</td>
<td>Water is an amphoteric substance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>That would be considered a divergent type question.</td>
</tr>
<tr>
<td>12. Attribution</td>
<td>X is a characteristic of Y.</td>
<td>Pure water is clear and colorless.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>He seems to know a lot about genetics.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divergent questions allow for a number of answers.</td>
</tr>
</tbody>
</table>

14. Although relationships 5 - 12 may reflect legitimate domains of teachers' comments, in the context of this study they may also be considered sub-domains of domains (semantic relationships) 1-4.
For example, the domain called Alternatives (#3, knowledge of alternative teaching strategies) would very likely include comments whose semantic relationships could also be coded as Function (6), Sequence (7), Means-end (8), or Location-for-action (9). Of these "Other" domains, you will probably encounter more propositions that code into domains 5, 11, and 12 and fewer propositions that code into domains 6-10.
15. A summary of the four major semantic relationships and the remaining ancillary relationships is now stated.

<table>
<thead>
<tr>
<th>Code #</th>
<th>Relationship</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Descriptive</td>
<td>X is a behavior of Y.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X is an inferred or stated feeling/thought of Y (teacher, student, or observer)</td>
</tr>
</tbody>
</table>

Note: Code as "1" only if the descriptive proposition is not part of a rationale (4). If part of a rationale, code as a "4".

Code: 1 for teacher, 1-s for student, 1-o for observer.

| 2.     | Evaluative          | X is an evaluation of Y.                  |

Code: 2 for teacher, 2-s for student, 2-o for observer, 2-d for demonstration.

| 3.     | Alternatives        | X is another way to do Y.                 |

Code: 3-o for alternative used by observer in his or her for teaching.

| 4.     | Rationale           | X is a reason for Y.                      |

"Other Knowledge":

5. Cause-effect   X is the cause of Y.
6. Function       X is used for Y.
7. Sequence       X is a step (stage) in Y.
8. Means-end      X is a way to do Y.
9. Location-for-action X is a place for doing Y.
10. Spatial       X is a place in Y. X is a part of Y.
11. *Strict inclusion X is a kind of Y.
12. *Attribution  X is a characteristic of Y.

* Most common of the last eight domains.

Note - A few propositions are given subdomain codings, e.g., 1-o, and 1-s. The letter subcodes are designed to help you clearly identify the object being discussed in the proposition. Inter-coder reliability, however, is based only on agreement.
between you and this researcher in terms of the numerical code numbers assigned to the propositions.

16. You may tear off the previous page and use it as a quick reference guide as you code the protocols.
APPENDIX O

Instructions to the Coder for Coding the Protocols of the Critical-Stop Task and Follow-up Interview

(Part II: Encoding +, −, P, V, D, X, & CC)

Goal: As a coder for this study, you will be coding several protocols that reflect teachers' pedagogical knowledge of chemical demonstration teaching. The protocols were obtained from two methods of probing teachers' knowledge, namely, from a think-aloud critical-stop task and a follow-up interview. The protocols generated by each method have separate coding instructions.

A. Instructions for Coding of Protocols of the Critical-Stop Task

To assist you in coding teachers' think-aloud comments of effective and ineffective chemical demonstrating, you will first be viewing a videotape of a teacher conducting a chemical demonstration. The videotape will let you become familiar with what the research subjects were critiquing. After viewing the videotape, you will be given protocols containing teachers' critiques of the videotaped demonstration. The object in coding these protocols is to identify the number of "Perceived strengths" and "Perceived weaknesses" that were identified by the research subjects while viewing the videotape. Here are some specific directions to assist you.

1. Begin by viewing Videotapes #3 showing a teacher performing the Density Column demonstration. You will be given a script of the videotaped demonstration to assist you in the listening task. Assume that this presentation, as well as others you will be viewing, are geared towards the middle school level. Videotape #3 represents one of four demonstration videotapes my subjects critiqued.

2. After viewing the videotape, read through the think-aloud protocol supplied to you by the researcher. This protocol tells you what was said by a representative subject during the critical-stop task. In this task the subject discusses the effectiveness of the chemical demonstration performance at critical points during its presentation.

3. Each critical stop is identified with the abbreviation, C, and a number. For instance, "C 3" stands for critical stop #3. For each each critical stop determine the number of critical features the subject discusses. Most subjects simply comment on one feature or aspect of teaching at a time. Some make two or more (rarely above five) distinctly different comments during a single critical stop. If a subject makes more than one critical comment per stop, separate each major thought with a slash (/).
4. Classify each critical feature as either a perceived "Strength" or "Weakness" identified from the subject's point of view, using the letters "St" or "Wk", respectively. Enter this code on the line provided next to the Subject and Videotape Statement number, [e.g., C 1 (S: 3e) ________]. With multiple entries, separate each entry with a slash ("/", e.g., St/Wk).

5. Occasionally, a subject makes a comment that cannot be identified as a strength or weakness. Code such comments as Neutral (N). This assigned code is frequently encountered when a subject simply describes what he/she observes on the videotape without making a judgment as to the strength or weakness of the episode.

6. In the event you cannot code an item as a strength, weakness, or neutral comment because of your unfamiliarity with the context or the confusing manner in which the subject has expressed him/herself, please code the identified feature as Nebulous (Nb).

7. You may find that several critical comments are repeated or refer to similar critical issues, such as the issue of teacher's questioning skills or the issue of dealing with new vocabulary terms. Categorize each subject's comments independent of the next. Identical critiques on recurring features evident in the videotape are not considered "Repeats". The only exception to this rule would be if a subject repeatedly comments on an a teachers' overuse of "O.K., Uh, huh," a catch phrase, or slogan.

8. Tally the total number of perceived Strengths, Weaknesses, Neutral, and Nebulous critical features identified by the subject on the top of the subject's protocol sheet. The identified features will represent major as well as minor aspects of effective/ineffective chemical demonstrating.

9. Use the videotape script as a resource to help you remember the context of the subject's comments.

10. Follow the procedure described above (Steps 1 - 8) to code the remaining think-aloud protocols corresponding to the critiques of videotapes #1, #2, and #4.

11. Remember, to code teachers' comments as a "Strength" or "Weakness" as perceived from the subject's point of view.

12. See the following two pages of helpful hints and examples.
13. Helpful hints:

The comments associated with each critical feature contain one or more of the following evaluative elements:

a. Description of the critical incident.
b. Evaluative judgment, (poor, good, etc).
c. Suggestion for pedagogical enhancement, (a clearly-stated improvement).
d. Rationale or reason for the evaluative judgment or suggestion for improvement

A critical feature can usually be coded as a 'Strength' or 'Weakness' if it contains any one of the elements, b. - d., listed above. If a subject simply describes what he/she observes on the screen (element a.), it is usually coded as a 'neutral' or 'nebulous' comment. It is not important to analyze each critical feature at this level of detail, but this scheme can be useful for coding more difficult items. Use your best judgment if a comment does not code neatly into one of designated categories (Strength, Weakness, Neutral, Nebulous).

14. Examples

The examples below serve as illustrations of the coding scheme and your task as a coder.

Example 1. (From protocol E4., Videotape #3)

This was good. He said, "This [column] has something to do with density. O.K. Now tell me about it." And of course now he puts the paper behind it which is a strong point. You can make the difference [i.e., the different layers] show up to show that there is a dark area, a medium colored area in a sense, and what appeared to be on the screen, a colorless area.

The critical incident above discusses the use of a paper background to enhance visibility of the density column. It can be coded as a perceived "Strength" simply be noting the positive value terms ('good' and 'strong point') that were expressed.

A careful examination of the verbal critique shows that it contains three evaluative elements, a, b, and d.

a. Description: "He said, 'This has something to do with density. O.K., now tell me about it.' And of course now he puts the paper behind it..."

b. Evaluation : "This is good," and "...which is a strong point."

c. Rationale : "You can make the difference show up to show that there is a dark area, a medium colored area in a
sense, and what appeared to be on the screen, a colorless area."

Element b. provides sufficient evidence to properly code this critical incident as a perceived strength. You can now enter the code "St" for "Strength" on the line provided on the protocol.

Example 2. (From E2., Videotape #4)

She looks like she only has like a 100-ml cylinder there. I think if she had a liter cylinder it would have been much more effective. It's just difficult to see it.

This critical incident discusses the size of a graduated cylinder being used. It does not contain a value term that would simplify the coding of this observed incident as a perceived strength or weakness. It simply contains elements a, c, and d.

a. Description: "She looks like she only has a 100-ml cylinder there."

b. Provides sufficient evidence to properly code this critical incident as a perceived strength. You can now enter the code "St" for "Strength" on the line provided on the protocol.

c. Improvement: "I think if she had a liter cylinder it would have been much more effective."

(Pl) "I think if she had a liter cylinder it would have been much more effective."

d. Rationale: "It's just difficult to see it."

Here, the presence of elements c and d suggest that the subject has identified a perceived "Weakness". If a subject indicates a way to improve a demonstration performance characteristic, this would suggest that the observed incident was perceived to be weak or weaker than it should have been. The presence of a rationale further supports coding this critical feature as a perceived "Weakness". Enter the code letters "Wk" on the line provided in the protocol.

Coding is still possible even if the subject's evaluative comment contains no more than an Improvement element, c, (also called a Pedagogical enhancement, P). The following comment exemplifies this type of response.

Example 3. (From E2., Videotape #4)

She should have had a kid do that.

This critical incident contains only one evaluative element, c.

- c. Improvement, (P): "She should have had a kid do that."

This comment suggests there is a way to enhance student participation in the demonstration, (see video script), and thus, the overall effectiveness of the presentation. The comment, therefore, suggests that the subject has identified a perceived "Weakness" in the videotaped model of chemical demonstrating. It receives the "Wk" code.
B. Instructions for Coding the Clinical Interview Protocols

The objective in coding the clinical interview transcripts is to identify (i) additional strengths and weaknesses identified by the subject viewing the videotape and (ii) the number of suggestions the subject viewing the videotape and (iii) the number of suggestions the subject viewing the videotape and (iv) the number of distinctly different demonstrations, D, that were mentioned by the subjects with respect to the targeted science concepts. The following directions will be help you as you code the verbal data.

1. Read through the interview transcript and separate each new thought with a slash (/) mark.

2. Upon second reading, identify those comments made by the subject that indicate additional Strengths and Weaknesses that can be identified in the videotaped demonstration. Code each distinct idea with a "+" if it is a strength or a "-" if it is a weakness. These items usually appear in the first half of the interview protocol.

3. Code the remaining comments according to the scheme described below. Specific examples are provided in steps 4-6.

P: Pedagogical enhancement - A suggestion made by the subject to improve videotaped performance of the air pressure or density demonstration. These suggestions include alternative teacher behaviors that could be implemented during interactive or preactive teaching. Pedagogical suggestions address issues such as teacher's questioning strategies, use of inquiry, interaction with students, clarification of new terms, and use of equipment that can enhance visibility (e.g., lighting, colors, background, etc).

V: Variation - An alternative way of presenting the Collapsing Aluminum Can demonstration or the Density Column demonstration observed on videotape by (i) adding, deleting, or substituting alternative materials/chemical substances, (ii) showing a simpler/more complex presentation of the videotaped demonstration, (iii) performing the demonstration in a different order, or (iv) performing the demonstration in a manner that is more or less dynamic. In a demonstration handbook, this variation usually appears as part of the original demonstration write-up, e.g. as shown in ICE sourcebook (Sarquis & Sarquis, 1987).

D: Other Demonstrations - Demonstrations that illustrate the concept of air pressure or density that are different from the Collapsing Aluminum Can Demo and the Density Column Demo. These demonstrations usually appear as separate write-ups in a demonstration handbook and has its own distinctive title.
Discrepant events similar to the videotaped demonstration also qualify as "Other Demos".

DV: Variations on Other Demonstrations, D - There may be variations in conducting "Other demos" (D). Keep track of such variations for each new demonstration cited. Variations on other demonstrations involve similar procedures that include (i) simple substitution of substances or materials, or (ii) a slight change in the presentation sequence of the original demonstration.

4. Examples of P.

Review the instructions on the previous two pages (p. 3 and 4, Instructions for coding the critical-stop protocols). They provide examples of comments that meet the criteria of a Pedagogical enhancement (P). Remember that a pedagogical enhancement (P) is a clear, explicit suggestion for improving a perceived weakness in the videotaped demonstration.

Inferences are only acceptable in the following case.

Acceptable Inferences of P:

Occasionally, suggestions for enhancing teacher behavior is couched in terms of student behavior. For example, "The kids should have had more time to answer that," indicates that the teacher should have provided more wait time for the students to answer the teacher’s question. It would therefore be coded, "P".

Unacceptable Inferences of P:

Statements expressing perceived weakness

Some statements indicate the identification of a weakness, such as, "He just kept looking down at the can which, to me, is poor." A pedagogical enhancement can be inferred from this statement by assuming the statement means, "He should look at the audience more." Since this information was not clearly provided, do NOT code such statements as "P". The original statement only provides a description of the situation and the subject’s evaluative judgment about it, namely, that it was a weakness.

Remember, negative evaluative judgments do not get coded "P" unless an improvement is explicitly provided along with the judgment statement. Do not infer the improvement from a negative evaluation, even if it is logically apparent. Inferences are only acceptable in a few instances as described above and below. For example, in the statement, "There are better ways of doing that," is too weak to be coded as a P or since it does not provide a clear solution to the problem.

Is it a P or something else?: 
Important: Do not assume that each perceived weakness mentioned in the protocols is followed by a clear statement for improving the weakness. They are missing in several instances. Before coding a statement or paragraph a "P", ask yourself, "Is it also a demo (D), variation (V), Lab (L), Activity (Act), etc.?" If it is, code as D, V, L, or Act. Do not code these items as "P", even if they do suggest that it would be a pedagogical enhancement to the observed demonstration.

The example of visibility deserves special note. If a subject suggests using larger equipment to enhance visibility, this is usually coded "P". If, however, the larger equipment is sufficiently different from the original to change the kinds of observations that are made during the demonstration, it would then be considered a variation of the demonstration.

Planning issues:

Also, do not consider long-term planning suggestions as a P for the videotaped performance.

5. Coding P' (P Primes).

There are two cases where the pedagogical enhancement must be inferred from the critique. This situation is encountered when the subject:

(a) has identified a missing behavior, or
(b) suggests deleting a behavior.

Code each clearly-stated "missing or deleting behavior" suggestion as an inferred P: \( P' \) (P prime).

Acceptable Inferences:

(a) Example of a Missing Behavior.

Examples of a missing behavior would include the following comments:

"He did not ask students to observe!"
"He didn’t have any closure."
"He stopped asking inquiry questions towards the end of demonstration."

Here, the subject identifies a weakness by commenting on teacher behaviors that are conspicuously absent. Note that an enhancement is not explicitly stated in these remarks, only a perceived weakness. It can be inferred, however, that the converse of these statements would suggest the type of improvement the subject has in mind, (i.e., "He should have had students make observations," or "He should have had some closure," etc.). Therefore, label any "missing behavior" comment, \( P' \), if the converse is not explicitly stated.
Example of Deleting a Behavior.

Sometimes a subject suggests deleting an inappropriate teacher behavior from the demonstration performance. You can infer from such statements that the simple omission of this behavior (rather than the substitution of another more appropriate behavior) would improve the observed performance. Such items would be coded as P'. For example, "He shouldn't make that kind of remark to students who don't know the answer. It's embarrassing." Here, the preferred behavior, simply omitting the derogatory comment would be the implied pedagogical enhancement and should therefore be coded P'. If the subject provides another alternative way of handling the situation of the ignorant student in addition to the 'delete' suggestion, enter a single code, P, to reflect the presence of a directly-stated pedagogical enhancement. (Do not enter P' and P for such a dual response).

Errors to avoid:

Weaknesses are not synonymous with P' (prime's):

Do not consider statements that simply cite a weakness as a "P'", as in, "His introduction was kind of weak." In this case the behavior is perceived to be weak, not absent. It is clearly a weakness (Wk), not a P'.

The following statement is also not to be coded as P because of their evaluative emphasis. "What he is doing here is asking leading questions and that just gives them the answer!" This is not a P' since this is not an explicit statement of the behavior that should be avoided. Admittedly, it can be readily inferred what the avoidance behavior should be from this proposition. For example, if the subject followed this statement with "He should really stop doing that," it could be coded P'. If the subject said, "A better question would be, 'What do expect would happen if I were to invert this heated can into this pool of water?'" This discourse would be coded P.

'Lack-of-knowledge' statements are not P' (prime's):

Also, consider the following: "He's not too knowledgeable about the day-to-day use of that chemical substance." Do not code this as a P' even though it can be inferred that the improvement to this observation would be for the videotaped teacher to provide accurate information about the substance in question. It is simply a statement of weakness (Wk). If the subject follows this critique with a statement that indicates the actual use of the substance in daily life, then code that portion "P", but not otherwise.

Examples of a variation (V) on the Density Column demonstration observed on videotape #3 which shows a teacher displaying a static
system (i.e., a completed density column), would be the suggestions:

(a) Example 1: "Building a density column."
   Code: V1. It represents a more dynamic approach, or

(b) Example 2: "Dropping in more solid objects having different relative densities after the column is built."
   Code: V2. It suggests the use of more materials to show the relative densities of solids and liquids.

Each of these variations involve the common use of single clear vertical column containing multiple layers of liquids.

Sometimes subjects indicate that a particular variation can pedagogically enhance a demonstration. Code this variation, "V", not "P".

A list of variations for the two Density Column and Collapsing Aluminum Can demo are provided below. They are taken from the 1987 ICE demonstration sourcebook. They represent about a half of all the variations the subjects discuss.

Variations of the Collapsing Aluminum Can
- Use duplicator fluid can instead of a soda can.
- Heat an empty can (i.e., without water inside).
- Use different size cans to examine extent of collapse.
- Invert into different temperature of water.
- Invert into different depths of water.
- Use plastic bottle (Half-filled with hot water, empty, then cap).

Variations on the Density Column
- Add one or more solid substances
- Add other liquids besides those used.
- Add immiscible liquids in different order (besides density order).

The remaining variations cited in the protocols should be apparent, given the instructions and examples you have been provided.

7. Other Demos (D) illustrating the concept of density would include:

(a) Example 1: "The demo involving a U-tube containing two immiscible liquids. You know, the one having two different liquids placed in each arm of the tube and observing that one meniscus is higher than the other. It's a good discrepant event."
   Code: D1.
   Not on the Level Demo (#34 in ICE Guidebook)
Note that this is not a variation on the density column since it does not involve a multiple-liquid system layered in a straight column.

(b) Example 2: "I remember the one where you can pour CO2 gas over a burning candle and watch it suddenly be extinguished. The greater density of this gas relative to the density of air causes it to pour down over the candle instead of going straight up or out of the opening of the CO2 container."

Code: D 2.
Extinguishing a Flame with CO2.
Note that this demo also qualifies as a demonstration illustrating one of the characteristic properties of carbon dioxide, namely, its non-combustibility. Some demonstrations can illustrate multiple concepts.

(c) Example 3: "It is possible to set up an equal-arm balance with identical bags sitting on each pan. You can then pour CO2 into one of the bags and watch the needle tip in the direction of the heavier or more dense gas. It's kind of neat."

Code: DV 1.
The CO2 and Equal-Arm Balance Demo.
This demo is very similar in principle and procedure to D 2., Extinguishing a Flame with CO2 demo, discussed above. It represents a slight variation of D 2. with respect to the materials used (equal-arm balance instead of a candle) and observations made.

(d) Additional examples: To aid you in coding the protocols, a list of demonstrations in the ICE demonstration sourcebook related to air pressure and density are provided below. They represent about 1/3 to 1/2 of all the demonstrations that subjects discuss. Variations on these demonstrations are also provided, (DV).

Air Pressure
- Balloon Inverted in a Flask
- The Chemical Fountain (Round bottom flask with ammonia gas draws water up glass tube and into flask)
- Crushing Cans Reversibly (Draining a 2 liter plastic soda bottle filled with water through a 10' tube)
  
  DV: Substitute ditto fluid can for soda bottle
  DV: Study drainage time and tube length

- Egg in the Bottle (Heat flask with some water inside then stopper with egg)
DV: Burn paper inside flask then stopper
DV: Remove egg from bottle by blowing through a straw inserted between bottle and egg
DV: Remove egg by reheating the flask with egg in the neck (inside of flask)

Density
- Carbon Dioxide: Dancing Raisins
  DV: Density "Bobbing" (using mothballs or spaghetti)
- Density: "Not on the Level" (Saturated salt water and fresh water in each arm of a U-tube)
  DV: Color salt water and fresh water with different food coloring
  DV: Substitute alcohol for salt solution
- Density "Sink or Swim" (Uncooked egg in salt water and fresh water)
  DV: Use a small water-filled balloon as a float
  DV: Use hot and cold water
  DV: Use a rotten egg
- The Great Balloon Race (Using H2 or He, air, and SF6)
  DV: Use a propane and CO2 balloon (Have similar molecular weight)
- Water Fountain (Colored heated water rises out of a capped jar through hole into surrounding cold water jar)
  DV: Use two florence flasks and a cardboard square
  DV: Place two capped jars with hole (containing hot and warm colored water) into separate large jars.

8. Identify each P, V, D, or DV with the designated letter(s) and number and record it in the left hand margin of the protocol along side the statement. If the item is repeated, indicate the proper code letter and number followed by the word "Repeated" in parenthesis, e.g., P 3. (Repeated).

9. If the subject only mentions the 'Title' of a demonstration (e.g., "Not on the Level" demo) consider this as sufficient minimal evidence that the subject has some basic knowledge of this Demonstration (D) stored in memory.

10. Tally the total number of P's, V's, D's and DV's you have identified at the top of each interview protocol. Do NOT include repetitious items in your count.
11. Some items cannot be easily classified as P, V, D, or DV. These items are considered Extraneous items (X). Extraneous items should be coded as Labs (L), Discussions (Ds), or Activities (Act) if they are positive in nature. Extraneous items should be coded as Erroneous (E), Pedagogically Unsound (U), or Nebulous (Neb) if they are negative in nature.

12. The nature of these extraneous items (X) are described below.

Positive X’s:

Labs (L) are those items where the subjects suggest that the demonstration observed on videotape is better suited as a lab or that a variation of the observed demo would be a good laboratory on density or air pressure.

Discussions (D) are those items where the subject refers to discourses the teacher suggests are good to have with students.

Activities (Act) refer to those items where students are involved in individual or group seatwork, and may involve the use of handouts or problem sheets that may be a follow-up activity or an activity independent of a demonstration. It would also include quizzes.

Negative X’s:

Erroneous demos (E) are those demos that clearly address another concept, not the targeted concept. An example might be the suggestion that igniting a flammable gas-filled balloon demonstrates the powerful influence of air pressure. The focus is on erroneous demonstrations, not on erroneous explanations of the demonstration concepts.

Pedagogically unsound (U) items are demonstrations that primarily illustrate a non-targeted concept, even though the targeted concept is embedded in the suggested demonstration. An example of this would be a demonstration on sedimentation rates to illustrate the concept of density. Remember, that sedimentation rates are influenced primarily by particle mass, size, shape, and fluid viscosity. It would be a poor illustration of the concept of relative densities the objects. The focus is on unsound demonstrations, not on unsound explanations of the demonstration concepts.

Nebulous items (N) are those demonstrations that are so poorly communicated it is not possible to understand the idea being conveyed. Caution is needed here since a coder’s unfamiliarity with an obscure yet perfectly legitimate demo made be incorrectly coded "Nebulous". To minimize this error the titles of demos taken from the ICE Demo Guidebook are provided at the end of this document. For example, the Great Balloon Race may not have any
meaningful connotations for the coder but it refers to a simple and appropriate demonstration illustrating the density of gases. (See demo #46 of the ICE Demo Guidebook).

13. After the protocols have been coded for Extraneous items, tally the total number of L’s, Ds’s, and Act’s, items (positive examples) and the number of E’s, U’s, and Neb’s (Negative examples). The grand total of these two subtotals represents the value X, (Extraneous examples).

14. Occasionally teachers’ state Technical Improvements (T) to the demo by suggesting the use of some extra piece of laboratory hardware or safety equipment while performing the demonstration. Consider these suggestions as P’s, Pedagogical enhancements.

15. Other comments that are occasionally encountered are Applications (Application) of the density or air pressure concepts. These examples refer to comments about real life situations or daily encounters with the concept. Code these items "Appl". An example of an application comment would be one where a teacher says, "We see the idea of density as work in battery testers and hot air balloons." This particular example contains two application items, "battery tester" and "hot air balloon". Consequently, "Appl" should appear twice in the margin of the protocol.

16. Sometimes a subject repeats a thought more than once during the follow-up interview. Code these repetitious items in a consistent manner. Indicate that these items are repetitious, e.g., P 3. (Repeated) or V 1. (Repeated), so that tallies reflect the total number of unique comments.

17. Remember to read and code the entire protocol since subjects occasionally make passing references to demonstrations, variations, applications, etc. in unexpected sections of the interview, such as, during question I 10., science concept explanations.

18. **Summary of Follow-up Interview Codes**

   P = Pedagogical enhancements (Also, P’)
   V = Variation on demo observed on videotape
   D = Other demos dealing with the concept addressed
   DV = Variations on another demo, D.
   L = Lab on air pressure or density
   Act = Activity for students, usually individual or group seatwork
   Ds = Class discussions
   E = Erroneous demo on the targeted concept
   U = Pedagogically unsound demo on the targeted concept
   Neb = Nebulous reference to a demo on the targeted concept

   X = Sum of (L, Act, Ds, E, U, Neb) items
   X+ = Sum of (L, Act, Ds) items
X- = Sum of (E, U, Neb) items
Appl = Application of the targeted concept
CC = Concept Correction (See Section C.)
P, V, L, E...(Repeted) = Same comment/idea mentioned more than once in the protocol.
C. Extended Instructions for Coding the Protocols of the Critical-Stop Task

1. Since the think-aloud protocols (discussed in section A) contain numerous suggestions for Pedagogical enhancements, P and P', the think-aloud protocols should be re-coded in order to determine the number of P's embedded in the text. P and P' statements and thoughts should be reasonably explicit. Tally the total number of P and P' comments on top of the first page of these protocols.

2. Occasionally the videotaped demonstrator makes an erroneous statement about the chemistry/science associated with the demonstration. These comments may be spotted and critiqued by the research subject. These critiques should be coded "Wk" for weakness. If the subject states the correct conception that should have been made, code these comments as CC, e.g., CC 1. (Do not code these as P's).
APPENDIX P

Instructions to the Coder for Coding the Protocols of the Critical-Stop Task and Follow-up Interview

(Part III: Encoding GPK, PCK, & Content Categories)

Goal: As a coder for this study, you will be coding several protocols that reflect teachers' pedagogical knowledge of chemical demonstration teaching. The protocols were obtained from two methods of probing teachers' knowledge, namely, from a think-aloud critical-stop task and a follow-up interview. The protocols generated by each method have identical coding instructions.

A. General Instructions

To assist you in coding teachers' think-aloud comments of effective and ineffective chemical demonstrating, you will first view a videotape of a science teacher conducting a chemical demonstration. The videotape will let you become familiar with what the research subjects (chemistry and physical science teachers) were critiquing. After viewing the videotape, you will be given protocols containing teachers' critiques of the videotaped demonstration and their responses to several follow-up questions. The objectives in coding the protocols is to code teachers' comments in terms of (i) nine pre-defined content categories and (ii) two pedagogical knowledge systems, i.e., Pedagogical Content Knowledge (PCK) and General Pedagogical Knowledge (GPK). Here are some specific directions to assist you.

B. Instructions for Classifying Statements into Content Categories

1. Begin by viewing Videotapes #3 showing a teacher performing the Density Column demonstration. You will be given a script of the videotaped demonstration to assist you in the listening task. Assume that this and all other videotaped demonstrations are geared towards the middle school student. Videotape #3 represents one of four videotapes the teachers critiqued.

2. After viewing the videotape, read through the critical-stop protocol supplied to you by the researcher. This protocol tells you what was said by a research subject, a chemistry of physical science teacher, during the think-aloud critical-stop task. In this task the teacher discusses strengths and weaknesses he/she observes at critical points during the videotaped presentation.

3. Each critical stop is identified with the abbreviation, CS, and a number. For instance, "CS. 3" stands for Critical Stop #3. The critical features and suggestions for improvement discussed during the critical stops have already been identified for you by two
independent coders and are separate by paragraphs in the verbatim transcripts.

4. Read through the protocol a second time and encode each critical feature and suggestion for improvement into one of the following nine pedagogy categories using the numbers 1 - 9 derived from the outline below.

1. Investigative, Inquiry Approach

a. Deals with higher-order questions related to science processes. These process questions include predicting, hypothesizing, and inferring the outcomes of a chemical demonstration. They also include questions where the teacher asks students to provide a scientific explanation for the demonstration outcome or to predict the purpose of using certain materials during the demonstration. It includes questions where the teacher asks students to come up with evidence to support their hypotheses or solutions to a scientific problem or phenomenon posed by the demonstration.
b. It also includes issues related to having students predict the identity and location of chemical substances based on their power of observations and prior knowledge of these substances. It also includes issues where the teacher purposely keeps the identity of chemical substances from students so that students, at some point, can exercise their science process skills.
c. This category deals with issues related to a teacher providing too many answers and forecasting the outcomes by asking poor questions. It also includes the issue of the teacher forecasting the concept being addressed by the demonstration. It also deals with the importance of students drawing conclusions.
d. Comments about having (asking) students perform basic sight observations from their seats are also included here (Lower-order science process questions). If, however, one or more students are asked to come forward to make close-up observations, then the comment is placed in category 5 (Interactive, participatory style).
e. Also deals with questioning strategies such as wait time, feedback, leading questions, fielding questions, and follow-up process questions regarding these process questions. It includes statements about teachers modeling science process behaviors.
f. Comments related to the failure of a teacher to perform, or have students perform, any of these process skills are also included in this category.

2. Questioning Strategies

a. Deals with questions about students' prior knowledge and comprehension of science terms, concepts, and experiences.
b. Deals with follow-up questions about how various science concepts are related to the demonstration after the correct
concept has been predicted by a student or has been openly declared by the teacher.

c. Also deals with questioning strategies such as wait time, feedback, leading questions, how these questions are phrased, fielding questions, and follow-up questions regarding these knowledge and comprehension questions. These questions do not require the use of basic science process skills (i.e., observing, smelling, feeling) to answer.
d. Explaining new science terms, concepts, and explanations are placed into Categories C and D, respectively.

3. New Terms

a. Deals with statements which require the teacher to define or clarify terms that may be new or not very meaningful to middle school students in a science class. This category includes statements about the level of attention given to new term that needs defining. It also includes basic definitions for scientific concepts that may be new to students.
b. It includes statements about deleting terms that are inappropriate or irrelevant at the middle school level. It also includes suggestions for using simpler, or alternative terms.
c. It also includes errors and omissions in providing a basic definition for a new term or concept word.

4. Clarifying an Explanation

a. Statements that deal with the need for the teacher to clarify, elaborate, or explain scientific concepts (beyond a basic definition), generalizations, and demonstration procedure associated with the presentation. The focus is not on defining new terms (Category 3) as much as it is on explanations of how a new term/concept is and is not related to others.
b. It includes how teachers use student experiences to clarify the concept being addressed. It also includes statements about how other demonstrations can illustrate the same concept.
c. It includes errors and omissions made by the teacher in conveying scientific concepts and generalizations, as well as, deleting explanations that are inappropriate or irrelevant to the topic at hand. It also includes communicating to students the difficulty of a given concept.
d. Explantions associated with transitions to new topics are not included here. This would be classified into Category 8 (Organization).
5. Interactive, Participatory Style

a. Deals with matters involving student hands-on involvement in a demonstration. Also includes the use of student volunteers/student assistants to make close-up observations, recording of observations on blackboard, etc. (Comments about having students make observations from their seats are coded into Category 1, Inquiry Approach).

b. This category also refers to student participation in class discussions in response to a series of teacher questions (more than one) that promotes continuous verbal interaction between teacher and students. General statements about classroom interactions and getting the class to respond to teacher questions on content or process are also included.

c. It does not refer to a single response obtained from a single content or process question unless the teacher prompts the class to additional responses from several students. Comments about specific questions would be placed into Category 1 or 2.

6. Mechanics of Demo

a. Statements about how to streamline the mechanics of presenting a particular demonstration. It includes issues related to (i) visibility, (ii) handling the equipment and materials, (iii) safety considerations, and (iv) modeling good psychomotor laboratory skills. Also includes descriptions of other demonstrations that can address a given concept.

b. It deals with how to do the demo, but not with the pace of presentation. Pacing of presentation and its mechanics is considered an Organizational issue (Category 8).

7. Use of Blackboard/Visual Aids

a. Deals with the effective and ineffective use of blackboards, overheads, and related visuals during a demonstration to clarify new terms, record observations, and illustrate the demonstration system.

b. Issues related to the use or failure to refer to blackboard information while summarizing the demonstration presentation is considered an Organizational issue (Category 8).

8. Overall Organization

a. Includes statements about the sequence of events presented in a demonstration. Also includes statements about the best placement of questions, new terms, and concepts during a demonstration.

   Includes the issues of how to sequence various mechanical aspects of a demonstration, what to include, and what to delete. Also deals with the appropriateness of the observed demonstration to illustrate the targeted concept as well as
the sequencing of different demonstrations over time with respect to the targeted concept (unit planning issue).
b. Also includes logistic issues such as the location of demonstration equipment and visual aids. It includes issues of pacing of the demonstration and explanations. Matters that pertain to transitions and relating various parts of the demonstration to each other are also relevant.
c. Includes statements about purpose of demonstration and motivational strategies. Also includes introductions to set up lesson and get students attention (e.g., hidden signs or equipment).
d. Also addresses matters pertaining to closure, i.e., especially tying key aspects of the demonstration presentation together at the end. Adding extra information (e.g., concept examples) to a closure would be coded into Category 4 (Clarifying an Explanation).

9. Presentation Style

a. Deals with verbal and nonverbal teacher behaviors that relate to personality, gestures, demeanor, rapport, recurring teacher movements, and eye contact. It also deals with the matter of showing respect for students and student volunteers, such as use of students' name.
b. Do not code 'Use of volunteers' in this category. It belongs in Category 5.

5. The Codes are summarized below:

1: Investigative Inquiry Approach
2: Questioning Strategies
3: Clarifying New Terms
4: Clarifying an Explanation
5: Interactive Participatory Style
6: Mechanics of Demonstration
7: Use of Blackboard
8: Overall Organization
9: Presentation Style

6. You may find that several critical comments are repeated more than once, especially when demonstrators identify similar critical incidents, such as recurring patterns in teacher's questioning behaviors or in dealing with new vocabulary terms. Code repeated comments independent of the next since the context may be different. Identical critiques elicited during different portions of the videotape that are associated with different terms or questions are not considered "Repeats".

7. Critical features and suggestions for improvement have been identified for you and separated by paragraphs in the verbatim transcripts. You will find that a number of critical features
appear as though they could be coded into more than one category. In cases showing multiple encoding possibilities, enter each possibility (code number) in the space provided and circle the number which best fits the entire paragraph. If you come across a situation where the coding is truly a toss-up and the comment appears to give equal emphasis to two categories, code it with the lower of the two code numbers. Issues mentioned first are of slightly greater interest to this researcher. Consider this option only if you really cannot decide on what the overall emphasis of the discourse appears to be.

8. Underline the key term or phrase in each paragraph that helped you make the coding choice(s). When you encounter situations with multiple coding possibilities, try to limit yourself to one underline per coding category.

9. You may use the videotape script as a resource to help you remember the context of the subject’s comments. Even though this researcher has attempted to provide you with some contextual information in the verbatim transcripts using bracketed [] statements, you may find the scripts helpful as you encode the data.

10. Follow the procedure described above (Steps 1 - 9) to code the think-aloud task and follow-up interview protocols that correspond to teachers’ critiques of Videotapes #1, #2, and #4.

11. Remember, to code teachers’ comments as best you can, realizing that in some instances coding won’t be easy. If you have any uncertainty regarding the coding of a particular statement, make a comment describing why you had the difficulty somewhere in the margins next to the statement.

12. In addition to coding selected verbatim protocols, you will also be coding one-line summary statements of several critical features.
C. Instructions for Coding Statements Representing Chemical Demonstrators’ Pedagogical Knowledge Systems

1. Classify each paragraph in the protocols according to whether it represents Pedagogical Content Knowledge (PCK) or General Pedagogical Knowledge (GPK). A literature-based description of each of these knowledge systems is provided in steps 6 and 7 below.

2. Enter the code letter PCK or GPK in the space provided next to each critical-stop number in the transcript (e.g., CS 1. ___ ). Some critical stops have several spaces to code multiple entries (e.g., CS 3. ______ , ______ , ______ ). Each space needs an entry and corresponds sequentially with the paragraphs in the critical-stop discourse, e.g., first space receives code for first paragraph, second space for second paragraph, etc. Each space should already contain a number from 1-9 based on the coding described in section B. The paragraphs that you will be coding represent critical features (Strengths & Weaknesses) or suggestions for improvement (P’s) that have been identified by other coders.

3. If a given paragraph seems exceptionally difficult to code into the PCK or GPK category, code such comments as SM or NC (discussed in step 4).

4. If a given comment has absolutely nothing to do with pedagogy, consider coding the discourse into one of the following categories: Subject Matter Knowledge, (SM), or "No Code", N. With many critical features, you will find that a demonstrator’s critical-stop discourse addresses more two or more knowledge system, e.g., pedagogical content knowledge, subject matter knowledge, and knowledge of the learner. Since the focus of this study is on pedagogical knowledge, each paragraph should be be coded as PCK, GPK if at all possible. Do not use the codes (SM or NC) if a pedagogical knowledge code can be provided. A brief description of coding categories, SM and NC, are provided at the end of these instructions and should be used only if this is the only thing a demonstrator talks about in a given discourse. Code NC is reserved for situations where the comment cannot be encoded into any category (PCK, GPK, SM). Code NC frequently applies to nebulous, confusing, and incomplete statements.

5. Remember to enter one code letter for each paragraph in the verbatim transcript. Use the space provided to make your entries. Tally the total number of features identified as PCK, GPK, SM, and NC on the top of the subject’s protocol sheet. If you think that a given paragraph needs two codings, e.g., one code for the first half and another code for the second half of the paragraph, please separate each half of the paragraph with a slash (/).
6. Pedagogical Content Knowledge (PCK) -

a. "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding." "It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction." (Shulman, 1987; p. 8).

b. Knowledge of how to teach the subject matter. Includes how to present the idea, what materials to use, how to sequence those materials, and what misconceptions the students have about the topics of interest (Wilson & Gudmundsdottir, 1986, p. 8).

c. Subject matter knowledge for teaching. Pedagogical content knowledge still speaks of content knowledge, but the particular form of content knowledge that embodies the aspects of content most germane to its teachability (Shulman, 1986).

d. Within the category of PCK, for the most regularly taught topics in one's subject area, includes:

(i) the most useful forms of representation of those ideas,
(ii) the most powerful analogies,
(iii) illustrations,
(iv) examples,
(v) explanations, and
(vi) demonstrations (Shulman, 1986).

e. In other words, the WAYS of representing and formulating the subject that makes it comprehensible to others (Shulman, 1986).

f. It also includes an understanding of what makes the learning of specific topics easy or difficult: students' misconceptions and knowledge of strategies to reorganize the understanding of the learner (Shulman, 1986).

g. Not separating content from how to teach it (pedagogy); (Shulman, 1986, p 6).

h. Subject and topic-specific pedagogical knowledge associated with the subject matter.

Content-specific pedagogical knowledge =

is equivalent to pedagogical content knowledge (PCK).

i. Researcher's note - Teachers' comments must reflect pedagogical knowledge (i.e., subject-matter representations) that is unique to the teaching of density and air pressure before it qualifies
as pedagogical content knowledge. Knowledge of inappropriate subject-matter representations would also be included in this category.

j. Discussions on "check for understanding of content during interactive teaching" also qualifies as PCK (Shulman, 1987, p. 19). It represents another way pedagogical content knowledge is used.

7. Examples of Pedagogical Content Knowledge (PCK)

Several examples of PCK codings are now provided using examples obtained from the critical-stop task. The examples cover many of the nine content categories described in Section B (Instructions for Classifying Statements into Content Categories). Each example is followed by a rationale for coding the discourse as PCK. Reference to the particular definition of PCK given in Step 6. [a-h] are provided in brackets following the explanation.

I. Inquiry, Investigative Approach

"My main gripe with her ... is the questioning. It seems as if she is not trained to use inquiry. And not that I think inquiry is it, but as far as demonstrations go, it is it! I mean, you don't want to tell them the whole answer and then say, 'Here it is!' ... She could set up her column but then get another column ready and ask the kids, 'What's going to happen when she puts the different substances in?' Or, if - she could have them all different colors, saying, 'If I want to come up with this particular format, what would I put in?' something like that." (E2, VT #4)

In this example the demonstrator realizes that the videotaped model uses very little inquiry in her demonstration teaching. She suggests that students should be given an opportunity to figure out how to reconstruct a given density column from its component parts once they have seen the original demonstrated. This demonstration enhancement is specific in its description and exemplifies this demonstrator's pedagogical content knowledge (PCK). [Definition: 6.d.(vi)]. Consider also the following example.

"This is a strength. Here again he is being interactive with the students, asking them to make hypotheses [about the identity of the liquids in the column (S:66)], and then following up with, 'How would we know if that were true?'. In this particular case, he asked them a very broad question, 'What liquids might be in the container?' which they probably don't have a whole lot of experiences for, but [the students provide a] couple guesses, and then he follows it up with,
'Well, how can we determine it, if those guesses are in fact valid?'" (S:69). (E3, VT #3)

In this example the videotaped model is asking students to support their hypotheses about the identity of the three liquids they observed in the density column (inquiry). He indicates that it is important in chemical demonstration teaching to have students support their guesses of "mystery" substances used in the demonstration. The teacher critiquing this segment of the demonstration makes a comment that reflects his knowledge of subject matter, questioning skills, and knowledge of the learner. It is therefore coded pedagogical content knowledge (PCK). [Definition: 6.j.].

II. Questioning Strategies

Subject matter knowledge and comprehension questions are usually coded as pedagogical content knowledge. Such comments related to 'check for understanding' definition given by Shulman (1987).

"One of the weaknesses I saw was that he never answered the [student] who said, "Weight per unit volume", and I think I was left with the idea of, maybe [the student's answer], 'weight per unit volume' was right but maybe it wasn't. But he certainly grabbed on to the [answer] "mass per unit volume", so that one is right." (E5, VT #3)

In this example, a comment is made about the videotaped model providing ambiguous feedback to a student answering a question about the definition of "density". Feedback related to specific subject matter questions is considered pedagogical content knowledge (PCK). [Definition: 6.j.].

III. New Terms

"I'm going to stop [the videotape] again because he's saying that he's not going to talk about phenolphthalein, but this part of the demonstration is predominantly on phenolphthalein and what it does and does not do; and it really does not have much to do with the problem of density." (E1, VT #3)

This demonstrator discusses the inappropriateness of discussing 'phenolphthalein' with middle school students (a chemical used to make one of the density column layers visible) when the focus of the demonstration is on density. This comment reflects this teacher’s pedagogical content knowledge because it relates to knowledge of the most powerful (and ineffective) explanations of a given science concept. [Definition: 6.d.(v)].
"Then he writes it out on the board as, 'mass over volume'. O.K., now for a middle school group he has just taken a quantum leap past them, looking at the middle school. He should of said, 'Mass per unit of volume.' I would, for the audience your aiming at here, try to say, 'What do I mean by: unit of volume?'" (E4, VT #3)

In this example, the demonstrator discusses the appropriateness of the 'mass over volume' term in the definition of density. He suggests that the use of more concrete terms provides a better explanation of density at middle school level. This exemplifies pedagogical content knowledge (PCK) because it talks about the teacher's knowledge of appropriate and inappropriate explanations of the density concept. [Definition: 6.d.(v)].

"That was good. There might have been some people who didn’t know what an interface was so he bothered to take the time to define that word." (E1, VT #3)

The issue here relates to the importance of the teacher defining a new science term 'interface'. This comment reflects knowledge of students, content, and pedagogy and therefore codes as PCK. [Definition: 6.d.(v)].

IV. Clarifying an Explanation

"This is real good here. He's tying this concept [density], which they've had the word that defined it, and talked about it in reference to this particular system, and now he is applying it to something that the students are more likely to know about, oil on water, in a boat - in a lake situation." (E3, VT #3)

This teacher's critique relates to the value of discussing the application of the density concept to students' lives once the chemical demonstration has been performed. Such illustrations of density will presumably help clear up students' understanding of the concept of density. [Definition: 6.d.(iii)].

V. Interactive, Participatory Style

"Well, he could have maybe set up one of those ethanol and water, with the food coloring to pass around to the kids while he was doing this, although, sometimes when you pass things around in the class and you are trying to something in front of the class, that could be a diversion but he could have pulled that out first." (E1, VT #3, S:76)
In this example the demonstrator suggests that it would be appropriate to pass around miniature density columns to the students in the class so they could have hands-on experience with the demonstration and make observations up close. This specific suggestion for improving the demonstration would be coded as pedagogical content knowledge (PCK) since it provides an unique variation in demonstrating the density concept. [Definition: 6.d.(vi)].

"It would be nice, before he'd go on - he gave one example from the students' lives, and he volunteered it. It would be useful to come to closure on the topic if he had also drew out from the students more experiences of density that have in their life, just to help come to closure on it would have been nice." (E2, VT #3)

This demonstrator makes the suggestion of having the class provide additional examples of the application of density to the students' lives. He appears to know enough about the chemical concept, pedagogy, and middle school students to know that this is an important teaching strategy to pursue with the density concept. It illustrates this teacher's pedagogical content knowledge (PCK). It would be considered PCK even though a specific application example was not provided with the discourse. He does acknowledge that it is needed when teaching the concept of density as, thus, reflects a fundamental pedagogical content knowledge. [Definition: 6.d.(v)].

VI. Mechanics of Demo

"You should make sure that people have an understanding of the comparisons between densities of single substances such as a rock and a piece of styrofoam the same size." (E5, VT #3)

This demonstrator provides a description of another demonstration that can illustrate the targeted concept (e.g., density), namely, the hand-weighing two different solids of the same size. These examples strike at the heart of pedagogical content knowledge. [Definition: 6.d (vi)].

"One approach to use with a demonstration that is a little less investigative but good is to just be honest with people up front what the concept is that you are going to be teaching. In this case here, he's verbalized that "one of those concepts involves density." (S:2), and he also put it on the board so he can associate that with what he is going to be showing them with the actual label, the name and the label for the concept." (E3, VT #3)
In this example the demonstrator remarks that it is good to use the blackboard for new terms, such as 'Density'. Writing new terms on the board reflects pedagogical content knowledge, because the subject knows enough about this chemistry term and his students' understanding of that term that warrants visual reinforcement (pedagogical content knowledge). [Definition: 6.d.(iv)].

VII. Use of Blackboard/Visual Aids

"Here, it would be preferable - he's identified these layers - it would be preferable if he had a physical drawing on the board or an overhead that indicated the different liquids relative to the actual set-up so people have a direct visual of it, rather than just his words that, "Well, water is here and methanol is here." (E5, VT #3, S:97)

The case of having insufficient visuals of the physical system drawn on the blackboard reflects PCK (knowledge of the complexity of the system which makes a visual of the system mandatory). [Definition: 6.d.(iv)].

"And I think I would like to see some visual rather than abstract sketches on the board. The thing he put on the board were pretty much words whereas a few sketches of how equal masses of material might have varying volumes [would be constructive]." (E5, VT #3, S:15)

Here, a demonstrator makes the suggestion of using the blackboard to diagram two objects of equal mass and different volumes to help explain the concept of density. This example further helps represent the concept of density to middle school students. [Definition: 6.d. (iv)].

VIII. Overall Organization

"This choice of a demonstration [the Density Column] at this point is inappropriate. Certainly density is a difficult topic. You should not start with a complicated system where you have a mixture of different densities." (E5, VT #3)

This demonstrator mentions that the observed chemical demonstration is too complex to introduce students to density. This comment reflects this demonstrator's knowledge of the appropriateness of a given demonstration to teach the concept of density to middle school students and represents pedagogical content knowledge (PCK) of how particular topics are organized in light of the ability of the learners. [Definition: 6.a]
IX. Presentation Style

Coded GPK.

8. **General Pedagogical Knowledge (GPK)** is now defined based on common usage in the education literature.

a. Knowledge of generic principles or methods of classroom organization and management. The focus of much research on teaching (Shulman, 1986). These organizational and management issues include:

(i) maintaining order,
(ii) maintaining equity in the distribution of teacher time among students,
(iii) considering the number of students who can work on a given task appropriate for them,
(iv) the amount of student-student interaction, and
(v) timeliness, or how to get to each student in time (Cohen, Intili, and Robbins, 1979).

Management skills also include:

(i) procedures for controlling student movement and student talk,
(ii) ensuring smoothness and momentum,
(iii) cuing and signaling,
(iv) managing inappropriate and disruptive behavior,
(v) projecting confidence,
(vi) using rewards and punishment, and
(vii) establishing rapport with students (Arends, 1988, pp. 245 and 541).

b. Knowledge of general pedagogy. This pedagogical knowledge is distinct from subject matter. (Shulman, 1987)

c. Knowledge of pedagogical principles and techniques that is not bound by topic or subject matter. (Wilson, Shulman & Richert, 1987, p. 114). Such principles and techniques include:

(i) verbal and nonverbal communication skills such as
- encouraging participation,
- listening to students,
- promoting discourse, and
- signaling,

(ii) presenting information using techniques such as
- determining prior knowledge,
- establishing set,
- speaking clearly,
- using advanced organizers, and
- using enthusiasm,

(iii) Questioning skills such as
- using different difficulty of questions,
- using different levels of questions,
using wait time, and
providing feedback (Arends, 1988, p.xv-xvi).

9. Examples of demonstrators' comments reflecting general pedagogical knowledge (GPK).

I. Inquiry, Investigative Approach

"Also, I think he was asking students for very simple tasks such as you know, "'What do you see? What do you observe?'" Most of the explanations seem to come from the demonstrator. I personally like to present students with problems and ask them to come up with solutions from their observations which I think is a higher level teaching strategy." (E5, VT #3)

In this example the demonstrator makes a statement about his preferred teaching strategy which is to have students use their observational skills to solve problems rather than to simply describe objects. This comment is not content dependent (although it can be inferred) and can therefore be coded as general pedagogical knowledge (GPK). [Definition: 8.c.(iii)].

II. Questioning Strategies

"He is good at accepting people's answers all the time." (E2, VT #3)

This brief critical comment refers to the videotaped teacher's ability to be open and accepting of students' answers in a way that promotes continued student response to teacher questions and shows general enthusiasm for teaching. The comment is coded general pedagogical knowledge (GPK). [Definition: 8.c.(ii)].

III. New Terms

"Now, [after completing the demonstration] he defines terms ... which was good. He's summarizing up some of the observations, so he's defining terms to make sure that everybody is on the same wavelength." (E4, VT #3)

Here the demonstrator points out that the videotaped teacher defined new science terms at the end of the demonstration just in case someone in the class didn't know their meaning. Such comments reflect general pedagogical knowledge because it reflects the issue of closure and reinforcing major points in a presentation. [Definition: 8.c.(ii)].

I did not notice any indication in this discourse about which science terms needed to be stressed during closure and which did not. Had this issue been addressed it would have been
coded PCK. The critical comment appears to be a general reference to the importance of summarizing new terms, almost irrespective of what they may be.

IV. Clarifying an Explanation

"He’s explaining his procedure real well, here." (N1, VT #1)

Here, a demonstrator makes a brief comment about the appropriateness of verbalizing the procedural steps while performing a chemical demonstration so that students can better follow what is going on. This comment has little emphasis on science content. It can therefore be coded as general knowledge of pedagogy (GPK). [Definition: 8.c.(ii)].

V. Interactive, Participatory Style

"Here he involving students. Rather than him just talking and showing, he’s already asked students for their input [student observations on density column]. And in this case he is having one student be a recorder for him which makes the class more involved." (E3, VT #3)

This comment talks about the videotape teacher asking the class to make observations and using a student recorder to keep track of students’ observations, two effective general pedagogical strategies. [Definition: 8.c.(i)]. This item could be coded pedagogical content knowledge (PCK) if one assumes that this demonstrator was stressing the importance of student involvement in demonstrating the density column system, in particular. The comment appears to be more general in nature, however. The comment about using a student recorder during the demonstration is more clearly a general pedagogical issue (GPK).

VI. Mechanics of Demo

I could not find a good example of a mechanics issues that would also be considered a generic teaching skill. Such codes may be appropriate for some discourses, so use your judgment. Comments in this category were usually coded PCK (e.g., what materials to use to teach a given concept) or No Code, if they dealt with manipulative or psychomotor issues.

VII. Use of Blackboard/Visual Aids

"That’s always good. ... His writing is big enough on the board so everybody can see it." (E2, VT #3)
Comments related to issues such as the legibility of teacher's boardwork is related to general pedagogical knowledge. [Definition: 8.b.].

VIII. Overall Organization

"One of the weaknesses is that he seems to be continually walking from the front to the back of the bench and he was asking the questions and he knew he was going write them down. He probably should have stayed at the back." (E5, VT #3)

This organizational comment about the teacher's movement around the class is generic in nature. [Definition: 8.a.(v)].

IX. Presentation Style

"He gave a good introduction. Nice and clear. His volume is up. And he's looking around like he is looking at every one in the class and not just talking to himself." (E2, VT #3)

In this example, a demonstrator talks about having good volume and good eye contact while performing a chemical demonstration. These comments reflect knowledge of general pedagogical skills, in particular, to the importance of speaking clearly and establishing rapport, issues that are content-independent. [Definitions: 8.a.(vii) and c.(ii)].

12. Sometimes the difference between the pedagogical knowledge system used in demonstrators' critical-stop discourse (PCK & GPK) is reflected by the degree of specificity provided in the critical-stop critique. Consider the context of the explanation given in the video script supplied to you.

13. If a critical-stop comment definitely does not fit into category PCK or GPK consider whether it might be coded into the following two categories (or knowledge systems):

14. Subject Matter Knowledge (SM)

a. Understanding of the facts or concepts within a domain.

b. A grasp of the structures of the subject matter (Wilson, Shulman and Richert, 1987, p. 113). The ways in which the fundamental principles of a discipline are organized. Knowledge of the syntactic structure of a discipline - the canons of evidence and proof that guide inquiry in the field.
15. **No Code**

For items that do not fit into the categories PCK, GPK, or SM, simply register a "No Code" or "NC" entry.

16. **Summary of Knowledge Coding Symbols**

- **PCK** - Pedagogical Content Knowledge
- **GPK** - General Knowledge of Pedagogy
- **SM** - Subject Matter Knowledge
- **NC** - No Code
### Critical-Stop Task Frequency Scores for Experienced and Novice Chemical Demonstrators Examining Four Videotapes

#### Tables Q.1

#### Videotape #1 (AP, +)

**Favorable Model**

<table>
<thead>
<tr>
<th>Subject</th>
<th># Str.</th>
<th># Weak.</th>
<th># S + W</th>
<th># Crit. Stops</th>
<th>Overall Rating</th>
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<tbody>
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<td>E4</td>
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</tr>
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<td><strong>15.2</strong></td>
<td></td>
</tr>
<tr>
<td>Novice Pre-training</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
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Tables Q.2

Videotape #2 (AP, -)

Unfavorable Model

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### Tables Q.3

**Videotape #3 (Density, +)**

**Favorable Model**

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**Novice, Pre-training**

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<td>4</td>
</tr>
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**Novice, Post-training**

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<th># S + W</th>
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Tables Q.4

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</tr>
<tr>
<td>E1</td>
<td>11</td>
</tr>
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<td>E3</td>
<td>2</td>
</tr>
<tr>
<td>E4</td>
<td>6</td>
</tr>
<tr>
<td>AVE.</td>
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</tr>
<tr>
<td>Novice, Pre-training</td>
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</tr>
<tr>
<td>N5</td>
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<td>N7</td>
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</tr>
<tr>
<td>N8</td>
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<tr>
<td>N1</td>
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<td>N2</td>
<td>13</td>
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<td>N3</td>
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<tr>
<td>N4</td>
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<tr>
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</table>
### Table Q.5

**Summary Of Critical-Stop Task For Videotapes #1-4**

by Two Groups of Chemical Demonstrators

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<th>SUBJECT</th>
<th># Str.</th>
<th># Weak.</th>
<th># S + W</th>
<th># Crit. Stops</th>
<th>Overall Rating</th>
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</thead>
<tbody>
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<td><strong>Air Pressure</strong></td>
<td></td>
<td></td>
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<tr>
<td>Videotape #1 (+):</td>
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<tr>
<td>E</td>
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</tr>
<tr>
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<td></td>
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<td>E</td>
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</tr>
<tr>
<td>N (Pre)</td>
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<td>3.8</td>
<td>7.5</td>
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<tr>
<td>N (Post)</td>
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<tr>
<td><strong>Density</strong></td>
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<tr>
<td>Videotape #3 (+):</td>
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<td>E</td>
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<td>10.0</td>
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<td>N (Pre)</td>
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<td>16.5</td>
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</tr>
</tbody>
</table>

**Notes.**

(1) "Str." refers to critical features judged as strengths.
(2) "Weak." refers to critical features judged as weaknesses.
(3) "S + W" refers to sum of critical features judged as strength or weakness.
(4) "+" and "-" refer to more and less favorably rated videotaped performances of a given demonstration, respectively.
APPENDIX R

Frequently Cited Critical Features Identified by Experienced and Novice Subjects

Key.

Exp (#): for experienced chemical demonstrators critiquing Videotapes #2 and #3, two subjects does not constitute a majority.


#1.+ Asking students to support their hypotheses. S:46-50. (Exp: E2, E4)
#1.+ Good comprehension question requiring students to explain what is happening inside the can while it is heating. (S:33e). (Pre: N7; Exp: E1, E4)
#1.+ Questioning the student to get him and class to think about what caused the first can to crush. S:17-24. (Pre: N6, N7; Post: N1, N3)

#3.+ Asking students to make observations about density column. S:17-45. (Exp: E1, E3, E4)
#3.- Guessing of liquids is inappropriate/unimportant. S:69. (Post: N5, N8)

#4.- Affirming students' answers/prediction before demonstrating. (S:38-45). (Pre: N7; Exp: E2, E4)

#4.- Not getting the entire class to predict sink or float outcomes. S:38,48,119. (Pre: N7, N8; E2)

B. Questioning Strategies  [Pre: 4  Post: 2  Exp: 3]

#2.+ Good follow up question to student’s response (greater than what?). S: 31-48. (Pre: N1, N3; Post: N7, N8; Exp (#): E2, E4)

#3.+ Asking students to volunteer their knowledge of density term. (S:3). (Pre: N1; Post: N5; Exp: E1, E2, E3, E5)
#3.- Inappropriate feedback to student’s answer. (S:7). (Pre: N1, N2, N3; Post: N5, N7; Exp: E1, E2, E4, E5)
#3.+ Probing prior experiences. (S:70). (Pre: N1, N3)

#4.- Insufficient wait time when asking students about the meaning of phrase "larger density". (S:30). (Pre: N5, N7; Exp: E2, E3)

#3.- Inappropriateness of (or insufficient attention to) 'mass and unit volume' terms in definition of density. S:13. (Pre: N1, N3, N4; Exp (#): E2, E4)

#3.- Insufficient attention to 'interface' term when first mentioned. S:42. (Pre: N1; Post: N8; Exp (#): E2, E3)

#3.+ Defined interface term later in demo. S:63. (Pre: N1; Post: N6; Exp: E1, E2, E4)

#3.- Phenolphthalein term is either irrelevant, given insufficient attention, or appropriate. S:81. (Pre: N2+, N3; Post: N5; Exp: E1, E2, E3)

#3.- Inappropriate to introduce 'solubility' term. (S:85). (Pre: N3; Post: N5; N6)

#4.- Using fingers to illustrate the size of a cubic centimeter is ineffective. S:15-16. (Post: N1; Exp: E1, E3, E4)

#4.- Lack of clarity in defining 'density'. S:8,10. (Pre: N7, N8; Post N4)

D. Clarifying an Explanation [Pre: 4 Post: 7 Exp: 2]

#1.+ Referred back to prior demo to provide conceptual explanation of can's collapse. S:55. (Pre: N7, N8; E1)

#2.+ Good explanation of phenomenon. (S:44). (Pre: N2; Post: N6, N7, N8)

#2.+ Posing a perplexity about not feeling air pressure. S:10-15. (Post: N5, N7; Exp (#): E1, E4)


#3.- Inappropriate concluding generalization: solids generally more dense than liquids. S:92. (Post: N7, N8; Exp (#): E4, E5)

#3.+ Applying density concept to student experiences. S:76. (Pre: N2; Post: N5, N7; Exp: E1, E2, E3, E5)

#4.- Inaccurate statement about corn syrup (mis-speak). S:76. (Post: N1, N2)

#4.+ Clarifying/confusing statement that identical relative density does not mean identical absolute density (penny/stopper) S:108,111. (Pre: N7-; Post: N1, N2)

#4.- Overemphasis on scientists and their units of measure. S:9-14. (Pre: N1, N3; Post: N5, N7; E2)

#4.- Inaccurate statement (weight of rubber is heavier than water). S:44e. (Exp: E2, E4)

#4.- Using 'weight' and 'mass' interchangeably. S:9,22. (Post: N1; Exp: E2, E3)

#4.- Interchanging 'heaviest' and 'density'. S:87-95. (Pre: N5, N8; Post: N1; E3)

#4.- Insufficient explanation of how density values are derived. S:21, 109. (Pre: N6, N8)
E. Interactive Participatory Style  [Pre: 2  Post: 1  Exp: 2]

#1.+ Using a participant (to crush can).  S:4-8.  (Pre: N7, N8;  
    Post: N4;  Exp: E1, E2, E3, E4)

#3.+ Used student recorder.  S:25.  (Pre: N2, N4;  Post: N5,  
    N8;  Exp: E1, E2, E3, E4)


#2.- Big tongs could crush the can.  S:25-29.  (Post: N5, N8)

#3.+ Used white background.  S:19.  (Pre: N2, N3;  Post: N6;  
    Exp: E1, E3, E4, E5)

#3.- Density column difficult to see.  S:17-49.  (Pre: N3;  Post:  
    N5, N8;  Exp (#): E2, E3)

#3.+ Hand obscured top of cylinder, but later corrected.  S:38-47.  
    (Post: N5, N7, N8;  Exp: E2, E3, E4+)

    (Exp: E2, E4)

#4.- Cylinder too small and difficult to see.  S:51-99.  (Exp:  
    E2, E4)

#4.+ Use of food color to enhance visibility.  S:51-55.  (Pre: N7;  
    Post: N2;  Exp: E1, E2, E4)

#4.- Insufficient visibility of colors.  S:52-90.  (Pre: N8;  Post:  
    N2;  Exp: E2, E4)

#4.- Confusion in using different size solids.  S:109, 112.  
    (Post: N3, N4)

G. Use of Blackboard/Visual Aids  [Pre: 2  Post: 0  Exp: 1]

#2.- Lack of physical drawings of system.  S:44.  (Post: N8;  
    Exp (#): E3, E5)

#3.- Lack of visuals to illustrate density concept on blackboard.  
    S:95.  (Exp (#): E3, E5)

#3.+ Good to record students’ observations on board.  S:38-49.  
    (Pre: N3, N4)

#4.+ Listed all demo chemicals on board.  S:6-18.  (Exp: E1, E3)

#4.- Missing "0" as a placeholder in .8; should be 0.8.  S:31, 43.  
    (Pre: N7, N8)

H. Overall Organization  [Pre: 1  Post: 6  Exp: 1]

#1.+ Title of demo is catchy.  S:3-4.  (Pre: N5, N7, N8)

#1.+ Hand-crushing a can is an effective intro to air pressure 
    demo.  S:16-20.  (Post: N1;  Exp: E1, E3)
Good relevant intro of air around us. S:1-11. (Pre: N3; Post: N5, N6, N7, N8; Exp (#): *E4, E5)

Extended silence while waiting for secretary. S:38. (Pre: N1, N2+; Exp (#): E1, E2)

Introducing two concepts at once. S:3. (Pre: N3; Post: N8; Exp (#): E1, E4)

Awkwardness of walking around the demonstration table. S:3. (Pre: N2; Post: N7; Exp (#): E1, E5)

Not anticipating need for recorder in advance. S:23-36. (Post: N5, N7; E5)

Did not refer class back to observations on blackboard to summarize or make connections to density column. S:77. (Post: N5; Exp (#): E4, E5)

Providing a follow-up activity at end of demo. S:127-131. (Pre: N7; Post: N1, N2; E1)

Not providing aids for helping students remember order of liquids in column. S:52-114. (Pre: N5; Post: N3, N4)

Complexity of follow-up matching activity. S:124-131. (Pre: N7; Post: N3, N4)

Adding less dense liquid first. S:64-69. (Post: N1, N2)

I. Presentation Style [Pre: 1 Post: 1 Exp: 4]

Use of humor ('Can Man' phrase). S:3-4. (Exp: E1, E3)

Use of humor (To select volunteer). S:6-8. (Exp: E1, E4)

Derogatory use of the word 'genius'. S:26-27. (Pre: N1, N3; Post N6; Exp: E1, E2, E3)

Nervous demeanor. S:0,76. (Exp: E2, E4)

Showed excitement. S:74-96. (Post: N1, N2; E1)
APPENDIX S

Additional Quotes Pertaining to the Nine Pedagogical Categories

Key: E = Experienced demonstrators
N = Novice demonstrators (pre-workshop, unless otherwise indicated)

1. Inquiry:

E1: There was a little inquiry, some questioning, but not nearly enough with this kind of a demonstration. There should have been a tremendous amount more questions being asked of the participants, because there's certainly lots of things going on. [VT #3 Q.4]

E1: It's like all they have to say is, "Yes" or "No". He's giving them the information. He's not letting - his inquiry has come to a halt here. (VT #1 AP, S:60)

E3: He might have approached it from a more inquiry type way initially, in the sense, he could have had several set ups that share this common property and then have the property evolve out of that, but not all demonstrations need to be inquiry oriented. The approach he took, based on it, it appears that the students had at least read something on density, was fine. But there would be other approaches you can use with it. [VT #3, Q.4]

E3: [The U-tube demonstration] would be a nice follow-up, or had he wanted to be more inquiry-oriented at the start, as a discrepant event - and then lead into what he actually did use. [VT #3, Q.4]

Inquiry/Student observations:

E2.: Again, [the demonstrator] is telling them what is happening, ["I can feel it boiling..."]], rather than letting someone come up and tell him. (VT #1, S:51)

E2: That was it! I couldn't believe he said that. He just told them the steam was going to come out [of the can]. Well, obviously he shouldn't have done that. (VT #2, S:17)

Inquiry/Explaining or predicting phenomenon:

N7: Right there [the teacher asks why mineral oil sits on top of water?]; if I were a student, I would be saying, "No, [mineral oil is not less dense, but the oil] just can't get down there to get in between [the water and Karo syrup already in the column]. [The mineral oil] might be heavier [than water] but there is no way of knowing." ... I can imagine a student [thinking] that.
She might want to be prepared to have just the mineral oil and the Kayro, to do it by itself. (VT #4, S:86)

N2 (Post-workshop): That's good to get their hypothesis, ["Make some predictions..." (S:69)]. When you (students) go on record for something (respond to teachers' questions), you require more thought really, than ... if you are [just] sitting there thinking about it. (VT #1, S:70)

N8 (Post-workshop): He did more exploratory things but also, he should tell them or give them some more hints on what the three liquids [in the density column] are. Give them some possibilites over on the other side [of the blackboard] and show them the densities and then guess from there which one of them is most dense. "Well, it must be this one," you know. Give them some possibilities. He is pulling it out of thin air figuring out what kind of liquid this is. There are too many possibilities. (VT #3, S:68)

Inquiry/Evidence and Testing Hypotheses:

E3: Right there, I mean, that would not be a totally unreasonable hypothesis. I mean, he should have taken a can and attempted to crush it. Or better yet, let the student crush it with the tongs and they would have seen that they would have had a relatively difficult time and certainly not be able to crush it to the extent that the air pressure was. Rather than just saying, "No, that's the wrong answer," he could have showed that that isn't the case. (VT #1, S:58)

E2: Right there he could have said, "Well, how do you know it's a liquid? Is there anything else that it could be? Do you know of any substances that behave like this? Can somebody come up here and take a good close look at it and tell me about it? He's hogging the demo! (VT #3, S:62)

Inquiry/Forecasting observations

E2: Oh boy! That really destroys something right there because if some [student] asks, "Would it sink?", almost automatically a good science teacher would say, "Well, what do you think?" and "What could we do to find this out?" rather that just, "Yes". You just don't do that. She missed an opportunity. (VT #4, S:38)

N7: As she is going along, something that bothers me, she is just assuming that because I have these [density] numbers on the board, you have to take my word for it that this is correct [Water - 0.8 g/cm3; Rubber - 1.2 g/cm3]. I think, instead, she should have gone ahead with the demonstration and shown them [dropping rubber into alcohol] rather having them take my word for it, you know, [her writing that] rubber is more dense and alcohol is less dense. Students need to be shown. (VT #4, S:45)
Inquiry/Forecasting procedures:

E1: Right there he’s ruined the whole thing by saying, by introducing, or telling what he is going to do next, "Then we’re going to cool this air very, very rapidly...".
Interviewer: In terms of procedure?
E1: In terms of procedure. I think it would have been more effective if he didn’t tell. (VT #2; S:23)

N1: I think the problem with this thing and everytime - I haven’t done this experiment - but every time I am heating something or waiting for something to boil, you have that time lag. And you don’t always know what to say and sometimes you end up giving more information than you really wanted to. I’m not so sure that if he had sat down and maybe planned it a little bit differently, he probably wouldn’t have given information. Maybe he wouldn’t have given as much information. He would have talked about something else instead of clueing them in so much about what to expect. (VT #2, S:22)

Inquiry/Forecasting explanations:

E4: One good point is that no matter what a [student] has said, whether it be incorrect, or correct, he really hasn’t said all that much about, "Yes," "No," "It’s correct or incorrect." He’s kind of letting it develop and more or less letting the group agree on that. I like that idea, rather than saying, "No, you’re wrong." He’s letting the group discuss it. So he’s effectively leading the group in the discussion instead of giving all the discussion and explanation himself. And that’s good, because you’re trying to get the people to utilize their knowledge in answering. (VT #1, S:86)

E2: Why not let [the students] generalize? (VT #3, S:91)

2. Questioning Strategies

Questions/Leading questions:

E4: Again, going back, "What force is responsible?" (S:56) or, it’s the same thing as saying, "What happened?"; trying to get them to identify what’s taking place. I’d almost tend to say more, "What happened?" as opposed to "What force?" and let them, let the class develop that. (VT #1, S:56)

Questioning/Probing prior knowledge:

E3: Here he went and, rather than just defining [density] as the textbook would, he’s asked for volunteers to give him their definition of that and then he’s placed the textbook definition on the board. (VT #3, S:10)
E2: That’s always good; asking for volunteers [to describe what they know about density]. (VT #3, S:4)

Questioning/Quality:

E2 (Semantics): I don’t like the word ‘guesses’. I’d much rather, if he’s going to use the term ‘observations’ earlier, and it sounds like as if he has given his students some idea what science processes are, so I’d like to have heard, "Does anyone have a hypothesis about this?" rather than "a guess". (VT #3, S:66)

E2 (Phrasing): That ‘lighter and heavier’ stuff, she’s got to be careful with. She just keeps flipping back and forth (S:44,85,87,90). (VT #4, S:85)

E4 (Semantics): They ran into a semantic problem there. "Is the [air] pressure being greater?" or "differential in [air] pressure [greater after I heated the can]?" (VT #1, S:67)

3. New Terms

E1: That was good. There might have been some people who didn’t know what an interface was so he bothered to take the time to define that word. (VT #3, S:63)

N1: I like the way he defined what an interface is and then goes through and does point them out [using the density column] so the kids who didn’t grab it the first time at least now have an idea what it is he’s talking about, there. (VT #3, S:64)

4. Quality of Explanations

N5 (Post-workshop) (Application): Good example ("Have you ever had the experience of going out in a boat with a ...?"). Brings it back to real life. (VT #3, S:76)

N3 (Post-workshop) (We/they terminology): Again, I think that probably the contrast what we use [weight] and what scientists use [mass] is a false contrast. I think, perhaps, ‘How do we do it?’ [is more appropriate], because if she is doing a demo, she is the scientist at that point. And I think it (there) shouldn’t be that chasm. (VT #4, S:12)

6. Mechanics of the demonstration

E4: No, it’s not obvious. I don’t think he made it all that obvious that there was water in the can. (VT #2, S:14)

E4: This is probably personal preference on my part, but if you’re using the cans like that, and you want to show them there’s water in the can, I would probably premeasure some water
into a beaker and pour it into the can in front of the individuals. Just so they can see that, 'Yes, water indeed was poured into the can'. (VT #1, S:31)

7. Use of Visual Aids

E3: At this point, it would clearly be preferable if he would draw on the board, at least two set ups. One is showing, what happens - (i) what we envision happening as we boil water. The fact that air molecules will be forced out of the opening of the can, as well as the can being filled up with steam or gaseous water molecules and (ii) that then, when that [can] is rapidly cooled, the steam will condense, and with arrows he can show that the arrows on the outside of the can are bigger than the arrows inside, to just bring this home a little bit. (VT #2, S:44)

N3: I think he is doing a good job making sure that the comments [observations] get up [on the blackboard]. (VT #3, S:38)

8. Overall Organization

E2 (Ideas): O.K. That was a good [application] example. I would have liked to have heard it earlier but I still think it's good. (VT #3, S:77)

E4 (Tasks): That demo, dropping the rubber stopper into the water would have been better done when she was back in that [introductory] discussion, developing the density right in context. (VT #4, S:55)

N1 (Post-workshop) (Sequence in presenting the materials): I think what she did right there (demonstrate only two substances initially) was good because if, for God's sake, she had lost somebody with these numbers (density values) up there (on the blackboard), they're not having to deal with six solutions. All they are dealing with there is the water and that rubber stopper, alright. And we see what happens, she drops it in, it falls to the bottom, and she is telling them, "If it's more dense then it (the rubber) falls to the bottom (of the beaker of water). If it's heavier, it's got more mass for it's volume. (VT #4, S:56)
APPENDIX T
Clinical Interview Protocols of Selected Experienced and Novice Subjects

I. Protocol for Subject E3 (First Interview)

A. Critical-Stop Task for Videotape #3: (Density, +)

C = Critical-Stop Number
S = Videotape Script Statement Number (Appendix I)

C 1. (S:3)

One approach to use with a demonstration that is a little less investigative but good is to just be honest with people up front what the concept is that you are going to be teaching. In this case here, he’s verbalized that ["One of those concepts density." (S: 2)] and he also put it on the board so he can associate that with what he is going to be showing them with the actual label, the name and the label for the concept.

C 2. (S:10)

Here he went and, rather than just defining [density] as the textbook would, he’s asked for volunteers to give him their definition of that and then he’s placed the textbook definition on the board.

C 3. (S:19)

Here, this has helped cause he had [the density column] up, cause different fluid has different colors but the visibility isn’t great; and so he placed this white backdrop behind it, which is what he is doing now, which improves the visibility of what he is trying to show.

I: So that would be a strength?
He picked that up after he [showed the column]. Didn’t have it right away but subsequently picked it up.

C 4. (S:24)

Here he involving students. Rather than him just talking and showing, he’s already asked students for their input and

in this case he is having one student be a recorder for him which makes the class more involved.
C 5. (S:45)  

Here he - I don't think it was intentional for him to have the cylinder sort of covered with his hand. I think it was just the way he was holding it. I don't think it was a major problem but in terms of visibility, ideally he should have held it in such that they can see the whole thing unless he had a distinct purpose in hiding part of it. At least it is not obvious at this point that he did.

C 6. (S:49)  

At this point it would be nice if he had - he's not holding- there's a light table just a couple inches away from his cylinder. If he used that table they would be able to see those distinct layers even better with lighting from below. They can continue to focus on that as the discussion proceeds.

C 7. (S:61)  

And he is providing some evidence rather than just going on the assumption that it's liquid [in the column], he's providing some evidence by showing - by moving the cylinder around.

C 8. (S:65)  

The term 'interface' that a student used and then [the demonstrator] is using it again, he's sort of defining [interface] indirectly by showing it, [pointing to interface in density column].

The word [interface] has been used twice and I suspect it would have merited putting on the black board for people to see the word because some people wouldn't know what interface means.

C 9. (S:71)  

Here again he is being interactive with the students asking them to make hypotheses and then following up with, "How would we know if that were true?"

I: What kind of hypotheses are you referring to?
In this particular case, he asked them a very broad question, "What liquids might be in the container?" which they probably don't have a whole lot of experiences for, but they [the students provide a] couple guesses and then he follows it up with, "Well, how can be determine it if those guesses are in fact valid?"

I: I see. So that's a strenght, your saying? (Silence. Nod?)
Yeh. He’s taking a demonstration which doesn’t have a whole lot of action going on in it, in a sense it’s a static type of demonstration, but he’s turning it into, in addition to the concept of density, a little mini-lesson on how we know what we know in science? If you have a guess, what do we do about that guess?

This is real good here. He’s tying this concept (density) which, they’ve had the word that defined it and talked about it in reference to this particular system (the density column), and now he is applying it to something that the students are more likely to know about, oil on water, in a boat - in a lake situation.

Here he’s telling them that he’s dyed the water which has changed its visible properties. It is good that he’s telling that.

Telling them that it’s a dye alone would probably be sufficient rather than saying its phenolphthalein which is just some other chemical name for people and telling them that chemical name is not important. I would have preferred just saying them that the water has been dyed and letting it go at that. By throwing in "phenolphthalein", is another word that the students now have to think about, even though he’s told them it’s not important. If your going to use words, they are important -use simpler words that you don’t have to define.

Here, it would be preferable - he’s identified these layers - it would be preferable if he had a physical drawing on the board or an overhead that indicated the different liquids relative to the actual set-up so people have a direct visual of it, rather than just his words that, "Well, water is here and methanol is here."

It would be nice, before he’d go on, he gave one example (of density) from the students’ lives, and he volunteered it. It would be useful to come to closure on the topic if he had also drew out from the students more experiences of density that have in their live, just to help come to closure on it would have been nice.

I: What kind of closure did he come to here?
Well basically he sort of generalized and said that solids are generally more dense than liquids and with gases it’s difficult to see them and so that’s why he was working with liquids. But in fact there
are dense gases that are colored. Nitrogen dioxide for instance if you wanted to show a dense gas. Carbon dioxide in water you can see the condensed water vapor, not actually the CO2, you can see that it is denser. There are demonstrations where you can pour CO2 and see it flow down. So there are gases, ways of seeing dense gases, that he could demonstrate simply by putting them in balloons and watching the rate at which they fell would be another way of doing that.

B. Semi-Structured Interview for E3 (Density & Videotape #3, +)

Questions and Responses:

I 4. Any other specific strengths or weaknesses in this presentation that you noticed and haven’t already mentioned?

I don’t know if I would define it a strength or weakness but as an issue of style he was relatively interactive with the students. He might of approached it from a more inquiry type way initially in the sense he could have had several set ups that share this common property and then have the property evolve out of that but not all demonstrations need to be inquiry oriented. The approach he took, based on it, it appears that the students had at least read something on density, was fine. But there would be other approaches you can use with it.

I 5. Summarize overall strengths of the presentation?

Using student as a recorder. Trying to make it visible which he did with the white backdrop as he proceeded. He didn’t necessarily have that planned. He would have done that a little better with the light board. He could have set up several of those and sealed them and passed them around for students to take a look at more closely would have improved the demonstration, have perhaps one large one, set up a light table, and then have several small ones that could be passed around would have improved the demonstration, but the strengths tended to be that he was interactive with the students; that he had a system that he had made visible by using color, that he made good use of the blackboard in terms of defining the concept. Those were the strengths of the demonstration and then, tying it with at least one example and I think it would have been preferable to use more but one example that students might relate to their own lives. Those tended to be the strengths. His interaction was good in a sense that he acknowledged students’ answers and if he didn’t hear it clearly he asked them to repeat. Those are good basic good teaching strategies independent of whether you use demonstrations or not.

I 5. General overall weakness.

Most of the strengths and weaknesses, its a matter of degree. It’s not so much, in the sense of a weakness, that he did something
that was totally wrong. Some of his strengths he could have done better on in terms of visibility, in terms of drawing out more examples from the students' lives, so most of the characteristics of a good demo, given that he had a static system, seem to be exemplified in this demonstration in some form. It's more a matter he could improve what is already a pretty good demonstration.

I 6. What would be your overall reaction to the presentation on a five-point scale?

4 or a little bit more than a 4.

I 7. Intended lesson objective?

(Skipped)

I 8. Variation, twist, or extension of this demonstration.

Somewhere in his discussion he mentions what he really wanted to talk about was density of gases. There are a number of ways to show the density of gases. You could contrast helium versus air versus some dense gas like freon or sulfurhexafluoride, all of which can be placed in balloons and one can watch the rate of fall or rate of ascent and compare densities that way. One could blow those same gases through soap bubbles. Again one gets at the concept of density in there. One gets probably a little better concept of floating versus sinking which was built into his demo but he didn't really address it directly so there is a number of ways of showing the density of gases which are perhaps even more dramatic than density of liquids, which tend to, after you set it up, it's sort of static. It's all sitting there versus, had he done that live, adding liquids on top of liquids, perhaps it would have been a little more dramatic but the gases tend to be the most dramatic, heat up balloons or soap bubbles.

I: Any variation on the presentation he just made on the density of liquids?

There are some which basically revolve around the liquids being immiscible, not mixing with each other and layering out. One way, which is more of a discrepant event would be to use two different density liquids in a U-tube. If you pour them correctly you get an uneven level in the two arms of the U-tube. That tends to be a pretty strong discrepant event since they tend to think that liquids seek a common level and they would be balanced in the two ends of the tube. That would be a nice follow-up. Or had he wanted to be more inquiry-oriented at the start as a discrepant event and then lead into what he actually did use.
I 9. Any other demos that show the concept of density?

Of density of any substance?

I: Uh huh.

Well there’s the gas ones that I already mentioned, two or three, and there’s the U-tube set up with liquids. With the one he use, had he investigated, he probably could have found solids that would have floated in each specific layer. Another descrepant event type one is using salt water with fresh water on top and hard boiled eggs float in salt water and sink in fresh water and if you use that layer type of effect you can get something to actually sort of float in what appears to be in the middle of a liquid, actually at the interface of two liquids. There are several demonstrations that can be used to illustrate the concept of density that would lead to a more inquiry type of approach, although with the demonstration he did, he did a good job with, but there are other ones which I would probably start off with in a classroom setting if you had total choice.

I: Do you know of any other demos that deals with the concept of density?

There are many that would be extension type things. The concept of density relative to floating and sinking and why things float and sink. There are simulations that you can run on say a boat is floating in a closed area with heavy masses on it. What would happen to the water level if those masses were thrown off the boat. Now you can simulate that with a little aluminum pipe fan and a lead weight and a beaker of water so one can get at the related concept of why things sink or float. So you can extend it in that direction. There is household items. The floating oil candles where you have a foil floating on top of water and buring through a wick. The concept of density applies in hundreds of applications in day to day living that could be drawn and everything from submarines to fish swimming to density of battery acids to many, many, many applications of density.

I: Any other demos?

I think I’ll stop here.

I 10. General principles that can be drawn from this particular demonstration?

That with liquids, the level that a liquid will appear relative to another liquid depends on the density. That more dense liquids are lower than less dense liquids. One may also conclude incorrectly from this demonstration that liquids that are different densities will always layer out when in fact many liquids that are different densities will mix with each other and therefore not layer out and form a homogeneous solution. So that would be an incorrect conclusion one might draw from this particular demonstration, but otherwise the
main item the relative level of a liquid depends on its density and
denser liquids will be located below less dense liquids.

Q. At molecular level do you know what influences the density of a
substance?

The density of a substance depends on at least two parameters. One is the size of the molecules, the size, weight, mass of the
individual molecules. And two, the relative packing of the molecules
in the substance.
II. Protocol for Subject N2 (Pre-Workshop Interview)

A. Critical-Stop Task for Videotape #3: (Density, +)

C 1. (S:3) __________________
I think it’s difficult to have to walk around the table as much as he did. Maybe he can walk around the other end because it’s shorter. But you still want to be with the kids and not separate it from your audience.

C 2. (S:13) __________________
I was just going to say, I think it’s best to discuss each answer if you can and bring out the good points in the answer if possible.

C 3. (S:14) __________________
Oh yes, using formulas is helpful. It crystalizes the concepts. So I think that’s a strong point. And it gives them something to put in their notes so they can have something to review.

C 4. (S:22) __________________
I think he does a good job of providing the background so they can see. And he shows each side of the room well with enough time and I think that is a strong point. He probably should have started off with paper behind it but we don’t always think of everything when we are talking.

C 5. (S:25) __________________
Secretaries are important. It involves the class and makes it easier on you.

C 6. (S:38) __________________
And that’s good too because in demonstrations you have to slow down because in demonstrations you have to slow down so that people can take [notes], so it’s good that he did that.

C 7. (S:72) __________________
That’s good to mix chemistry with real life.
C 8.  (S:85)

I think it's good to introduce them to things like phenolphthalein even though they don't have to know about it because they become familiar with the words that they'll hear later on if they have more chemistry. And yet, at the same time, he says you don't have to worry about it so the pressure is off, but the information has been planted. So, I think that's an O.K. technique.

C 9.  (S:96)

That's a good idea, to show something simple to bridge to something complex.

B. Semi-Structured Interview for N2 (Density & Videotape #3, +)

Questions and Responses:

I 3. Have you ever seen this demonstration before?

No recollection of this demo.

I: Ever seen this principle demonstrated?

Not like this.

I 4. Any other specific points you would like to comment on that you may not have already mentioned in terms of specific strengths and weaknesses?

I don't think so.

I 5. How would you summarize the general strengths of his presentation?

Well, he relates well to the audience. He takes time with them. Provided a colorful demonstration. I thought it was a pretty good demonstration.

I: How would you summarize any general weaknesses?

I didn't think there were too many. It's sometimes a little bit hard to know how to hold things and how to move but I thought he did a pretty good job. There might be slight room for improvement.

I 6. So if you were to give your overall reaction to the performance on a five point scale.
Probably a five. Cause I think about how he does it compared to how poor I do it.

I 7. What do you think his intended lesson objective was?

To show that different items have different densities. And to show what density is.

I 8. Do you know of any other twists or variations on that demo that could be done?

None that particularly know of.

I: How else you could present it or something?

No, not really.

I 9. Do you know of any other demos that deal with the concept of density?

The one where you fill the container and then insert something and watch the water displaced. Or you use the container that has the side arm where water can go out. And that helps illustrate density by showing volume displaced.

I: Any other demos that you are familiar with dealing with the density of substances?

Not really.

I 10. What principles of density can be drawn from this kind of demonstration?

Well, solids are generally more dense than liquids. Liquids within themselves have different densities and some of them mix more readily than others.

I: At the molecular level do you know what influences the density of a substance?

How close the molecules are together.

I: Is there anything else?

It could be something involving the angle of the bonds in the molecules because that effects how closely they can pack, and the type and nature of bonds.

I: Is there anything else involved to your knowledge?
Sometimes they're in layers where they can slide on top of each other and somethings they're not, they're spaced rigidly apart so that type of structure would affect the density.

I: Anything else you want to say about that?

No.

III. Protocol for Subject N2 (Post-Workshop Interview)

A. Critical-Stop Task for Videotape #4: (Density, -)

C 1. (S:8) ______________________

She dances around a little bit more than a lot of people do. It was good that she accepted the student answer because the other demo person with this demo got that answer and didn't like it and went on. She thinks on her feet well, which is good. I mean it doesn't flow as smoothly as some, but she takes time to get it [explanation?] out correctly which I think is good because she is developing that skill. I think she could go on and let more students talk and then they would bring out what she is going to say.

C 2. (S:10) ______________________

She is writing very neatly on the board. I really noticed that. I have trouble with that myself.

C 3. (S:16) ______________________

Seems like they have talked about this before so she might work for more student interaction. And an overhead or a picture on the chalkboard of a cubic centimeter would be helpful, or an example such as a playing dice, depending on whether they're introducing it or whether it's new review. And I get the feeling it is review so it's probably O.K., but if it is review then she should solicit more of their responses instead of just telling. And she uses the same hand motions I do, maybe a little bit too often. She hasn't said O.K. yet. but she uses O.K. quite often also.

C 4. (S:18) ______________________

She just went through the distinction between 'mass' and 'weight' and now she is using the word 'weigh'. Everybody knows what she means but I guess if we're going to try and make a distinction we should try to follow through.
I wish she'd bring out a little bit more how they know it has a larger density (S:29). Of course she is pointing at the number so it's really fairly clear but maybe some audio to go around along with that would be good.

I: Audio?

Something that she says. Instead of just pointing at the numbers, saying, "1.2 has a larger absolute value than one," something like that. I mean it's good to point at the board though, cause that's - I just kinda would like to have something said.

She agreed so fast with their answer. It doesn't give much time for discussion. But I do that too. I think, since she was going to follow it up with 'Why would it sink?', it would have been nice if she had said that instead of, "Yea." (In reference to a student's response, S:38). Because that cuts off the thinking in the other people.

It was good to pause before she did it [drop in the rubber stopper] and review their expectations. She does make good use of color. It's visible.

I even thought that was good to dry the rubber off because she is planning to use it again later and that way it helps keep the demonstration controlled.

She is just a little unfamiliar with her products.

I'm glad she did it in that order so that students could see the displacement. I think that is very good because some people just build the column from the bottom up. And uh, I did that. I added the syrup after I had done everything else and watched it go to where it went. And I think that's fun cause it's good for the kids to see that.
I: So you did the demo?

But not as little as she did though. I mean, I just did it in lab and I used—she had a wise use of materials for testing the density of them [the solids] because they floated at different levels and mine just all went to the bottom and I had a big rock in there. It was dumb... So she got more out of it.

C 11. (S:72)  

From this I realized your clothing interferes with the demo. And a lot of times she will hold it up so that’s really out. There’s no background behind it which helps (visibility). I think using a white block or the table light, the demonstration lamp would help. She does make a concerted effort for people to see it but ...

C 12. (S:74)  

I kind of like the way she gets excited. It might interfere with some peoples’ observations of the demo but if your not enthusiastic it rubs off on the kids and if you are enthusiastic it can rub off as well. They say, 'Be yourself,' and she is; so that’s alright. A little different, but I don’t think — I think it’s alright.

C 13. (S:77)  

Not corn syrup, mineral oil. But she corrects that in a minute.

C 14. (S:87)  

When she introduces the mineral oil she said, "It was colorless," (S:72) and that was good, not to say, "Clear" but "Colorless" so that is good.

C 15. (S:101)  

That brings up a good point. How do you handle something that happens so quickly that they miss it? [Penny falling to the bottom of the cylinder]. She realized that there were some that probable missed it and she needed to emphasize that so she’s aware of what is going on and their reactions. Like I say, if she were using the light box or something or a background it probably would be easier to see. I am trying to think if there is a way to drop a penny in slowly, like a liquid, you can pour against the edge of the cylinder but I don’t think you can do that with a penny.

I: There’s a challenge.

Yea, that’s a challenge.
I am glad she brought that point out, [Rubber can still sink to bottom without being as dense as a penny]. Just because they go to the same level doesn’t mean they have the same density. And she is showing that it just means that it’s more dense than the fluid but it doesn’t really tell you how they compare to each other.

Now that is floating in the corn syrup right?

I: Uh huh.

And I think she says later on that it is resting in the bottom of the ‘corn syrup’. I think she meant to say ‘water’, later on.

Yea. That is what I was talking about because it [the rubber stopper] is "floating in the corn syrup." She meant, "It’s not much denser than the water." [S:112, (Actual statement): "...but it’s not much denser than the corn syrup"].

Somehow, the way she tossed it up made the cork look light and that what she was intending. You can’t toss anything up and it wouldn’t necessarily be light but she made it look effortless and drawing on their experience is what she was doing cause they’ve all worked with cork. I thought that was effective. I don’t know. It just worked with me anyway.

I: Did you do what?

Throwing the cork up to make it look light. You can throw anything up that is not light and but - I don’t know. It worked with me though.

I: What did it do for you?

It gave me the impression that the cork was very light.

I: Oh, give you a clue then?

Right she’s giving us a clue and I’m just saying that throwing something up doesn’t mean it’s light but it worked though. That is what I was trying to say.

I: OK, I got your point now.
Cause she did give the impression that cork was light. They were being slow on response. Not really slow, but she was just giving them a hint while they were awake.

C 20. (S:119)

I think she should give them a little bit of time to see if anybody will think it will float on the alcohol or if anybody will think it will float on the oil. Cause she lead right up to it but then went on maybe a little bit too fast.

C 21. (S:131)

That is good to relate the column to the exercise. So I was waiting to see if she did that and that's good; otherwise they will just match them without comparing them at all.
B. Semi-Structured Interview for N2 (Density & Videotape #4, -)

Questions and Responses:

I 3. Have you ever seen this demonstration before?
   (Not asked)

I 4. O.K. Any other specific points of strength?

Well, I think it is going to be good to have them think through the last exercise, matching the densities. It was very clear and she made her points obvious. It was deliberate.

I: Any other specific weak points you haven't already mentioned?

Well, I have mainly mentioned them.

I 5. If you were to summarize the major points the strengths?

Those would definately be that she took her time with it. It was clear. It was deliberate. I understood every step she was doing. I liked the coloring. I liked the order in which she built her columns so that we could see the one replacing the other. I thought she made good choice of materials to float in the column.

I: If you were to summarize the general weaknesses of the presentation what would they be?

I think it was probably too long because you edited it. She kept it flowing, even though there were some hesitations and I don't mind that. But it would be a little bit weaker than somebody who didn't have the hesitations. She made redundant use of certain expressions such as "O.K.", and "Woops", and hand motions. A couple of times she could have got more student input or waited longer for them to voice some expectations before she did the demonstration.

I 6. What was your overall reaction to this demonstration on a five point scale 1 terrible, 2 poor, 3 fair, 4 good, and 5 excellent?

4.5

I 7. And intended lesson objectives?

To illustrate the concept of density and the different densities of different materials.
I 8. The last set of questions. I might sound redundant in asking this [question asked with first videotape interview], but, any other variation or twist on this particular demo?

Well, you can carry this a step further and cork it off and invert it. Or, having gone this far, you could add another liquid. Of course when you do that though, some of the miscible liquids blends, so that creates a problem. It might be a little bit hard. Well, there are density experiments, but we (want to) keep it to the density column.

I 9. That will lead me to my next question. Any other demonstrations that illustrate the concept of density?

Well, the density bobbing. Where you have a fake rock and a real rock and you can startle the student by throwing them the fake rock that looks just like a real one but is a very, very light and not dense. Building boxes; and they’re the same, with different materials, and letting them compare the masses. Balloons filled with different gases. See I learned some things.

I: Keep going!

Let’s see. Well, you can...; well, that’s too expensive. I was thinking, like mercury. We used to illustrate density with mercury but that’s too dangerous now. I didn’t know that all those times I’ve played with it seventh grade. Hot air and cold air density problems. That’s fun to illustrate, (smoke going in air up). That’s mainly it.

I: So if you think of any others during the course of the interview here just feel free to mention them if they come to your mind.

O.K. The U-tube where they have the different densities and I guess you could even go into the miscible liquids where 50 plus 50 doesn’t equal a 100, and get into density if you wanted to.

I: And that’s with the U-tube you’re just referring to now, related to density?

That’s two different ones.

I: Oh, that’s right. One is just a simple mixing.

Yea, the other is a discrepant event. They both are.

I 10. Lastly, what principles of density can be drawn from this demonstration?

Well, if items have different densities, we’ll say liquid items, then they will set up a column and in order of most dense on the bottom and least dense on the top. And one will displace another if a more dense one is put in on top of the less dense one, it will sink to the bottom.
and then solid objects put in will find the level of appropriate density. Well, they will float on top of items that are more dense than they are, even if it is not on top of a column.

I: O.K., lastly, at the molecular level do you know what influences the density of a substance?

The size of the molecule, the shape of the molecule, the type of bonds involved in the atom or molecule. The arrangement in layers or solid or liquid form, whether they can slide on each other.

I: So the last thing you were saying was...

With the gas, the pressure effects the density.

I: Anything else you know at the molecular level influences the density of a substance?

Well, it could be the atomic number of a atom, also.

I: What does that refer to, the atomic number?

The number of protons or the atomic mass. Obviously, the protons and neutrons, the heavier an element the possibility that it would be more dense.

I: Anything else?

Well, that's enough.
APPENDIX U

Additional Quotes from Experienced and Novice Chemical Demonstrators Related to Knowledge of Alternatives (Domain c: P’s, V’s, D’s, & X’s)

A. Pedagogical enhancements, Post-workshop novices

N7 (Visibility): Another thing he is doing that I don’t like - I think he should have just left it on the tabletop or had perhaps a larger cylinder or stuck it, like we have the light source, even stuck it on an overhead projector, to give it height or something, because he is constantly moving it around and it’s just not clear. He’s also not - the way he is holding it, you find out later that he is actually obstructing some of the students view. So it would have been much more effective in the larger container with the light source on. (VT #3, S:25)

N8 (Visibility): A better way of dealing with this is if he went and started with the demonstration instead of all this explanation and all this teacher talk. If he came up with, “Here is the tube (graduated cylinder). It is filled with three different solids (liquids),” put it on the glass bottom thing (light board) with the white background, and not walk around the room with it so you can’t see the three levels, I’d think you would do a lot better. That would be visible to everybody if you did the (black) with the white background and the light underneath it so you could see the object that was floating underneath of it. (VT #3, S:7)

B. Variations

1. Collapsing Aluminum Can variations

N5 (Pre-workshop): I have seen that done where you crumple one of those. You then you plunge it in cold water and it goes ‘Tzzz’; it twists off, which is kind of neat. You can really see it go. And it’s a little bit slower that the coke can. (VT #1, I. 8)

E5: Well, perhaps other variations of this can thing would be taking the spirit can, you know, spirit or with a big maple sugar e with a big maple sugar put the cap on it, and it goes ‘Tzzz’; it twists off, which is kind of neat. You can really see it go. And it’s a little bit slower that the coke can. (VT #1, I. 8)

That’s happening [case observed on videotape], because I really think in that [coke] can situation, it’s so complicated, water has to enter and that serves to quick and in some ways might be more instructive than the quick happening [case observed on videotape], because I really think in that [coke] can situation, it’s so complicated, water has to enter and that serves to quicken the cool down. (VT #1, I. 8)
2. Density Column variations

N3 (Pre-workshop/Shake system): I’ve seen variations of it where various liquids are put on top [and you] try to shake it. (VT #3, I. 3)

E4 (Add liquids in a different order): Sometimes you can take certain substances and literally pour the heavier substance in and watch it go through all the layers down to the bottom. So the order doesn’t always have to be most dense first. You can put in a more dense substance last, provided it’s not going to mix, or cause the mixing of any other substances in the column. (VT #4, I. 8)

E3 (Use more solid objects): With the one he (the videotaped model) used, had he investigated, he probably could have found solids that would have floated in each specific layer. (VT #3, I. 9)

E4 (Use more solid objects): It might have been good to have a block of wood or something that would float between the water and the oil, or the oil and the alcohol, in addition to just having the cork which floats on top. To get a few more items in between. That may not be her [the videotaped model’s] fault. That may be the fault of the material that was available when she was doing this, because you can use different woods which have different densities to fill in the spaces. (VT #4, I. 8)

N3 (Post-workshop/Demonstrate a Simple System and Work Up): I think I would have stuck with just liquids and not done the copper and the cork ect. at the beginning. I would have kept it with straight liquids.

N1 (Post-workshop/Dynamic vs Static Approach: Building a Column): The only other variation I know is you layer them all except the corn syrup and you run the corn syrup down last.

N2 (Post-workshop/Use Other Types of Liquids): Having gone this far, you could add another liquid. Of course when you do that though, some of the miscible liquids blends, so that creates a problem. It might be a little bit hard. [Subject see complications]

N5 (Post-workshop/Use More Solid Objects): You could drop objects in with various densities. That might be another twist.

N6 (Post-workshop/Use More Solid Objects, Other Types of Liquids, & Wide-Mouth Container): I was probably better off if I used something that had a wider opening and maybe just make my layers more horizontal (wider) than more vertical (higher) so that I could put in a lot of different solid objects with the liquid objects to see where what would float at different areas, and stuff. Yea, if the things starts getting away, if it floats there and you put in something a little bit bigger in size, it’s
got to go through it to get down and sometimes it pulls that
[less dense object] down with it.

N8 (Post-workshop/More solid objects): He should have different
solids in the interfaces. ... I told you about putting
different solids in, and the cork and the penny and something
else in the middle that floats, but I forgot what it was.

C. Alternative Demonstrations (DV)

E4 (Crushing Bottles Reversibly): You can do the same thing
with the ditto can, or you can use a two liter or three liter
plastic soft drink bottle, where you fill it to the very top with
water, put a one hole stopper in it that has a piece of glass
tubing to it and a long hose connected to it, and either climb up
on a table or walk up the stairs until the pressure differential
is enough to push the water out into a receiving container. The
can will crush, or the container will crush. Two liter or three
liter beverage bottles usually will start to crush when there’s
about a six foot or better differential in height between the
container and a bucket down below. And, of course, the higher
you get, the quicker it crushes. With a metal duplicator fluid
cans, I found that it works best if you have somewhere between
thirty and thirty five feet differential in height, since the
strength of the can is enough that it needs a greater
differential in air pressure to allow the crushing. Plastic is
very flexible in the bottles. The can is relatively sturdy. (VT
#1, I. 9)

D. Extraneous Examples (X)

N7 (Lab): I had them do a lab by themself in which they used
water and a beaker, and they had a series of objects. And they
would place them individually and watch how high the water level
rose; and they would make a chart and determine, based on that,
which would be more dense. (VT #4, I. 8)

N5 (Lab): I just think the kids could have done all that. I
could see that being a real interesting lab, you know, where
everything was color coded, and they could even do a couple
unknowns. Throw some things at them that would float at some
level in the column. Maybe have a density chart with a bunch of
different things on it where they could then pick and choose, if
you could put it in a relative density between two knowns or
something. Figure out the unknown or something like that. I
could see me using this more as a lab. (VT #4, I 3.)
APPENDIX V

List of Air Pressure Demonstrations Cited by Experienced and Novice Chemical Demonstrators

I. \( V = \) Variations on the Collapsing Aluminum Can Demo

A. Variations on Can Size, Shape, Composition, & Content
   1. Collapsing Large Metal Cans (Collapsing Ditto Fluid Can)
   2. Collapsing an Empty or Filled Aluminum Can (Unstoppered)
   3. Collapsing Steel (or Various Aluminum) Cans

B. Variations on Method of Cooling
   4. Cool Aluminum Can Right-Side Up
   5. Spray Can with Water

C. Variation Using Collapsed Can
   6. Inflating a Collapsed Ditto Fluid Can
II. Different Demos on Air Pressure

A. Primary Concept Demos

1. Collapsing Milk Jug
2. Crushing Bottles Reversibly
3. Egg in the Bottle
4. Balloon Inverted in a Flask
5. Pulling a Bag Out of a Jar
6. Inflating a Balloon in a Flask
7. Magnemburg Hemispheres
8. Balloon in a Vacuum Chamber (or Evacuated Container)
9. Boiling Water at Low Temperature (i.e., Pressure)
10. Blowing Ball out of Funnel
11. Blowing Between Two Tennis Balls
12. Blowing Card & Pin off of Spool
14. Breaking a Stick/Board with Air Pressure
15. Straw Through a Potato
16. Emptying Water Bottles
17. Siphon Demo
18. Barometers

B. Multiple Concepts Demos

19. Ammonia Fountain
20. Cartesian Diver
21. Stand on an Empty Aluminum Can?

X. Deflating a Balloon?
III. Extraneous Examples

A. Positive Examples

1. Labs (L)
   a. Air Pressure Labs
   b. Determining the Horsepower Needed to Crush an Aluminum Can.

2. Discussions (Ds)
   a. Air Foils and Flight (Bernoulli's Principle)
   b. Determining Horsepower Needed to Crush Can

3. Activities (Act)

B. Negative Examples

1. Erroneous Examples (E)
   a. Rate of Thermal Expansion/Evaporation
   b. Exploding Hydrogen Balloons

2. Pedagogically Unsound (U)
   a. Heating a Balloon
   b. Heat Can with Non-Water Liquid Inside

3. Nebulous Examples (Neb)
APPENDIX W

List of Density Demonstrations Cited by Experienced and Novice Chemical Demonstrators

I. $V = \text{Variations on the Density Column Demo}$

A. Variations in Dynamics (Showing the Column)
   1. Start with Simple 2-Liquid System
   2. Dynamic Approach: Build a Column/Drop in Solids
   3. Shake a Container (or Column) of Immiscible Liquids

B. Variations in Materials
   4. Use More Solid Objects, Other Types of Liquids, & Wide-Mouth Container
   5. Use a hand-full of pennies

C. Variations in Quantifying a Qualitative Demo (Absolute vs. Relative Densities)
   6. Mass the Liquids before Building the Column
   7. Estimate Densities of Unknown Objects Using the Column
   8. Start with 1 liquid and 2 solids and compare density values with sink and float properties
II. D = Different Demos on Density

A. Density of Gases
   1. Gas-filled Balloons (The Great Balloon Race)
   2. Gas-filled Soap Bubbles
      - Floating a Bubble of Air
      - Flammable Bubbles
   3. Pouring CO2
      - Extinguishing a Flame with CO2
      - Pouring CO2 and the Equal-Arm Balance
   4. Bubbles Floating to Surface of a Liquid
   5. Gas Column

B. Density of Liquids
   6. U-tube with Two Immiscible Liquids
   7. Beverage Density Column
   8. Mixing Two Miscible Liquids

C. Density of Liquids & Solids
   9. Sink or Float Demos
      - Dropping in various solid objects
      - Diet and Regular Soda
   10. Buoyancy of Boat with Varying Masses
   11. Sink to Interface Demo
      - Cooking Oil, Water, & Grape System
      - Water, Ethanol, & Cooking Oil System
   12. Density Bobbing
      - Using Raisins
      - Using Spaghetti
      - Using Moth Balls
   13. Temperature and Salinity Effects on a Density Float
   14. Floating Oil Candles
15. Using an Equal-Arm or Standard Balance
16. Floating Razor Blade (Discrepant Event on Density)

D. Density of Solids
17. Hand-Weighing Two Substances of Equal Size

III. Extraneous Examples (X)

A. Positive Examples
1. Labs (L)
   a. Absolute Density Determinations
      - Density of Marbles (+ Jar) by Water Displacement
   
   b. Styrofoam and Acitone
2. Discussions (D)
   a. Why Ice Floats
   b. Why Water Expands Upon Freezing
3. Activities (Act)
   a. The Density of Planets

B. Negative Examples
1. Erroneous examples (E)
   a. Archimedes Principle - Water displacement by solid objects denser than water.
      - Density of Marbles (+ Jar) by water displacement
   b. Floating Razor Blade - As a non-discrepant event
   c. Breathing Pure Gases
   d. Vacuum Effecting Liquid Levels in a Manometer
2. Nebulous Examples (Neb)
3. Pedagogically Unsound (U)
   a. Sedimentation Rates
APPENDIX X

Additional Quotes of Experienced and Novice Chemical Demonstrators Related to Discourse Rationales (Domain d)

Rationales Involving:

A. Complexity of the Demonstration

E5: Inappropriate demonstration to use for the production of density. ... It was much too complicated system to begin with. I don't think it left me with any further understanding of density than I had before I saw it. (VT #3, I. 5)

B. Solutions for Working with Inherently Complex Demonstrations

N8: And another way to prove that, is to take another can, another Pepsi can, and try to crush it with the tongs and see that it couldn't have been done by just manipulation of the tongs. (VT #2; S:29)
APPENDIX Y

Major and Minor Critical Features Cited by Experienced and Pre/Post-Workshop Trained Novice Demonstrators for Videotape #3 (Density, +) (7.5 min tape)

One sentence summary statements of observed strengths and weaknesses in the presentation of the Density Column demonstration, Videotape #3.

Key: - Indicates a weakness + Indicates a strength * Item showing 50% group agreement # Item showing 40% group agreement [ ] Total number of entries per group | | Total number of entries adjusted for group size of four


FrP +1. Kept identity of liquids a mystery. S:15. (E1)
O +2.* Asking students to make observations about density column. S:17-45. (E1, E3, E4)
T -4. Insufficient probing of student’s correct response on form of matter in cylinder. S:62. (E2)
Q -5. Not allowing enough wait time for students to identify solid substance on bottom of density column. S:90. (E1)
E +6. Asked students to support their hypothesis about identity of liquids in column. S:70. (E3)
O -7. Teacher provides too many observations and hypotheses. S:90. (E2)
FQ -8.# Poor fielding of simultaneous student responses on liquid identity question. S:69. (E1, E2)
O +9. Good question about the location of the most dense material. S:49. (E1)
F -10. Inappropriate for teacher to draw conclusion/generalization for density column demo. S:91. (Pre: N3; E2)
FQ -11. Poor fielding of student observational comments on density column. S:24. (Post: N6)

H -12.* Guessing the identity of the mystery liquids in column is inappropriate/unimportant. S:69. (Post: N5, N8)

Ex -13. Teacher providing too many answers about why one liquid layer remains colorless. S:87. (Post: N7)

# Features: Pre = 1 Post = 3 Exp = 10 Total = 13

EvT Evaluation and Testing  O Observation  I Inquiry
Ex Explaining Concepts  F Forecasting  H Hypothesis
QFQ Questioning & Fielding Questions  P Prediction


QE -1.# 'Guess' is poor term to use when asking students to predict identity of liquids. S:66. (E2, E4)

LQ -2. Teacher leading students with MC question regarding state of matter above solid object. S:62. (E4)

Pr -3. Insufficient probing of student's correct response on form of matter in cylinder. S:62. (E2)

FQ +4. Good at accepting people's answers. S:77. (E2)

Pb -5. Accepted density definition without probing for comprehension. S:13. (E2)

Pb -6. Asking student for his 'experience' (rather than evidence about oil being less dense than other liquids. S:70. (E2)

PK +7.* Asking students to volunteer their knowledge of density. S:3. (Pre: N1; Post: N5; E2, E3, E5)

Fd -8.* Inappropriate feedback to student's questionable definition of density. S:7. (Pre: N1, N2, N3; Post: N5, N6, N7; E1, E2, E4, E5)

QE +9. Good/Inappropriate leading question on 'form (state) of matter' of substance(s) in column. S:53-61. (Pre: N3; Post: N5-, N8; E2)

Pb +10.* Probing prior experiences. S:70. (Pre: N1, N3)


QE -13. Poor question about observations on cylinder. S:17. (Post: N8)


# Features: Pre = 6 Post = 6 Exp = 9 Total = 16

QE Question Evaluation  Fd Feedback  LQ Leading Questions
PKn Prior Knowledge  Prb Probing  MQ
FQ Fielding Questions  WT Wait Time
3. New Terms

-1. 'Immiscible' not defined. S:77. (E4)

-2. Inappropriateness of (or insufficient attention to) 'mass and unit volume' terms in definition of density. S:13. (Pre: N1, N3, N4; E2, E4)

-3. Insufficient attention to 'interface' term when first mentioned. S:41-65. (Pre: N1; Post: N8; E2, E3)

+4. Defined interface term later in demo. S:63. (Pre: N1; Post: N6; E1, E2, E4)

-5. Mentioning phenolphthalein term is either unnecessary or given insufficient attention. S:81-84. (Pre: N2, N3; Post: N5; E1, E2, E3)

+6. Appropriate to mention/introduce the term 'phenolphthalein'. S:81. (Pre: N2; Post: N8)

-7. Not providing a concrete definition of 'density' for students. S:50. (Pre: N3)

-8. Inappropriate/Confusing to introduce 'solubility' term. S:85. (Pre: N3; Post: N5, N6)

-9. 'Equals and Per' terms in density definition are unclear. S:14. (Post: N6)

# Features: Pre = 7 Post = 6 Exp = 5 Total = 8

4. Clarifying an Explanation

Cn +1.* Verbalized difficulty of concept. S:14. (E1, E2, E4)

ClCn -2. Unclear connection between classic definition of density and question about relative density of liquids in column. S: 55. (E2)

Pr +3. Indicated purpose for dye. S:82. (E3)

AcC -4. Error in solubility statement. S:88. (E4)

AcC 5. Inaccurate to say that gases are difficult to see [and therefore demonstrate]. S:97. (E3)

Ap +6.* Applying density concept to student experiences. S:76. (Pre: N2; Post: N5, N7; E1, E2, E3, E5)

AcC -7.* Inappropriate generalization: solids generally more dense than liquids. S:92. (Post: N7, N8; E4, E5)

Cn +8. Good generalization about densities of solids and liquids. (Post: N5)


ClCn -10. Should clarify the states of matter in the cylinder. S:15. (Post: N8)
MPy -11. Should say that dyes used to identify different liquids. S:38. (Post: N8)
MCn -12. Failure to state relative density of gasoline. S:77. (Post: N8)

# Features: Pre = 3 Post = 7 Exp = 7 Total = 13

Ac Accuracy C Conceptual Cl Clarity Cm Completeness
E Error M Material O Observational P Procedural
Ps Process S Student Us Usefullness


In -1. Not having students provide further applications of density. S:97. (E3)
Re +2.* Using a student recorder. S:25. (Pre: N2, N4; Post: N5, N8; E1, E2, E3, E4)
In +3. Good interaction. S:36. (Pre: N3; Post: N5; E4)

# Features: Pre = 2 Post = 2 Exp = 3 Total = 3

As Assist In Verbal Instruction Po Positioning
Re Record Observer Rf References TT Teacher Talk


1. Visibility
V +a.* Used white background. S:19. (Pre: N2, N3; Post: N6; E1, E3, E4, E5)
V +b.* Hand obscures top of cylinder, (but later corrected). S:38-47. (Post: N5, N7, N8; E2, E3, E4+)
V -c.* Density column difficult to see - layers not visible enough. S:17-49. (Pre: N3; Post: N5, N8; E2, E3)
Md -d. Too much movement of cylinder. S:25. (Post: N7)

2. Handling the equipment and materials
Cp -b. Demo too complex for introducing students to density. S:15. (E5)
Vr +c. Providing students with some visual evidence (movement of cylinder) to help them answer state of matter question (about materials in column). S:61. (E3)
MC - d. Unequal amounts of liquids can mislead students. S:96. (Pre: N4)
MK - e. Shouldn’t use solids. S:96. (Pre: N4)
MK + f. Walking around with column adds animation. S:38. (Post: N5)

# Features: Pre = 4 Post = 5 Exp = 6 Total = 10

7. Use of Blackboard/Visual Aids

CnCm -1. Lack of visuals to illustrate density concept on blackboard. S:95. (E3, E5)
CnT +2. Good to use blackboard for new term, density. S:3. (Pre: N1; Post: N6; E3)
Nt +3. Large hand-writing on the board. S:4. (E2)
O +4.* Good to record students’ observations on board. S:38-49. (Pre: N3, N4)
-5. Lack of blackboard use. S:49. (Post: N8)
O -6. Teacher fails to monitor what goes on the board. S:45. (Post: N6)

# Features: Pre = 2 Post = 3 Exp = 3 Total = 6

8. Overall Organization

S -1. Application of density not given soon enough. S:77. (E2)
P +2. Extended silence while waiting for secretary. S:38. (Pre: N1, N2; E1, E2)
S -3. Introducing two concepts at once. S:3. (Pre: N3; Post: N8; E1, E4)
P -4.* Awkwardness of walking around the demonstration table. S:3. (Pre: N2; Post: N7; E1, E5)
Tr +5. Good transition from density demo to discussion of gases. S:96. (Pre: N2; Post: N5; E1)
P -6.* Not anticipating need for recorder in advance. S:23-36. (Post: N5, N7; E5)
Cl -7. Did not refer class back to observations on blackboard to summarize or make connections to density column. S:77. (Post: N5; E4, E5)
Mo  +8. Clear introduction of concept to be discussed. S:2.  
    (Pre: N1)
Cl  -9. Not relating demo back to formula. S: 96. (Pre: N1;
    Post: N5)
R   -10. Lack of clearly stated purpose. S:3. (Post: N8)
S   -12. Late clarification of there being three liquids on top of 
    solid object. S:62. (Post: N8)
S   -13. White background wasn’t up immediately. S:17. (Post: N7)

# Features: Pre = 6 Post = 10 Exp = 7 Total = 13

Cl  Closure (Review)  Cx  Complexity  Et  Esthetics
Mo  Motivational      P  Pacing       R  Relavance/Purpose
S   Sequence          Tr  Transition

    Sp  +1. Good volume. S:2. (E2)
    Mv  +2. Teacher moves from one side of room to other. S:29. (E2)
    NV  +3. Nice one-handed gestures. S:77. (E2)
    NV  +4. Good eye contact. S:2-37. (E2, E4)
    Ct  +5. Admitting a mistake in obscuring top of cylinder. S:47.  
        (E5)
    Ct  -6. Avoids use of student’s name. S:63. (E2)
    Ct  +7. Acceptance of students’ answers. S:77. (E2)

# Features: Pre = 0 Post = 1 Exp = 7 Total = 8

Ct  Courtesy & Raport  En  Enthusiasm  H  Humor  M  Movement
NV  Nonverbal Gestures  Sp  Speech
BIBLIOGRAPHY


