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Case studies of the pedagogical content knowledge development of concept-oriented teachers.

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CASE STUDIES OF THE PEDAGOGICAL CONTENT KNOWLEDGE DEVELOPMENT OF CONCEPT-ORIENTED TEACHERS

A Dissertation Presented

by

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DEDICATION

This dissertation is dedicated to my husband Nat, for his patience, continued interest and loving support, and to my son Luke, who provided me with a refreshing balance.

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Many have supported me in bringing this effort into being. I would like to thank my committee chair, Patt Dodds, for her unflagging belief in the worth of this project, her reminders to count my experience, and her high standards; Dick Konicek, for leading me to the work of concept-oriented teachers and his gentle support; Charles Moran, for his penetrating and thought-provoking insights into teaching and learning; my participants, for sharing their time and teaching memories with me which allowed me to contact and more deeply understand my own; Irving Seidman, for his early guidance in my graduate career, especially for orienting me toward the PETE seminars which influenced the direction of this work; Larry Locke, for opening the doors of educational research through his rich knowledge and enthusiasm; Sandy White, for her vision, cheer, and friendship and for her generous offer to edit my paper; Judith Harmon Miller, my graduate school colleague and friend, for seeing 180 degrees from me; Peggy Ann Jayne, for taking such loving care of Judy and me; and my auditor and mentor, Barbara Piane, for her kindness, humor, wisdom, and guidance throughout the years I took to complete this process.

ABSTRACT

CASE STUDIES OF THE PEDAGOGICAL CONTENT KNOWLEDGE DEVELOPMENT OF CONCEPT-ORIENTED TEACHERS

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Pedagogical content knowledge -- a type of teaching knowledge derived from years of blending subject matter with pedagogy -- is only beginning to be mapped, notably in elementary math and science education. By reviewing teacher-made revisions of regularly taught curriculum units in math, science, English, and social studies, this set of case studies describes similarities and differences in the pedagogical content knowledge development of four concept-oriented middle school teachers, with particular emphasis on the nature and use of their instructional representations. In these cases, refinements in teacher knowledge surrounding the use of instructional representations for particular concepts resulted in more interactive, visual, and student-centered experiences. Various kinds of collegial exchange provided a major impetus to pedagogical content knowledge development. (120)

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

OVERVIEW

"One who learns from one who is learning drinks from a running stream."
(Native American expression, quoted in Fogarty & McTighe, 1993)

Statement of the Problem

In the crush of daily teaching, teachers seldom have time to collect their thoughts on what worked well with students and why. Those who do create a strong, though usually private foundation on which their teaching knowledge grows. Because this foundation is largely invisible, it has been under-appreciated as a source of insight into the development of teachers' pedagogical content knowledge (PCK) -- where knowledge of subject and pedagogy combine in response to individual students' needs to create a domain of expertise particular to the effective classroom teacher.

A poor understanding of the PCK of effective teachers has contributed to gaps in teacher education and to policies by state boards of education supporting shortcuts to certification in content areas with critical shortages. Such gaps and practices have subjected school children to people mostly unaware of the need to bridge between students and curriculum, and unskilled in transforming content into meaningful chunks which students can easily use. PCK focuses precisely on these concerns.

This study examines the PCK development of four experienced middle school teachers: one each of math, science, English and social studies. Because transformation of content is a central feature of teaching for conceptual understanding (Hollen, Roth &

Anderson,1991; Peterson, Fennema & Carpenter, 1991; Prawat, 1989, 1993), all four were selected for their commitment to teaching concepts. This study also attempts to address the gap in the literature on comparisons in teaching knowledge across content areas at the secondary level (Stodolsky & Grossman, 1995).

Questions posed are:

1. What changes over time do experienced teachers committed to teaching for conceptual understanding make in subsequent versions of an often-taught unit of study?

2. What is the nature of their PCK of the instructional representations used to depict core concepts within these units?

3. What are the major influences on the choices and possible refinements in ways they use these representations?

4. Are there underlying patterns across cases in the nature of unit revisions, choice of representations, and refinements in knowledge?

Definitions

1) *Teaching for conceptual understanding*: Concept-oriented teachers resist pressure to cover content for content's sake, choosing instead to target key concepts, processes, and attitudes for students to explore. They work for student understanding through a wide variety of creative modes; intentionally use their knowledge of patterns in students' misconceptions and conceptual breakthroughs; continually analyze students' experiences with content; and help students transfer their learning to the real world (Brooks & Brooks, 1993; Prawat, 1989, 1993). Students of such teachers, regardless of performance level, appear to have a clear sense of their teachers' curricular goals, have found them meaningful, reach them by and large, and are able to use what they've learned in the pursuit of their own interests (Brooks & Brooks, 1993; Prawat, 1989, 1993).

2) *Instructional representations*: An essential and creative component of a teacher's PCK, representations comprise the analogies, metaphors, examples, simulations, demonstrations, and concrete models used to bridge between students' current understanding and a core idea (Ball, 1991, 1993a; Brophy, 1989; Lampert, 1991; Shulman, 1986, 1987).

3) *Core ideas*: Propositions teachers consider most important for students to understand (Brooks & Brooks, 1993; Prawat, 1989;1993), (e.g., "Is Fascism an inevitable part of human nature?"); disciplinary processes (e.g., how to construct an essay); and basic attitudes the teacher sees as key for enabling students to acquire other kinds of targeted knowledge (e.g., a sense of personal agency in problem-solving).

Context of the Problem

Voices from many corners have raised concerns about the abilities of American school children to face the challenges of life in an increasingly complex world. Analysts of social change suggest the need for members of tomorrow's labor force to be good at problem-solving, working collaboratively, communicating effectively, thinking critically and creatively, understanding diverse technologies, and relating thoughtfully to different viewpoints (Brandt, 1989; Paul, 1987; Tinzmann and Jones, 1991). Sharing many of these concerns, proponents of "authentic learning" stress, in addition, the need for teachers to help students connect content to the world beyond the classroom (Newmann & Wehlage, 1993). Critical educators of the productive (vs. reproductive) tradition argue for "problematizing" class content through explorations of teachers' and students' assumptions, those embedded in the curriculum and the culture at large, as a means of empowering students to become agents of social transformation (Ericson, D.P. & Ellett, F.S., Jr, 1990; Giroux, 1988; Shor, 1986). In our post-bomb world, philosophers of science argue for the need to develop the intellectual procedures to deal with large integrated systems, as separating the sciences masks the complexity of a given scientific subject and its relationship to the larger social and political world, increasing the potential for disastrous consequences (Moore, 1988; Toulmin, 1985; Trowbridge & Bybee, 1986).

Whatever the desired outcomes, a key prerequisite to achieving any lasting outcomes in students, argue experts in the learning process, is the teacher's appreciation for the way students construct knowledge (Brophy, 1992; DeRuiter, 1991; Newmann, & Wehlage, 1993; Trowbridge & Bybee, 1986).[1] This appreciation leads to creating true learning communities within classrooms, where students, with teacher as guide, help each other develop core ideas and skills (Brooks & Brooks, 1993; Prawat, 1993). Designing such communities is, however, a "complex, situation-specific, and dilemma-ridden endeavor" (Sparks-Langer, G. M, & Colton, A.B.,1991, p.37) which "places extremely difficult logistical and diagnostic demands on teachers." (Brown, 1991, p. 230). Even in schools where adequate resources and reasonable class sizes might favor the creation of active learning communities, a majority of secondary public school teachers still practice pedagogy emphasizing breadth over depth, lower order thinking, fragmented and often unmeaningful content, and passive instruction (Brown, 1991; Brophy, 1992; ; O'Neill, 1991; Powell, Farrar, & Cohen, 1985; Prawat, 1992).[2]

As others have pointed out (Britzman, 1986; McDiarmid, 1990), such pedagogy has proven highly resistant to change -- due, in part, to what Lortie (1975) has termed the "apprenticeship of observation," in which novice teachers, guided powerfully by their experiences as former students, often underestimate the complexity of teaching. This leads

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[1] As Samuel Wineburg (1991) usefully reminds us, "Educational change has never come about by exhortation nor been sustained without deep knowledge of student learning." (p. 518).

[2] Recent results from the Third International Mathematics and Science Study underscore these observations (Wingert, 1996). US students rank at the bottom of mid-range performers in math, based on data from a half million students in 41 countries. Videotaped classroom observations which accompanied test results revealed that eighth grade US math teachers emphasize concepts only 22% of the time as compared with their Japanese counterparts, who spend 83% of class time on them. Typical US math classes entailed teachers explaining how to do a problem, then giving students ditto sheets on which to practice, while Japanese teachers would offer a problem and ask students to discuss the different ways they might go about solving it.

to paradoxical myths like "anyone can teach," yet "teachers are born, not made." Both assumptions ignore the value of carefully designed professional training based on a significant body of knowledge about teaching and learning aimed at intentional and needed outcomes.

Research into the ways effective teachers transform subject matter knowledge into content students find meaningful holds promise for clarifying how students can develop the rich and flexible understandings needed to meet the demands of life in a complex world (Brophy, 1991; Grossman, 1990; Gudmundsdottir, 1990; ; Marks, 1990; Prawat, 1989,1993; Shulman, 1986, 1987; Wilson & Wineburg, 1993; Wineburg & Wilson, 1988, 1991). Studies focused specifically on the development of students' understanding of concepts highlight this transformation process, and point, in particular, to the key role instructional representations can play (Brophy, 1989; Lampert, 1989; Leinhardt, Putnam, Stein & Baxter, 1991; Vosniadou, 1994). Thus, studying the PCK development around the use representations in concept-oriented teachers seems like a fruitful avenue for clarifying the professional knowledge and the professional development environments responsive to the needs of the day.

The Purpose of This Research

Focusing on the "missing paradigm" of subject matter knowledge in studies of effective teaching, Lee Shulman (1986) first delineated the concept of "pedagogical content knowledge" in his1985 presidential address to the American Educational Research Association.[3] This concept is of central importance to this study because it defines the significance of instructional representations in a teacher's knowledge base. In devising a

[3] Shulman points out that this was not a new idea: Dewey (1964/1916 as cited in Shulman, 1986) had proposed that subject matter and method were closely linked; method, he felt, deeply influenced what students actually learned.

theoretical framework of teacher knowledge composed of three overlapping areas -- subject matter content knowledge, curricular knowledge,[4] and pedagogical content knowledge -- Shulman suggested PCK include:

- Ways of effectively representing content (via metaphors, analogies, models, illustrations, and examples) to make it accessible to learners;

- Insights into patterns of difficulty students of different ages and backgrounds have with particular content, as well as common preconceptions and prior knowledge students bring to targeted content; and

- Knowledge of the most effective ways to help students reorganize misconceptions into understandings shared by members of the relevant disciplinary community.

Recent research into pedagogical content knowledge tentatively suggests that, rather than just a third knowledge domain which integrates content and pedagogy, PCK is more fruitfully approached as a developmental process ("pedagogical content knowing" according to Cochran, et. al., 1993) in which the continual merging of content and pedagogy in response to perceived learner needs results in qualitative transformations of the teacher's understanding of each. The stages of such development K-12, either within or across content areas, have not been systematically mapped (Brophy, 1991; Marks, 1990).[5] This study could contribute to such mapping by providing histories of the instructional decision-making of experienced teachers dedicated to teaching for conceptual understanding in math, science, English and social studies. Looking at the changes in the various versions of a single curricular unit and choices of instructional representations over

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[4] He defined subject matter knowledge to include teachers' understanding of the substantive and syntactic structures of their disciplines (Schwab, 1978, as cited in Shulman, 1986; see Chapter 2 for additional detail) and curricular knowledge to include the understanding of which materials best suited students' needs, how to adjust them, if necessary, and how such materials related to materials and experiences students have had in concurrent and earlier classes.

[5] Though the mapping of PCK is further along in content areas like elementary math (e.g., Carpenter, Moser, & Romberg, 1982, as cited in Carpenter, Peterson, Fennema, & Carey, 1988; Resnick, 1985 as cited in Peterson, Fennema & Carpenter, 1991) and science (e.g., Vosniadou & Brewer, 1992), the related knowledge of how students' conceptions evolve within particular domains within these subject areas continues to need much further research (Vosniadou & Brewer, 1992).

time, one might begin to capture some of the influences shaping these teachers' PCK development along with snapshots of PCK in action.

Significance

Uncovering insights into patterns of development of this kind of professional knowledge could:

1) Expand the availability of "practitioners' wisdom" to prospective teachers, thus expediting novices' understanding of the distinction between subject matter expertise and what is involved in its transformation for learners. This, in turn, could help to achieve a variety of outcomes, among them lower attrition rates from frustrated under-prepared teachers and more effective instructional practices.

2) Cut through the isolation curtailing teachers' professional growth by providing stories for in-service teacher development of teaching insights that are often undervalued as not generalizable and therefore remain unpreserved (McDonald, 1986). Such insights could be especially interesting to experienced teachers with strong pedagogical skills about to teach new content, as well as to those with strong subject matter knowledge, but less developed pedagogy. This seems particularly important at a time when many US students appear to lag significantly in math and science achievement as a result of practices which fail to emphasize conceptual understanding (Wingert, 1996).

3) Integrate grounded examples of longitudinal teacher development into on-going discussions among qualitative researchers interested in concept-oriented teaching and constructivist practices, to help inform teacher educators and curriculum developers.

4) Continue the work of others which clarifies that effective teachers are professionals who, though highly intuitive, make careful judgments within complex settings and whose knowledge continues to evolve over time, rather than simply coming in the form of a fixed "style" or mysterious talent which cannot be analyzed and learned from.

5) Provide insights into those influences most linked to the development of concept-oriented teachers' PCK for use by administrators interested in promoting nourishing environments for teacher learning.

6) Illustrate various paths concept-oriented teachers take in the growth of their understanding of their students, purposes, methods, and content, which the National Board of Teaching Standards might integrate into their rubrics for evaluation.

Background Information

Influences on Professional Knowledge

Many overlapping variables influence a teacher's professional knowledge: Social identity (Weiler, 1988); experiences as a student (Britzman, 1986); type and degree of teacher education (Grossman, 1990; O'Loughlin, 1988); adult developmental stage factors (Oja, 1989); and teaching context (Zeichner and Tabachnick, 1981), to name some which have been explored. Pedagogical content knowledge, with its subject-specific, student-specific focus, is additionally affected by the type of subject matter taught (Gudmundsdottir, 1990); the nature of subject matter preparation (Ball, 1993a); and the degree of familiarity teachers bring to the concepts they want students to learn, as this affects the nature of their priorities (Gudmundsdottir, 1990), the clarity of focus (Feiman-Nemser, S. & Parker, M.B.,1990), and the flexibility of their instructional strategies (Buchmann, 1983; Carlsen, 1991; Shulman, 1987).

At the base of *all* these influences are epistemological orientations: those of different disciplinary scholars, the teacher, the student, curriculum and standardized test developers, and other players in the instructional setting such as parents and administrators.

> Identification of the various instructional elements that carry epistemological impact is essential [to understand how they affect others' views of knowledge and knowing] and may require observational and ethnographic studies. (Hofer & Pintrich, 1997, p. 124)

Orientations toward knowledge and knowing of the various players may not be consistent and if consistent, not desirable for furthering the aims many reformers seek. Teacher/researchers Ball and Wilson (1996) see it as part of their professional responsibility to be intentional about which orientations they adopt.

> Historians differ in their views of facts and interpretation, the roles and uses of evidence, the goals and purposes of history, the Schwabian structures that they apply to their work. Likewise, mathematicians differ. Plato and Lakatos have very different views of the nature, role, and purposes of mathematics. Our work as teachers is informed by an on-going exploration of various epistemological and disciplinary debates in mathematics and history, science and literary criticism. The assumptions and selections we ma[k]e about what kind of history and what aspects of mathematics to teach [a]re value laden and woven into the moral fabric of our classrooms, pedagogical decisions, and our actions. (Ball and Wilson, 1996, p.178)

Teachers' epistemological commitments probably drive both what they value for learning outcomes and their sense of the ways students achieve them (Buchmann, 1983; Hamm, 1981; Hollingsworth, 1989; Langrall,1994; Lyons, 1990; Rancourt & Dionne, 1981).[6] Teachers, for example, may want to aim for more constructivist ways of teaching, but because of their epistemological commitments continue to use activities and grading geared toward memorizing facts (Schoenfeld,1987, as cited in Hofer & Pintrich,1997).

Since several researchers have begun to attend to the role of epistemological orientations in the development of PCK (Ball, 1991; DeRuiter, 1991), data on PCK growth

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[6] I am viewing capacity as a structural entity reflecting a teacher's ability to view knowledge a particular way at a particular time. I suspect it shapes the way a teacher is able to think about the nature of knowledge and learning, but not necessarily how (s)he acts on those thoughts. I see commitments, on the other hand, as the product of belief about the nature of schoolwork, and circumstance, e.g., values, job security, or available energy -- thus a more immediate influence on what teachers actually do. Alexander & Dochy (1995) make a similar point in stating, "Dearly held beliefs hold a greater role in prompting actions than knowledge because they include more personal goals, intentions, decision-making. The former results from formal schooling, the latter from everyday events."

from this study are analyzed, in part, from an epistemological perspective. How do the epistemological commitments of concept-oriented teachers seem to affect their practice? Have their epistemological commitments changed over time? What are their experiences like in attempting to use constructivist teaching practices with students socialized to hold objectivist beliefs about the nature of school knowledge?

Teaching for Conceptual Understanding: Conceptual Wholes

Reading specialist Renee Fuller (1993), in distinguishing human capabilities from those of the most advanced machines, calls attention to our singular capacity to "create context, to impose a structure on the myriad stimuli that surround us, to organize information in unique or ... descriptive ways, of understanding complex wholes..." (p.1), yet contrasts this with our relative inability to remember bits of information. Schools typically teach and test for bits of information without reference to a conceptual whole (Anderson & Roth, 1989), expecting students, in Woodrow Wilson's pithy terms, to list "one damn fact after another" (Wineburg, 1991). As a result, our brains impose their own meanings, which may or may not be useful or accurate (Fennema, Carpenter, & Peterson, 1989, as cited in Brophy, 1989; Nuthall & Alton-Lee, 1993). Creating conceptual wholes is a characteristic of teachers dedicated to teaching for conceptual understanding (Prawat, 1989, 1993). Research into the PCK of expert teachers also suggests that it is typical of many veteran teachers, as they tend to think of curriculum in terms of a few superordinate categories or themes (Gudmundsdottir & Shulman, 1987; Leinhardt, 1988 as cited in Prawat, 1989).[7] This allows them to create frameworks based on these ideas at the

[7] This same tendency to group ideas into chunks based on principles, typical situations or categories of situations has also been found to characterize expert problem-solvers (Davis & McKnight, 1979, as cited in Davis, 1983).

beginning of the term or year, and refine students' understanding of them through subsequent layers of detail in later units of study.[8]

Instructional Representations

In classrooms where teaching for meaning is key, teachers convey core ideas or conceptual wholes through carefully selected instructional representations -- metaphors, analogies, simulations, explanations, demonstrations and concrete models (Brophy, 1991; Lampert, 1989; Prawat, 1989). In combining something a student already knows about a core concept, with unfamiliar content through which the concept will be fleshed out, representations are the hinges between known and unknown. They become tools for students to think with, as well as tools for teachers to diagnose with, as which representations students choose to use and how well they use them can show teachers what students understand (Ball, 1991; Lampert, 1989). Working with representations in school can lay a foundation for developing the critical and creative thinking ideally gained through the powerful natural organizing frameworks of real situations (Wineburg & Wilson, 1991).

To create effective representations, teachers need to rely on four areas of knowledge: Subject matter; learning; students; and context (McDiarmid, Ball & Anderson, 1989). Integrating these domains is often hard: prospective teachers, for example, have been found to lack the conceptual understanding needed to create adequate representations (Ball 1988a, Clement, 1982, Wilson, 1988, as cited in McDiarmid, Ball & Anderson, 1989); yet even where understanding is present, controversies within the disciplinary

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[8] The "chunked" or "packed" nature of expert teachers' knowledge is echoed in the findings of research into the nature of other kinds of expert knowledge (see Spoehr & Shapiro, 1991, Dawson,

community over the nature and substance of the discipline can complicate representational choices (e.g., should American history be presented from a strictly Eurocentric perspective or be more multicultural?); students are variously equipped for school, thus not all representations work for all students (McDiarmid, Ball & Anderson, 1989); teachers often rely on texts which tend to represent content unproblematically or one-sidedly, implying an "either/or" epistemology (Davis, 1983; Grossman, Wilson, & Shulman, 1989; Paul, 1987), and on methods which encourage memorization without understanding (Anderson & Roth,1989); and, finally, teaching contexts are frequently marked by competing agendas: Those of teacher education programs, public school communities, and state departments of education (Burch, 1989; Lawson,1990). How well novice and veteran teachers resolve these issues, I believe, relates in part to the kind and amount of their pedagogical content knowledge.

Support for my belief comes from my professional experiences and from the work of researchers like math educator Deborah Ball (1993a), who sees the hallmark of the expert teacher in the ability to have a "bifocal perspective," where one alternates between the diverse needs of students and the various components of the "mathematical horizon." Wineburg and Wilson (1991) concur:

> Teachers must first turn inward to comprehend and ponder the key ideas, events, concepts, and interpretations of their discipline. But in fashioning representations, teachers must also turn outward. They must try, as it were, to think themselves into the minds of students whose lack of understanding they, as teachers, do not possess. Martin Buber (1965, p.100) has called this the "process of inclusion." (pp. 332-333)

Discussing science teaching, Carlsen (1991) makes a similar point,

> ...th[e] ability to match concepts, arguments and context constitutes subject-matter pedagogical knowledge...[thus] the substantive knowledge of a teacher may include a number of alternative representations of a scientific concept. The teacher's capacity to choose a representation

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Zeitz & Wright, 1989, and Chi & Koeski, 1983, as cited in Spoehr & Shapiro, 1991).

appropriate to a particular teaching situation is what characterizes subject-specific pedagogy." (p.132)

Appropriate and knowledgeable use of instructional representations forms a vital core of subject-specific pedagogy or PCK and thus, a key piece of a teacher's ability to dance between subject and student.

Representations vary with the material they try to embody and with teachers' goals. McDiarmid, Ball, & Anderson (1989) catalogue various forms among the disciplines:

> In math -- words, symbols, graphs, and models reflect core ideas, link core ideas, link an idea or procedure with an idea from another discipline or to the world at large, and show how ideas can be subject to interpretation vs. true or false;
>
> In literature study -- analogies, dramatizations and differing interpretive frames help students to compare characters and ideas in one text with those in another, in films, or in life;
>
> In writing instruction -- representations depicting a range of purposes and readers and dealing with the relationships between writer and reader, originality and convention, and spoken and written forms of expression;
>
> In science -- pictures, graphs, diagrams, models and tables allow students to "describe, explain, predict and control aspects of the everyday world" (Anderson & Roth, 1989);
>
> And in history -- analogies between now and then, maps and other graphics, stories, role-play and simulations try to capture events, figures, places, movements and themes.

Various attributes of instructional representations are illustrated in the following examples taken from studies portraying teachers' PCK:

Class:	American History, general track, 11th grade, suburban?
Concept:	Comparing and contrasting the value of human property with the value of human life in the ante-bellum South
Form:	Example
Mode:	Auditory

Harry (Gudmundsdottir, 1990; Gudmundsdottir & Shulman, 1987) is a story-teller. He asks students to picture slaves and immigrants working together to roll bales of hay down a hill to awaiting barges in Natchez. Then he asks them to reflect on where they think the slaves are situated: at the top or at the bottom? In this way, he paints a vivid picture of the values of American owners -- slaves were valuable property; immigrants only offered a potential conflict to slave owners as free but poor people who needed jobs. Immigrants, therefore, were positioned at the bottom, where if squashed by a loose bale, they would be seen as no great loss. This word-picture sets students up to confront the notion that human "property" was not perceived as human and because of this was sometimes valued more than other human lives in the ante-bellum South.

Class:	General science, 3rd grade
Concept:	The relationship between light and shadow
Form	3D model and discussion
Mode:	Visual, auditory

Nan Rochester (Smith & Neale, 1989, 1991) creates a Styrofoam ball with bits of spaghetti sticking out to simulate the way unimpeded light fans out in all directions. While this offers students a concrete model, when she tries to simulate light bouncing off objects, several noodles break, muddying the fact that light can be absorbed or refracted. Also, her model fails to account for what happens to the shadows of thin objects which move so close to a light source that they seem to fit between the rays (the physics of penumbras).

Class:	American History, A.P., 11th grade, suburban
Concept:	The price of war as seen through part/whole relationships
Form:	Pie graph
Mode:	Visual (pictorial and reading), tactile (writing), auditory (discussion)

David (Gudmundsdottir, 1991) believes students need to be critically aware of peace issues because students will someday "inherit the land." In teaching the Civil War, he focuses on only one battle, Antietam --the bloodiest. A day before, he gives students a pie chart he has made showing American casualties on the battlefields of all the wars Americans have fought. Percentages are given, but not which wars are represented. For the next class, students have to figure out which percentages go with which war. In this way, he sets them up to focus on the huge number of casualties lost at Antietam, and to grasp the core idea that neither side really won this battle -- influencing students to share his belief in the futility of war.

Class: Math, 5th grade, urban, culturally diverse (one third are ESL students)
Concept: Decimals as a form of illustrating part/whole relationships
Form: Money, number line, and pieces of a circle; discussion
Mode: Visual, auditory

Lampert (Ball, 1991) begins her unit on decimals with students comparing the relative sizes of different dollar amounts and speculating on how size relates to the way the amounts are symbolized. As she uses language like "one tenth of" or "a hundred times the size of" students begin to pick it up. When one student comments that .0089 is negative, Lampert switches to a number line, which can represent both decimal parts and positive and negative numbers. The class uses knowledge of coins to help them locate places on the number line, but still has problems understanding that very tiny numbers are not necessarily negative. At this point, she switches to a circle, which has the benefit of being continuous and present, therefore not less than zero, and yet it can be divided and subdivided infinitely. Gradually, through different exercises, students come to see that the greater the number of pieces, the smaller they are, but they are always more than zero.

In these examples, the representations move from a single mode (auditory, in Harry's case) to multiple (listening /seeing/ reading/ discussing, in David's, and three different representational forms in Lampert's); from one vocally involved student (after asking the whole class to reflect, Harry asks one student to answer) to observable participation by many or all in the class (David and Lampert); from strictly teacher-made representations (Harry, Nan, and David) to those developed by teacher and students (Lampert); from single use for presenting a concept (Harry) to multiple uses: Present ideas, diagnose student understanding, give students a source of judging power for subsequent problems (Lampert). They also vary in the amount of content their structural patterns can integrate, Harry's dealing with a particular era; David's with many.[9] The representations in all of these examples are external illustrations of core ideas, acting as bridges between the shared ideas of a scholarly community and those students are beginning to form.

As Leinhardt, Putnam, Stein & Baxter point out (1991), representations are never perfect reflections of targeted concepts. Their concreteness and familiarity makes them desirable, but teachers need to deal with possibly irrelevant or inaccurate content associated with them. These researchers found that the more teachers effectively used representations, the more likely they were to have a deep understanding of the targeted content.[10]

Teachers' use of multiple representations can supply a rich repertoire of access points for accommodating the different ways students have been found to learn (Fischer,1980, and Bidell & Fischer, 1992, as cited in Fink, 1993), provided such representations are already familiar to students (Dufour-Janvier, Bednarz, & Belanger, 1987; Janvier, 1987, p. 102-103). Multiple representations for certain concepts have been linked with greater flexibility in student thinking (Ohlsson,1987, as cited in Leinhardt, et. al. 1991). Such flexibility, in turn, has been associated with better transfer of learning into the ill-structured domains typical of the real world (Spiro, Vispoel, Schmitz, Samarapungavan, Boerger, 1987). As an arena in which teachers' creativity can come to

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9 Structural patterns differ in their ability to integrate content; lists, for example, being less highly integrated than hierarchies. David Hyerle (1996) has created a set of "thinking maps" to help students think "connectively," that is, integrate content through making explicit inherent structural relationships. In this respect they are similar to instructional representations. These include: circle maps (for displaying students' brainstorming and the context for the ideas generated during brainstorming); bubble and double bubble maps (for describing and compare/contrast), tree maps (for classifying), brace maps (for part/whole relationships), flow maps (for sequencing), and bridge maps (for analogies). Also like representations, these structures vary in the amount of content they integrate.

10 In expert teachers, Leinhardt (1988) found that they used a "commonly known referent" 88% of the time, while novices only used one 25% of the time; however, one of her novices, while less skillful in her explanation, used more imagination in creating her teaching tools than did the expert with whom she was compared, suggesting the PCK of novices and veterans may be developed mutually.

the fore, instructional representations provide a temporary context for incubating student understanding. By blending familiarity and challenge to stimulate development, they are akin to Papert's "microworlds" (1980), Schoenfeld's "reference worlds" (1986, as cited in Leinhardt, et. al., 1991) and Kegan's (1982) " holding environments."

Assumptions

About Concept-Oriented Teaching

I think of concept-oriented teaching as a large category which overlaps in part with strategies associated with teaching for meaning. The former may be taught without attempting to connect with the learner's world; the latter may or may not be focused on concepts: its primary concern is with content and methods which strive to connect with students' lives (e.g., shared inquiry, personal narratives, affective responses to content). Within the union of these kinds of teaching, I see teaching for conceptual understanding. This consists of core ideas and representations; supported practice;[11] analysis and diagnosis of learning; and application of concepts to a new context (Brophy,1989; Leinhardt, et. al, 1991; Langrall, 1994; Peterson, et. al., 1991; Prawat,1989).[12] The teachers in this study were selected for their commitment to teaching for conceptual understanding.

Within the category of teaching for conceptual understanding are the teaching strategies specifically associated with conceptual change (thought to follow conceptual understanding). These strategies include identifying prior conceptions; providing

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[11] Supported practice consists of brainstorming, problematizing content, engaging with content (listening to each other's thinking, offering activities at varying skill levels, responding to teachable moments), modeling the use of new learning, coaching, and gradually withdrawing support.

[12] Some or all of these pieces may be part of teaching practices with outcomes other than explicit understanding of concepts; but I think that intentionally using them *all* is unique to teaching for conceptual understanding.

discrepant events which clarify the untenableness of the prior conception; representations of the targeted concept; examples and non-examples of the concept; developing plausible, usable explanations to accommodate events associated with the concept; and reorganizing thinking through guided reflection (Clement, 1993; Dagher, 1994; Kinnear, 1994; Strike & Posner, 1992).

About PCK

Researchers have catalogued the components of PCK in a variety of ways (Carlsen, 1991; Grossman, 1990; Marks, 1990; Shulman, 1986, 1987). In distinguishing it from knowledge of content or knowledge of curriculum, Shulman (1986) defines it, in essence, as knowledge of instructional representations and patterns of student difficulty based on prior knowledge and current understanding, as well as strategies to help students use the former to overcome the latter. Adding to this, Grossman (1990) includes curricular knowledge and the teacher's sense of purpose for teaching particular content.

The kind of teacher knowledge needed to teach for conceptual understanding delineated by researchers like Prawat (1989) overlaps in part with elements of Grossman's and Shulman's schemes. Three components Prawat identifies for concept-teaching overlap directly: "Analysis and diagnosis of learning" (similar to ascertaining students' prior knowledge and areas of difficulty); "supported practice" (akin to instructional strategies, including representations); and "specific ways content knowledge may be applied" (not directly addressed by either Grossman or Shulman, but could be seen as a component of curricular knowledge and/or instructional strategies).

A fourth component of teaching for conceptual understanding is teacher knowledge of core ideas. Identifying core ideas, as Prawat defines it, is a part of a teacher's subject matter knowledge, which both Shulman and Grossman separate from PCK. This could be linked to Grossman's "curricular knowledge" and "purposes for instruction," if available curricular materials dictate a teacher's content goals.[13]

Implicitly addressing students' prior knowledge and explicitly addressing teachers' subject matter knowledge, Carlsen (1991) highlights the need for teachers to be aware of and negotiate differences in the way scientists, teachers, texts and students conceive of science. Although Carlsen does not clarify what might be involved in students' conceptions, presumably these would be influenced not just by cognitive developmental stage factors, but also by cognitive, social and emotional experiences with earlier science instruction, all of which effective teachers would need to know about. While not calling this negotiation PCK of students' prior knowledge and patterns of difficulty, Carlsen seems to be addressing similar terrain.

And finally, based on my own classroom experience, well developed PCK enhances the teachers' ability to deal with the effect of compulsory school attendance on student motivation to learn. Students often resent the disrespect implicit in asking them to engage in required activities they perceive as meaningless; equally, they can balk when asked to meet challenging, but unsupported teacher objectives. PCK provides bridges between students and content -- the structural supports needed to help all learners understand and use challenging ideas.

Taking the above as a whole, for the purposes of this study, I am less concerned with a definitive catalogue of PCK's components than a clearer perspective on one piece of PCK: instructional representations. This piece is either explicitly or implicitly found in each of the schemes outlined above and I believe could provide a focused lens through which to magnify the details of the PCK used to shape a particular learning event.

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[13] This is an interesting point: Do teachers choose curricular activities to support their goals, e.g., to help students understand a core idea or process? Or do they come to identify instructional goals only after repeatedly using available materials?

What other assumptions does this study make about PCK? PCK has reciprocal qualities points out Marks (1990), i.e., it can include not just the translation of particular subject matter knowledge into pedagogic terms,[14] but also application of a general pedagogical principle through particular content.[15] Thus a strict demarcation of PCK from knowledge of content and knowledge of pedagogy is hard to make. Marks further points out the fuzziness of PCK in suggesting it can come in forms evenly derived from subject matter knowledge and pedagogical knowledge. He offers this example:

> ...while critiquing a textbook one of the teachers picked out a diagram showing five balls of different sizes [aimed at having students indicate] what fraction of them are [sic] yellow. The teacher said that students would be confused, because they were used to thinking of fractions as ratios of areas, which conflicted with the number-of-objects ratio intended in the diagram. (p.8)

This bit of PCK hints at what Cochran, et. al. (1993) speculate is a qualitative difference in the way teachers (as distinct from curriculum developers or subject matter experts) think about content and pedagogy as a result of their PCK development. Instead of thinking, "Here's a way to illustrate this concept," teachers think, "How does this representation reflect the target concept? What is the prior experience of these students with representations of this concept? What will their experience of this representation be like? If this representation poses problems for them, how might one use their prior knowledge to develop and extend their understanding of the target concept using a different tack?" As the teacher encounters and analyzes this new representation, we glimpse one way PCK evolves: It is built-up by the continual process of locating and strengthening bridges between diverse, possibly resistant students and targeted curriculum.

This evolutionary quality is part of the basis for Cochran et. al.'s idea of a continuum of PCK development within individual teachers. Coming back to Grossman's

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14 e.g., seeing that a core idea in a unit on astronomy could be the effect of gravity on celestial movements and creating ways to represent that concretely.

15 e.g., checking for understanding (general principle) of the relationship between a geoboard and fractions (specific content), by asking students if they know how to represent 100% on the geoboard, not just the particular fraction in the problem they are working on.

emphasis on purposes for teaching particular content, perhaps different PCK continua could be articulated for different types of instructional goals.[16] Because of my value for meaningful learning, I particularly wonder about the possibility of a continuum of PCK focused on teaching for conceptual understanding. I assume that finding developmental paths within individual concept-oriented teachers would be a logical first step in articulating such a continuum.

Having looked at assumptions this study makes about the "content" and "pedagogical" parts of PCK, let us turn to the "knowledge" piece. Brophy (1991) points out the need to distinguish pedagogical content *knowledge*, which he defines as that which can be objectively verified, from pedagogical content *belief*, defined as subjective myth based on

> misinformation acquired from others, misperception or misinterpretations of classroom experiences, the operation of defense mechanisms, and other factors. (pp. 357-358).

He also observes, however, that distinguishing between knowledge and belief isn't always possible:

> Given that the development of knowledge is a dynamic process that features both construction and deconstruction in response to experience and situation demands, and given that much of what is commonly called knowledge has never been directly verified by the knower, one cannot construe knowledge as static or distinguish it unambiguously from beliefs. (pp. vii-xiii)

Others concur (Stein, Baxter, & Leinhardt, 1990). Some have tried to clarify the way knowledge and belief relate by suggesting that distinctions between them are influenced by one's culture and level of formal education, with more highly educated people more tentative about distinguishing them definitively (Alexander & Dochy, 1995). Other researchers have looked at the distinction in terms of "the practices of a community" (Cobb, Yackel, and Wood, 1988, p. 106, as cited in Peterson, et. al, 1991, p. 61). With

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[16] I'm reminded here of the four types of instructional goals discussed in ASCD's video, *Instructional Strategies Library* (1987): Mastery, understanding, synthesis, and involvement; and the four orientations to content Kliebard articulates (1987, as cited in Brophy, 1991) academic, critical, self-

proponents of constructivism urging school practice away from its historically behaviorist assumptions (Anderson & Roth, 1989; Ball, 1991; Brandt, 1994; Hollen, Roth & Anderson, 1991; Lampert, 1991), I believe public schools are in a watershed period relative to belief. Because constructivist practices haven't been fully institutionalized (as Cobb, et. al. point out), they probably fall into the realm of belief; yet if enough people agree to their value and document results of their use, they will shift into knowledge. Likewise, for the PCK associated with them.

For these reasons, I believe that descriptions of PCK must be seen as some mixture of knowledge and belief, as evolving rather than fixed, and as partial rather than complete. The very slipperiness of its definition and the fact that much PCK may seem to be discontinuous (gained by working with particular students and particular content, neither of which may coincide again in quite the same way) may account, in part, for why it has eluded systematic study. Yet, in attempting to describe the nuances of the union of teacher, student, and content, I believe this concept captures the quintessence of teaching knowledge and that its particulars add up to a valuable map of selected curricular territory, which others may find useful as a starting point for creating or refining maps of their own.

About Representations

A stage in Shulman's pedagogical reasoning model under the category of "transformation," representations help to make content and concepts more accessible to students (Shulman, 1986,1987; Wilson, Shulman & Richert, 1987). Focusing on the metaphors, analogies, examples, demonstrations and models which teachers have used to convey key concepts and processes, instructional representations, as Shulman and his

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development and life skills.

associates define them, do not refer to the mental representations students already have of content to be learned (McDiarmid, Ball and Anderson, 1989). Yet, these are of great importance to the teacher committed to conceptual understanding. As Davis (1983) remarks in the context of math:

> The job of an instructional program is to make solid contact with the mental representations that a student already possesses and to provide those experiences and interpretations that will help the student develop his or her representational capability further, hence becoming able to represent more complex mathematical situations and mathematical knowledge. (p. 108)

Sensitivity to students' internal representations is a likely influence on the instructional representations teachers choose who are committed to teaching for conceptual understanding, thus some attention to research on students' mental representations of academic content is given in Chapter 2.

The definition of instructional representations used here includes those teaching and learning strategies which supply a *concrete* way to mirror core concepts, processes and attitudes a teacher or student has targeted for exploration. It excludes the fleeting analogies a teacher makes on the spot (which can be legitimate and fascinating, but not easily captured in the net of this study) as well as a host of other instructional strategies, such as asking and answering questions, soliciting personal reactions to a poem, story, or novel, inviting students to support a point of view, critique an argument, use an algorithm, or conduct an experiment, *unless* these strategies are intentionally used to mirror a target concept, process, or attitude.

I think it's not only possible, but common to teach without instructional representations as defined here; and, sadly, equally common to use them without teaching for conceptual understanding, as in many math classes where students may use graphs, for example, without realizing what they represent (Dufour-Janvier, et.al.,1987). But based on what I have read and experimented with, I do not think it's possible to teach for conceptual understanding without instructional representations.

I believe concept-oriented teachers may be at different points in their evolution toward clarity about their core ideas.[17] Similarly, I conjecture that some teachers may use representations, want students to develop conceptual competence, yet may not consciously lay bare their design for students to think about, so student learning, though meaningful, will probably be more inchoate and less transferable into new situations. I assume that the greater the teacher's explicitness in naming target concepts, processes, and dispositions, and asking students to think about their experiences with developing them, and the more concrete teacher- and student-made representations there are of them, especially with very abstract and/or unfamiliar ideas, the more effective the instruction will be for fostering their use in a new setting.

About Learning

I have a constructivist orientation to learning, i.e., that meaning resides in the knower and an objective reality can only be approached through a series of ever more workable approximations. Within this world view, facts have a temporary and value-laden place as markers for manipulation, useful until the learner encounters/devises a more workable set (von Glasersfeld, 1987; 1989a; 1989b). To expedite approximating, I value the intentional development of conceptual frameworks for integrating facts, and metacognition, where, as a regular part of instruction, students consciously attend to their strategizing. This view of learning is akin to the approach used in science which treats

> space, place, time and magnitude...as conceptual structures which [can] be revised when necessary, in directions dictated by large complexes of theory, diverse bodies of data, and numerous criteria of progress in science (Schwab, 1962, p.198).

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[17] I suspect that asking teachers to analyze their teaching in terms of core ideas could be valuable in helping them clarify their deep objectives, which may be obscured by competing agendas, time crunches, and the direction of convenient pre-made materials.

My experiences as a classroom teacher have shown me that most students can learn successfully given the right emotional and cognitive supports, so I value high academic and affective expectations for all students, and endorse both inquiry-oriented and didactic practices, depending on the amount of experience students have had with targeted concepts.[18] To make the most of the short time we have with students, I believe it is largely pointless to try to "cover" material if students see no meaning in it. This leaves me impatient with conventional forms of assessment, which typically ignore goals associated with transfer of learning to new settings beyond a particular class.

About Teaching

As an advocate of critical thinking once commented, I prefer objectives which test application of knowledge and take its learning as given, rather than those which stress the acquisition of facts and assume they will someday be used. Even though I believe that it is the responsibility of teachers to go more than half way in trying to find ways to reach students, with current funding and professional development arrangements, and the realities of class composition and size, planning time, and material shortages, there are limits to what the community should expect of schools. As Rose (1989) usefully reminds us,

> ...ours is the first society in history to expect so many of its people to be able to perform ...very sophisticated literacy activities. And we fail to keep in mind how extraordinary it

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[18] This parallels Willson's (1987) value for using both theory-building and theory-confirming approaches to scientific observation, depending on the observer's level of knowledge. Willson asserts that the former is of more use to novices because they need to develop the domain-specific knowledge and problem-solving processes which the expert already has. Thus, I believe that didactic approaches have a legitimate place in a teacher's repertoire when used to advance the meaning-making students have already developed.

> is to ask *all* our schools to conduct this kind of education -- not just those schools with lots of money and exceptional teachers and small classes -- but massive, sprawling schools, beleaguered schools, inner-city schools, overcrowded schools. It is a charge most of them simply are not equipped to fulfill, *for our educational ideals far outstrip our economic and political priorities.* (p.188, *emphasis added*)

I expect parents to be part of an educational team with the school, and believe that when parental support is absent, the teacher's effectiveness can be significantly compromised. Finally, I believe that the greatest educational gains come from teachers working collaboratively and that time should be made to do this.

About Adult Development

As with students, given a workable blend of challenge and support, I see myself and other teachers as capable of evolving both personally and professionally. Most school settings in which I have worked typically offer an information-poor environment and intensely crowded workdays with little time for reflection -- thus are not ideal for either type of development.

As I see people's knowledge evolving the more they interact in varied ways with their environment, I regard adult developmental schemes as guides that may provide a better understanding of people's needs while they learn, not as explanations for why they can't learn to understand in new ways. Based on research suggesting adults continue to develop in a variety of domains into old age (see findings by Kohlberg, 1979, and Heath, 1977, as cited in Thies-Sprinthall and Sprinthall, 1987), I believe teachers (like students) are more capable of growth than findings about their developmental levels seem to suggest (see, for example, Oja, 1989, on the modest levels of ego development she found in teachers). I believe such findings say more about the lack of environmental supports teachers face than about innate capacities.[19] Feuerstein (1979, as cited in Fisher and Kenny, 1986) has noted that developmental levels are rarely tested under conditions which pull for optimal performance. Others have found that as a person's optimal level increases, so does the gap between functional and optimal levels (Fisher and Kenny, 1986), underscoring the importance of supportive environments in which to work, grow, and be tested.

With several caveats, I believe that research based on epistemological schemes may be helpful in analyzing possible influences on the development of teachers' PCK. First, labels describing the way people act or think in particular situations must not be confused with innate capacities. As Roth and Roychoudhury suggest (1994, as cited in Hofer & Pintrich, 1997), based on what we still don't understand about the nature of personal epistemology, "it might be appropriate to speak of epistemological positions only in specific contexts rather than as descriptors of an individual's views in general" (p.121). Second, researchers have conceptualized epistemology in a variety of ways, leaving gaps and inconsistencies about not only such issues as whether it is a developmental process or a context-sensitive set of positions, but also which dimensions it encompasses, how it relates to age and educational level, how it evolves, how to measure it, its relationship to the syntax of different disciplines, how it varies with conceptions of academic tasks and motivation, and its relationship to gender, race, and culture (Hofer & Pintrich, 1997). Because of variations within these areas, observations based on epistemological schemes in

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[19] School organization, some have noted, actually "drives out more psychologically mature teachers" (Schlecty & Witford, 1983, as cited in Thies-Sprinthall, 1984). To illustrate, Glickman (I990) talks of how schools function in opposition to the natural transitions of an adult's life. Young teachers' idealism is undercut by a job with the same responsibilities as that of the twenty year veteran, the lack of variety of most teaching assignments, and the absence of advancement potential. The repetitive nature of the job subverts a need by middle-aged teachers to re-order priorities, while the older teacher's needs for a sense of generativity and accomplishment are undercut by administrators who often treat them the same as they do younger teachers.

this study are highly tentative, offered in the spirit of furthering reflection rather than defining specific terrain.

About Those with Different Assumptions

In many ways I adhere to the tenets of the Pragmatic tradition in education, perhaps best known through the work of John Dewey, who emphasized both teaching and learning (Hamm, 1981). I believe children learn most effectively by actively engaging in problem-solving in situations as close to real life as possible; and that teachers need to design learning experiences which intentionally build on students' prior experiences. I also believe that learning is enhanced by metacognition -- a component Dewey does not explicitly name.[20]

Advocates of the Realistic tradition (e.g., Edward Thorndike, B.F. Skinner, James B. Conant, and Lloyd Trump) would find fault with this intensive rather than extensive approach to curriculum (not efficient enough), the power-sharing needed to encourage students to teach each other (inappropriate to share with "lessers"), and the epistemological assumption that reality is not fully knowable. I would respond that unintegrated factual knowledge -- the usual way knowledge is presented in Realistic curricula -- yields inefficient learning in the long run because the emphasis is not on supporting transfer into new settings; that for better or for worse, students have rich inner lives which interact with school learning; and that worldviews based on absolute certainty tend not to be very effective in solving complex life problems.

Existentialists like A. S. Neill, whose educational beliefs emphasize learning over teaching, would find my emphasis on multiple perspectives, self-knowledge, and

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[20] For me, constructivist methods usually associated with Pragmatism are a potential means for any of the traditions named in this section, but are more likely to be found in classrooms where teachers are interested in having students develop conceptual understanding, have at least as strong as interest in process as product, and actively probe for the ways students are making sense of their experiences.

compassion, appropriate to developing responsible free-thinkers. They would probably disagree with the extent to which I think the teacher must intentionally use a professional knowledge base in order to create a learning environment effective for most learners. Adherents to the Idealist tradition (which Hamm sees as emphasizing teaching over learning, and underlying the philosophy of Christian schools, the back-to-basics movement, censorship, and those who push for teaching traditional values), in stressing reading and ignoring the role of experience in real learning, would do likewise. They would object to my sense of school, not as a mirror of society, but as one vehicle for transforming it, and see little worth in interdisciplinary thinking. Some Idealists (e.g., Paul Goodman, Jonathan Kozol, John Holt) would share my value for students' interests as well as my concern with students' character and creativity.

Classicists, whose beliefs inform Catholic schooling and most liberal arts colleges, rely on revelation (for religious Classicists) and intuition (for lay Classicists) as the highest sources of knowing (Hamm, 1981). I share an appreciation for intuition, as I believe that it plays a key part in the teacher's capacity to see from the student's emotional and cognitive perspective, which I consider a prerequisite for genuine dialogue. Intuition also plays a central role for me in the creative insights teachers have about ways to structure learning experiences which truly take hold and in the way they respond to the spontaneous and serendipitous convergences of subject matter knowledge, perspective-taking, pedagogy, and chance events characteristic of "teachable moments." For Classicists, however, intuition and revelation are pipelines to an absolute reality reachable by an elite (the most religious, the most academic), grounded in the "pure wisdom" of ancient texts; and thus seem quite removed from any dealings with students. More than the Existentialists and the Idealists, most Classicists would believe it unnecessary to shape a learning encounter other than through direct transmission, which is clearly out of step with Vygotskian learning theory (1986) to which I subscribe.[21]

Classicists would slight my assumption that depth is better than breadth by stating that students cannot think if they have no facts to think with, and they would consider my emphasis on pragmatic education too prosaic, too nearly vocational. The notion of teachers sharing agendas with students would strike many as absurd and approaching content open-endedly, as sloppy and irresponsible. For them, learning should be hard work. According to Hamm, recent proponents of Classicism like Maxine Greene and Robert McClintock, in attempting to redefine it for the modern age, are stressing critical thinking as a way to lead "an examined life" and achieve "excellence in autonomous action" (Hamm, 1981, p.102). They would laud my emphasis on the same ends, but question the means I might use to achieve them.

My response to my critics' concerns is to cite O'Hara (1989) that "no one system of truth can adequately account for all aspects of being." For me Pragmatism offers the most effective orientation to the demands of schooling today because it embraces eclecticism: variety of approach, both content and procedural knowledge expectations for all students, having students help each other, valuing the whole person and recognizing that students are far from blank slates. In my experience, practices based on these beliefs seem to have accomplished more for more students than those stemming from any other philosophical orientation alone.

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[21] By this, I mean that I agree with Vygotsky's notion that knowledge is built up, in part, from interactions between the individual and cultural elements like technology and the media, which shape how we construct our sense of the world. Understanding how a learner thinks, an experienced teacher can stimulate development by supporting him or her to move from functional to optimal levels of performance.

Exclusions

My intent in describing a developmental history of the units in which instructional representations are found is to locate such representations in a curricular context so that broad variables influencing revisions in both units and the teacher's PCK of representations may surface. Other aspects of PCK -- use of students' prior knowledge, purposes for instruction, curricular knowledge, instructional strategies, contexts for understanding and so on -- will be discussed as they augment a picture of unit and representation development, but are not a primary focus of this study.

CHAPTER 2

REVIEW OF LITERATURE

> "Expert teaching entails not a selection of methods but the transformation of knowledge. History teachers must take what they know and create representations of content that engender new understandings among children who often come to school with scant motivation to learn.... Under the right conditions, even third graders can grasp something of history's indeterminate nature to arrive at sophisticated interpretations of the past." (Wineburg, 1991, p. 517, 518)

Introduction

Before Shulman's delineation of the concept of pedagogical content knowledge as a significant, yet under-explored component of teachers' professional knowledge (1986), parts of PCK had been embedded in a variety of earlier research agendas.[1] These can be roughly divided into those exploring the nature of teachers' knowledge and those addressing how students think. Samples of studies from each are grouped below by discipline.

Studies Focused on Teacher Knowledge:

General - The relationship of teachers' knowledge and beliefs to their practice (e.g., Buchmann, 1983; Harlen, 1975, and McCutcheon, 1980, as cited in Smith & Neale, 1991; Thompson, 1984).

Math - Differences in the knowledge of experts and novices in teaching math (e.g., Leinhardt and Smith, 1985) and science (e.g., Anderson & Smith,1986); and the nature and use of instructional representations in math (e.g., Kaput, 1985).

Science - Strategies for inducing conceptual change in science (e.g., Posner, Strike, Hewson & Gertzog, 1982, as cited in Strike & Posner, 1992; Werner, 1948,

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[1] Many of these (e.g., naive conceptions in children and adults within a particular content domain) continue to be investigated without specific reference to PCK, yet these studies are directly related to this type of teacher knowledge.

Keil,1979 and 1983, Smith, Carey, & Wiser, 1985, and Carey, 1985, as cited in Vosniadou & Brewer, 1992); differences in the knowledge of experts and novices in teaching science (e.g., Anderson & Smith, 1986).

Studies Focused on Student Knowledge:

General - The role of students' prior knowledge in learning (for a review of this literature, see Bransford, 1979, as cited in Vosniadou & Brewer, 1987)

Science - How students' scientific theories develop (see Vosniadou & Brewer, 1987, for a review); students' prior beliefs and knowledge in science (e.g., Clement,1982, as cited in Clement, 1993; Anderson, 1984, and Davis, 1983, diSessa, 1982, Posner, Strike, Hewson, & Herzog, 1982, and Schoenfeld, 1983, as cited in McDiarmid, Ball & Anderson, 1989; Chi & Koeske, 1983, as cited in Spoehr & Shapiro, 1991);[2] children's knowledge about the shape of the earth and gravity (Nussbaum, 1979, Nussbaum & Novak, 1976, Sneider & Pulos, 1983, and Malie and Howe,1979, as cited in Vosniadou & Brewer, 1992).

Math - The thinking and problem-solving of young children doing addition and subtraction (e.g., Carpenter & Moser, 1983, and Riley, Greeno, & Heller, 1983, as cited in Peterson, Fennema & Carpenter, 1991).

Reading - Differences in the strategies of expert and novice readers (Nicholson, 1984; Palinscar & Brown, 1984, as cited in Scardamalia, 1984).

Writing - Differences in the strategies of expert and novice student writers (Scardamalia, 1984); stages of development in young students' writing (Graves, 1983; Rentel & King, 1983, as cited in Scardamalia, 1984).

Social studies - children's attitudes and knowledge about government (Hess & Torney, 1967 and Greenstein, 1965, as cited in Sinatra, Beck & McKeown, 1992).

Following Shulman's call to explore PCK during his 1985 Presidential address before the American Educational Research Association, subsequent research into pedagogical content knowledge seems to have clustered in three areas:

1) The relationship between the nature and amount of teachers' subject matter knowledge and their pedagogical decisions, (e.g., Anderson & Roth, 1989; Ball, 1991; Gudmundsdottir & Shulman, 1987; Hashweh, 1987; Hollon, Roth & Anderson, 1991; Lampert, 1989; Leinhardt, 1988; Leinhardt, Putnam, Stein & Baxter, 1991; Smith & Neale, 1987, 1989, 1991; Wilson & Wineburg, 1988,1993; Wineberg & Wilson, 1988, 1991).

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[2] Vosniadou & Brewer, 1992, also cite research in cognitive science, science education, and developmental psychology dealing with this issue, starting with Ausbel's work on preconceptions, published in 1968.

2) Other influences on teachers' PCK, including the effects of teacher education (Grossman, 1989, 1990; Stengel 1991); teachers' values (Grossman, 1987, 1991; Gudmundsdottir, 1990, 1991a, 1991b); teachers' belief (Hollingsworth, 1989; McDiarmid, 1990; Peterson, Fennema, & Carpenter, 1991); and teachers' epistemological assumptions (Brickhouse, 1990; Lovell, 1993; Paul, 1987).[3]

3) How PCK develops in pre-service teachers (Cochran, DeRuiter & King, 1993; Deruiter, 1991; Stengel, 1991)[4] and the use of case study as a way to develop teachers' PCK (Barnett, 1991; Kagan & Tippins, 1991; Marks, 1990).

This review samples theory and research in three areas relevant to a study of *concept-oriented* teachers' PCK development as it relates to representations: The first explores studies connecting teachers' subject matter knowledge with their pedagogical decisions; the second examines those studies aimed at delineating the type of knowledge needed to teach for conceptual understanding; and the last includes studies dealing with the nature and use of instructional representations.

Teachers' Subject Matter Knowledge and Their Pedagogical Decisions

Conducted in the 1960s and 1970s, the first branch of studies into teachers' subject matter knowledge tried to link the amount of college courses teachers had taken in their field with subsequent student achievement as measured by standardized tests (summarized in Grossman, Wilson, & Shulman, 1989). Little or no connection was found, but several studies in math did find a link between teachers' subject matter knowledge and students'

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3 Hollingsworth (1989) and Paul (1987) do not use the concept of PCK *per se*, but approach it in a concern for how teachers' beliefs affect their ability to "merge knowledge of human learning, subject, and pedagogy into specific academic tasks" (p. 163, Hollingsworth); and in discussing the needs and methods required to "provide an environment in which children can discover their own *activated* ideas [about their] mathematical...physical...personal, social, moral, historical, economic, and political views." (p. 137, Paul)

4 Ammon and Hutcheson (1989) offer a model of pedagogical development which, while not specifically addressing the subject matter component, may be useful to integrate with others' ideas of PCK development because it captures a shift in novice teachers' understanding of students away from what Belenkey, Clinchy, Goldberger, and Tarule (1986) would term "Received Knowers" toward seeing them as knowledge-builders, evolving along a cognitive-developmental path.

conceptual understanding (Begle, 1972, and Hunkler, 1968, as cited in Grossman, et. al.,1989).

A second branch of research into teachers' subject matter knowledge simply tried to describe what teacher knowledge was like (Calderhead and Miller, 1985, and Feinman-Nemser & Buchmann, 1985a, as cited in Grossman, et. al., 1989) or contrasted the subject matter knowledge of expert and novice teachers in order to clarify the nature of each (e.g., Anderson & Smith, 1986 in science; Leinhardt & Smith, 1985 in math).

Studies largely spawned by Shulman's Knowledge Growth in a Profession Project (1986) and his Teacher Assessment Project (1986-1989) form a third branch of this research. Adding back the subject matter component both to research on effective teaching and to the teacher testing and evaluation policies of the early 1980s, these Projects identified several "strategic sites" at which to collect data on the way teachers' subject matter knowledge influenced their pedagogical decisions (Shulman, 1986).[5] One was in observing how novice teachers taught themselves how to teach material they hadn't encountered before (Grossman, 1990; Wineberg and Wilson, 1988); another was in observing how teachers dealt with texts they disagreed with (Gudmundsdottir and Shulman, 1987; Wilson & Wineburg, 1993). Sample findings in the second and third generation of studies linking teachers' subject matter knowledge with their pedagogical decisions are discussed by discipline below.[6]

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[5] Shulman (1986) points out the interesting paradox that in ancient times the assumption was that to know something meant one could teach it, which underpinned the beliefs of educators in the 1870s who stressed content knowledge and assumed knowledge of pedagogical processes were implicit; yet 110 years later, educators stressed pedagogical knowledge and took content knowledge as given. Neither assumption recognized how one informed the other and the need for explicit instruction in how to blend them.

[6] In order to simplify the task of identifying subject matter knowledge in English (which has several subfields: Composition, literature, and language; and highlights several separate skills: Reading, writing, listening, and speaking), and because subject matter preparation in high school and college stresses literature, the studies of PCK in English associated with Shulman's Projects concentrate only on teaching literature in the high school. However, because one of the participants in this study describes her experiences with Atwell's (1987) reading and writing workshops, research in reading and writing is touched upon in this review.

Math

Math teachers with richer subject matter knowledge have been found to make many more connections between topics than teachers with less knowledge (Leinhardt & Smith, 1985). High knowledge teachers have also been found to place more emphasis on conceptual understanding, low knowledge teachers on rote memorization of algorithms for problem-solving (Ball, 1991; Leinhardt, 1988; Leinhardt, Putnam, Stein and Baxter, 1991). If the teacher has high subject matter knowledge, adopts constructivist methods, and believes that all children can learn, children of all performance levels can become numerate, i.e., able to think mathematically about everyday problems (Lampert, 1989). Without adequate subject-matter knowledge, it is unlikely that teachers will be able to realize the current math standards (NCTM, 1989), which emphasize complex problem-solving, connecting concepts and procedures across math topics using a variety of representational formats, and exposing students to the way math is developed; nor will they adequately prepare students for later classes in math (Stein, Baxter & Leinhardt, 1990). Instead, they are more likely to overlook key ideas, miss opportunities to help students link key ideas, fail to help students see broad patterns, and stress math facts with limited application (Stein, et. al., 1990).

Science

In primary science classrooms, less than adequate subject matter knowledge seems the norm, where classrooms tend to look more positivist or empiricist, reflecting older approaches to the discipline, rather than constructivist, reflecting current approaches to the history and nature of science (Smith & Neale, 1991). More knowledgeable elementary science teachers have been found to be better able to respond to training in constructivist methods, provided they agree with the basic notion of constructivist teaching that "less is more" (Anderson & Roth, 1989; Hollon, Roth, & Anderson, 1991; Smith & Neale, 1991).

In secondary science, one study found a teacher's high subject matter knowledge to be linked with a notion of scientific theories as "tools to think with," resulting in a more conceptual instructional emphasis; low subject matter knowledge to a view of scientific theory as empirically proven, rigid truth, resulting in a piecemeal instructional approach emphasizing rote learning of "right answers" (Brickhouse, 1990). Teachers of biology and physics with more subject matter knowledge have been found to have a greater capacity to connect material across topics and concepts, assess and respond more effectively to students' preconceptions, and make the most of teachable moments (Hashweh, 1987).

Literature

Degree of subject matter knowledge influences the clarity and nature of a teacher's goals (Grossman, 1991), yet may be less significant in determining teacher effectiveness than the kind of professional training prospective English teachers receive. Highly knowledgeable but untrained novices may be less clear about what makes content difficult for high school students and less willing and able to build bridges between it and students than trained novices with less background in literature (Grossman, 1989; 1990). Other studies have suggested that values exert a key influence on the way English teachers shape content, and by implication, on the type of PCK they develop: In teachers with comparable amounts of subject matter expertise, one teacher with a student-centered emphasis may use "reader response," while another, preferring a text-centered approach, will highlight textual explication and linguistic analysis (Gudmundsdottir, 1990, 1991).

Social Studies

Novice social studies teachers of American history who majored in history or American studies have been found to have more frameworks for organizing the facts of American history, a greater sense of interesting questions and themes to be transformed into units of study, a more complex sense of historical causation, and a keener sense of the constructivist nature of historiography, leading to a greater desire and ability to include different viewpoints and interpretations in instruction than those who major in the other social sciences (Wilson and Wineburg, 1988). In history teaching, high subject matter knowledge has been found to be critical to effective teaching, but no particular pedagogy is implied; effective teachers may place either themselves or students center-stage, depending on the lesson's objectives and the nature of the class (Wineberg & Wilson, 1988; 1991).

Veteran teachers with adequate background in history may have more ideas for how to shape units of study out of disciplinary knowledge and a clearer sense of the pros and cons of each than novices do (Gudmundsdottir and Shulman, 1987). However, those in charge of teacher assessment need to revise what constitutes adequate subject matter knowledge in history, due to developments within the discipline in the last quarter century, which many veterans, having been trained earlier, may not incorporate into their teaching (Wilson & Wineburg, 1993). While seldom cited as a concern by teachers, administrators, or even teacher educators, the gap between these substantive and syntactic developments in the field of history,[7] (e.g., inclusion of disenfranchised groups, an awareness of the constructivist nature of historiography) and the practice of teachers in history classrooms appears particularly wide (Banks & Parker, 1991).[8]

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[7] Substance and syntax are components of what Charles Schwab called the "structure of the disciplines" (1978, as cited in Shulman, 1986). "Substance" includes the concepts, principles and details making up the field; "syntax" involves the procedures by which what is true within the discipline is established, e.g., in science and history, how facts are determined; in literature study, rules governing hermeneutics; in math, what constitutes legitimate paths to solution.

[8] Teachers of social studies, for example, are called upon to teach a variety of subjects for which they may not have been formally prepared (Ball and McDiarmid,1990; National Center for History in Schools, 1991, as cited in Wineburg and Wilson, 1993). These range from standard courses in American and European history to anthropology, economics, world cultures, sociology, psychology, and family living, any one of which (with the exception of the last) could have been the lone conduit

Summary

Across content areas, the studies sampled here suggest that high subject matter knowledge leads teachers to have richer connections between topics within their discipline, thus more ideas about how to structure curriculum. It also appears to allow teachers to approach content with a greater epistemological sophistication, as seen in their emphasis on concept learning, appropriate representations, and students using tools to interpret and discuss content rather than on memorizing procedures and right answers. High subject matter knowledge appears to be associated with greater flexibility in responding to students' ideas and needs.[9] Values appear to play a key role in the kind of PCK teachers develop, as greater subject matter knowledge does not, by itself, ensure that teachers will use constructivist methods. Gaps between developments within the disciplines of science and history, and teachers' subject matter knowledge in these areas, at the elementary level for the former and at the secondary level for the latter, appear greater than in other content areas.

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through which certification in social studies is gained. Because of this, novice social studies teachers face exceptional pressure to learn content at the same time they are expected to know the relevant materials and methods needed to help students learn it.

[9] In thinking about differences between less and more skillful thinkers in the various content areas, it strikes me that one could characterize novices as more "noun-like," preoccupied with discrete facts in the process of "node"-building, experts as more "verb-like," preoccupied with how to "link" nodes. This is echoed in recent research into the development of student teachers' conceptions of planning and flexibility during the course of their practica, where their notion of planning shifted from lesson design and materials (noun-ish and node-like) to integrating design with classroom management and meeting students' needs (verbish and link-oriented); and of flexibility as preparing for class (one node: the concept of "class"), to differentiating instruction to accommodate students' needs and be responsive to unplanned "teachable moments" (verbish; linking the student teacher's agenda to the more complex concepts of "students' needs" and serrendipitous teaching opportunities) (Jones & Vesilind, 1996).

Teaching for Conceptual Understanding

This form of teaching involves making content accessible to students so that integrated understandings result and knowledge can be transferred effectively to the ill-structured domains of life outside school, rather than remaining unused because rote memorization limited its accessibility and usefulness (Anderson & Smith, 1987 and Nickerson, 1985, as cited in McDiarmid, Ball & Anderson, 1989). The effort to codify the components of teaching for conceptual understanding stems, in part, from the work of theory-based researchers interested in developing and testing models of good teaching, rather than from practice-based models developed by comparing and contrasting what expert and novice teachers have done (Brophy, 1991).

Based on a constructivist theory of learning, teaching for conceptual understanding entails:

* strong subject matter knowledge and knowledge of ways it must be transformed for students to find it usable (Anderson & Roth, 1989; Ball, 1991).

* a belief that given the right supports, most students can learn for conceptual understanding (Ball, 1991; Hollon, Roth, & Anderson, 1991; Lampert, 1986, 1989; Peterson, Fennema, Carpenter & Loef, 1989, as cited in Peterson, Carpenter, & Fennema, 1989).

* socializing students into a discourse-based learning community in which students' views are valued and built upon (Brooks & Brooks, 1993; Lampert, 1989).

* representation of content with students' prior knowledge in mind (Hollon, Roth, & Anderson, 1991; Prawat, 1993).

* curriculum emphasizing depth over breadth, integrated around core themes to develop links between material, depth of understanding, and retention (Prawat, 1989, 1993).

* scaffolded instruction with the intent of gaining students' independent use of content and skills in a range of situations both inside and outside the classroom (Brooks & Brooks, 1993; Prawat, 1993; Anderson & Roth, 1989).

* activities that include problem-solving and higher level critical thinking aimed at capturing the learners' personal motivations to learn (Brooks & Brooks, 1993; Brophy, 1991).

In recent years, researchers interested in conceptual change[10] have begun to realize the importance of motivation in affecting students' willingness to develop targeted understandings (Brophy, 1987, and Corno & Madinach, 1983, as cited in Lee and Anderson, 1993; Strike & Posner, 1992; Wade, 1994) and the fundamentally moral nature of the teaching enterprise embedded in the choice of content and method (Ball & Wilson, 1996). These researchers recognize that students are more than vehicles for transporting their brains into and out of the classroom, and teachers are more than intellectual functionaries, even though much of the conceptual change literature seems to have implied this.

Descriptors used to retrieve articles within each of the academic disciplines for this part of the review were "conceptual change," "concept development," "conceptual teaching," and "concept formation."[11] Articles reviewed include those most closely connected to the knowledge teachers need to teach for conceptual understanding, i.e., those dealing with elementary and secondary students' activities while engaged in learning concepts, research on teachers' thinking and beliefs about students' learning of concepts, and conceptual change theory.[12] Articles within each subject area are further grouped by whether the focus is theoretical, or on the teacher, the student, or particular methods and materials. Discussion begins with an exploration of general differences among subject areas and how these can variously influence the "conceptual contexts" in which students are schooled (Stodolsky & Grossman, 1995, p. 228).

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[10] thought to follow conceptual *understanding*

[11] Within the literature on conceptual change in science is a strand dealing with the role of analogies; studies with this focus are discussed more fully in the final section of this chapter, "Studies of Representation Systems."

[12] Excluded are curriculum guides, policy recommendations, and evaluations of teacher education programs with this emphasis. Because studies of conceptual understanding and change in science are abundant, this review is limited to sample studies conducted between 1990 and 1995.

General

The "conceptual contexts" in which students develop ideas are shaped by such factors as teachers' expectations, the types of students who take particular subjects, policies affecting curriculum and assessment, and the teaching and learning conditions of departments, schools and districts (Stodolsky & Grossman, 1995). They are additionally affected by how well defined a subject is (math and foreign language being most defined, least subject to differing views of what constitutes the subject); scope (number of subfields, with social studies ranking highest, followed by science and English); how sequential the content (algebra requiring more prerequisites than geometry; math and foreign language, in general, perceived as requiring more prerequisite knowledge than English, science, and social studies); how rapidly changing the knowledge -- hence instructional goals, content, approaches and techniques -- within the field (with the humanities, social studies, and science seen as more aligned with changing theories and new knowledge development than math and foreign languages); and whether a subject is required or an elective, with more students and status attributed to the former, but possibly more motivated students and smaller enrollments associated with the latter (Stodolsky & Grossman, 1995). So the following is offered with these distinctions in mind.

Math

Teachers

A study of the problem-solving abilities of first grade students found that teachers of students with higher achievement have more knowledge of their students' knowledge, and spend more time asking students about their processes and listening to their responses than do teachers of lower achieving students, who tend to talk about their classes' knowledge as a whole and spend more time explaining and watching students' problem-solve (Carpenter, Fennema, Peterson, & Carey, 1988; Peterson, Carpenter & Fennema, 1989). Higher achieving problem-solvers also had teachers who believed that they construct knowledge and that their prior knowledge is rich and should be built upon, as compared with teachers of lower achieving problem-solvers, who believed that students know relatively little, absorb math passively, and need to know basics before they can engage in higher level thinking (Peterson, Fennema, & Carpenter, 1991).

Conceptual mathematics educators stress the capacity of mathematics to help students conceive of themselves as able to act on the world to make social, technical, economic, and physical predictions about the size, space, numbers, and approximations of the real world (Vergnaud, 1987, p. 227). At the same time, they want students to be able to work with mathematical abstractions:

> What does it mean to understand that 4/4 and 5/5 are equivalent? On one hand, I know the arguments for connecting the mathematical explorations of children to real-world contexts. But at the same time, I want students to develop a repertoire of tools for working on mathematical questions that enables them to move across contexts and begin to wrestle with mathematical abstractions. (Ball & Wilson, 1996, p.170)

To these ends, conceptual math teachers help students understand why a concept can be represented in particular ways in a variety of given situations.

Students

In studies of math education reviewed by Davis (1983), most revealed that students do not understand the math they are learning.

> Our schools mostly teach rote aspects of mathematics and neglect strategy, analysis, heuristics, decision making, intuition, flexibility, and creativity. In art, the parallel would be to teach students to "paint by the numbers," rather than to analyze and create art. (p. 103)

But with improved curricula asking for a range of information processing, teachers identifying and working with students' ideas, more emphasis on experiential learning, well-designed pacing, sequencing, and notation, and adequate inservice teacher education, these studies indicated most students can learn more math than teachers using traditional methods think. This finding is echoed in studies of the unusual flexibility and range of problem-solving strategies used by first graders whose teachers had been trained in "Cognitively Guided Instruction."[13] Said one teacher who had been through the process:

> The more I challenged [my students], the better they got...It was the students who convinced me that CGI works, and they went far beyond what I ever expected that they could do. (Fennema, Franke, Carpenter, & Carey, 1993, p. 579)

How to characterize students' knowledge has become increasingly important to concept-oriented math teachers. The work of Peterson, et. al., (1989; 1991) offers a start at such a characterization by delineating eleven addition and subtraction problem types in first grade math books and the specific stages students seem to pass through in learning the concepts and processes associated with them.

Methods and Materials

Conceptual understanding in mathematics has been aided by predetermined exercises which ask students to translate concepts from one mode to another, e.g., from manipulative to spoken symbols, from experience to written symbol, from real world experiences to picture, or from one set of materials to another using the same mode (Post, 1986, as cited in Lesh, Post & Behr, 1987; The Rational Number Project, Post, Behr, Lesh, & Wachsmuth, 1985, as cited in Post & Cramer, 1989;). Exposition, discussion, hands on activities, problem-solving, applications of knowledge and an interdisciplinary approach have all been recommended for developing understanding of concepts in math (Cockroft Report, 1982, as cited in Post & Cramer, 1989). Supporting this, a study of inner-city second graders revealed that relating math to everyday experiences, multiple examples, clear explanations of what students would be doing and why, time for exploring

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[13] "Cognitively Guided Instruction" is a research and development project based on teaching teachers about the problem-solving strategies of first graders engaged in adding and subtracting, how to organize problems into types which make different demands of learners, and how to encourage students' ownership of effective solution paths (Fennema, Franke, Carpenter, & Carey, 1993).

math concepts with manipulatives in the context of small group problem solving, and positive reinforcement, increased interest, independence, performance and students' abilities to apply math skills they learned (Russell, 1988).

By easing computational aspects of the problem-solving process and focusing on setting up the problem, checking answers, translating ideas into number statements, and looking at alternatives, computers can aid both the gaining and the growing of conceptual understanding, as students spend more time thinking about their thinking. This, in turn, enhances transfer of strategies into new problem-solving situations (Lesh, 1987). By contrast, in a study of the way three different math texts for grades 3-8 presented decimals within multiplication and division problems, all were found to be structured in ways inconsistent with conceptual change theory and research, i.e., did not address common learner misconceptions about multiplication and division (Graeber, A. O. & Baker, K.M., 1991).

Science

Theories

Among the first to codify a theory of conceptual change, Posner, Strike, Hewson and Gertzog (1982, as cited in Strike & Posner, 1992) postulated that conceptual *change* arises from the presence of three conditions: Students' conceptual *understanding*; their dissatisfaction with their current conceptions; and finding the scientifically accepted conception believable. They later made several key modifications, one of which was to underscore the need for a developmental and interactional approach to working with students' "conceptual ecologies," which were comprised of:

> ...such cognitive artifacts as anomalies, analogies, metaphors, epistemological beliefs, metaphysical beliefs, knowledge from other areas of inquiry, and knowledge of competing conceptions (p.150).

The PCK needed to respond effectively to such ecologies would entail familiarity with them both as sets of notions needing to be brought in line with accepted disciplinary knowledge and as a source of pedagogical ideas for ways to make contact with the way learners think.[14]

Other theorists have worked to identify the various sub-types of conceptual change (see Table 1). In cataloging several of these, Dagher (1994) suggests that this multifaceted process requires a finer grain of analysis than is typically used. He feels even small shifts in conceptual understanding are worth pursuing, as we still know very little about their role in precipitating radical shifts.

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[14] The authors point out, for example, that a student's conceptions and misconceptions can vary in how articulated they are and be mentally represented in different modes.

Table 1: Developmental Theories of Conceptual Change Catalogued by Dagher (1994)

Type of Change:	Hewson & Hewson (1992)	Chi (1992)	Carey (1991)	Dykstra (1992)	Thagard (1992b)
Radical	Transform-ation	Shifts across categories of matter, events, and abstractions	1) What was periphery becomes core and v.versa; 2) Concepts are subsumed into a new category; 3) Concepts are embedded in logically non-comparable categories	Change in belief (reconcep-tualization) re: how world works due to dis-equilibration	9) Tree switching 8) Branch jumping 7) Collapsing a kind of hierarchy.
Normal	Conceptual Capture Conceptual Exchange	Reorganiza-tional change w/in the cats. of matter, events, and abstractions	Differentia-tion and coalescence of concepts (structured mental reps.)	Strengthen-ing of existing beliefs either via differentia-tion or class extension.	Adding: 6) A new concept 5) A new-kind relation 4) Adding a new-part relation
Weak					Adding: 3) A new strong rule 2) A weak rule 1) A new instance

Using the substages of Thagard (1992b, as cited in Dagher, 1994), Dagher discusses the groundwork needed to get to radical conceptual change (akin to Piaget's accommodation), and that much of what passes for conceptual change in classrooms is often conceptual exchange (akin to Piaget's assimilation), where differing conceptions of the target concept may co-exist.[15]

Teachers

The line of inquiry most closely related to teaching for conceptual understanding at this point appears to be studies of the relationship between science teachers' subject matter knowledge and how they respond to training in constructivist teaching methods. Please see the "Science" section of the first part of this review on teachers' subject matter knowledge and their pedagogical decisions for a discussion of sample studies in this area (e.g., Anderson & Roth, 1989; Hollon, Roth, & Anderson, 1991, Hashweh,1987; Smith & Neale, 1991).

Students

A meta-analysis of students' cognitive processes while engaged in conceptual change, and the influence of context on these processes, has revealed the need to explore growth patterns across grades and to use more culturally diverse student samples so that the patterns in language, social interaction in cooperative groups, experiences with text-learning, and prior conceptions can be revealed and used to devise more effective instruction and more culturally inclusive texts (Guzetti, 1993b).

In revising their earlier theory of conceptual change, Strike and Posner (1992) also highlight the importance of the context in which learners learn. They define context as students' motivations and goals, and how these may be influenced by institutional and

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[15] He points out that some of these may even conflict, which is echoed in the remarkable statistic that 80 percent of physics majors at universities have been found to be unable to connect concepts and the problem skills they show on classroom tests to any real world situation and continue to have inaccurate theories and misconceptions about the real world, despite doing well in class (Champagne & Klopfer, 1984, as cited in Yager & Penick, 1990).

social forces, which the authors now see as significant shapers of students' internal representations of core ideas. Their research on college students indicates that as they develop competence in reasoning about physics, they become more likely to insist on conceptual understanding rather than rote memorization, and are more likely to value science for its own sake rather than as a means to a grade.

In a study of sixth graders' experiences with conceptual change curricular materials, the authors concluded that,

> [a]though the [students] were taught by the same teachers using the same curriculum materials, the [individual] students understood and experienced the academic tasks differently. In effect, the nature of the tasks themselves was the product of interaction between the students' agendas and understandings and those of the teachers and curriculum materials. (Lee & Anderson, 1993, p. 603)

In line with the notion of students' agendas being important shapers of their academic experiences, a study of fifth graders learning about light revealed that students with the same starting conceptions concluded the unit with very different ideas (Shapiro, 1989). Intrigued by this, Shapiro set out to map the array of features interacting with students' science learning aside from prior knowledge. These included:

> the purposes of schooling as understood by the teacher, the purposes and uses of curriculum materials, the value and purpose of science learning as understood by the student, the teachers' conception of his/her role, responsibilities and relationships with students, inter-student relationships, students' self-perception as a science learner, the degree of responsibility individual students would take for their learning, the ways in which the individual student most enjoyed and best learned science, the nature of natural phenomena, and the nature of knowledge creation in science. (p. 729)

How inner-directed a student is to discover answers to his/her own questions and persist despite lack of peer support for his ideas, as well as his/her relationship to the teacher, whose word sometimes has to be taken on faith, appear to be significant factors as well. Shapiro felt that how these variables influenced the development of student ideas could be captured using a repertory grid technique (Kelly, 1955 and 1969, as cited in Shapiro, 1989), aimed at the unique ways individual students structure their thinking. Echoing findings of other researchers into concept-oriented teaching practices, she concluded that many children, given the support, could and would go well beyond the activities suggested in the teachers' guide in their pursuit of science questions of personal interest.

A major implication of these studies is the need for teachers to develop analytical tools to help them assess and tap into, not just the prior conceptions and students' ways of learning, but also students' personal goals and agendas, e.g., to see whether individual students identify with, negotiate with or reject the teacher's goals (Lee & Anderson, 1993), and to discover ways to create shared goals among racially and economically diverse people. Another implication is the need to encourage students to engage in more student-student dialogue in collaborative situations, so that greater opportunities exist to negotiate meanings among themselves and surface naive conceptions so that they can be brought into line with current conceptions of the scientific community. Reinforcing the importance of social interaction in learning, Ball and Wilson (1996) found that sometimes it's students' ideas and sometimes it's their *relationships* to each other and the teacher which drive their participation in discussion.

Methods and Materials

The importance of building on the prior knowledge and beliefs students' bring into classrooms based on their everyday experiences is a major theme found in the literature on conceptual-change teaching methods in science. In a study comparing the effects of text-based instruction, activity-oriented instruction, and conceptual change instruction on elementary students' understandings of science, only with the latter treatment, which intentionally built on students' prior knowledge, were gains made in conceptual understanding (Ross, in Saul & Jagusch, 1991).

The effectiveness of text-based science instruction in developing students' understanding of concepts is a second major theme found in this literature. Studies in this vein, for the most part, find the use of texts problematic (for a review of this literature, see

Rivard & Yore, 1992).[16] One issue Rivard and Yore highlight is that science teachers typically do not work to foster students' reading comprehension. However, even skilled readers in a study of middle school students' experiences with learning from text did not develop conceptual understanding unless they spontaneously used a conceptual change strategy which involved conscious comparing of their prior conception with that proposed by the text, identified discrepancies and confusions, and actively worked to resolve them (Anderson & Roth, 1989; Roth, 1985). In line with this finding, the need for support in making active comparisons between students' initial concepts and conventionally accepted ones [17] in order to produce "conceptual conflict" was found to be a common theme in a synthesis of research into experimental and quasi-experimental approaches to concept development in reading instruction and science education (Guzzetti, 1993a).

Another issue associated with text-based instruction is that texts, while relied upon heavily in science, are not written to foster conceptual understanding. An analysis of a commonly used science series revealed that it lacked three qualities associated with conceptual development teaching: "Connectedness among concepts, connectedness to prior knowledge, and usefulness" (Eichinger & Roth, 1991).[18] The need for texts to draw attention to common misconceptions which may exist as part of students' prior knowledge and contrast those with accepted theoretical explanations is iterated in a study of students given two sets of texts, one offering a typical description of Newtonian mechanics, the other a "refutational text," i.e., one in which description of the laws of motion is integrated with discussion of the common misconceptions people have about them (Hynd and Alvermann, 1985). Only students with the latter treatment showed evidence of having

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[16] For additional information, see DiGisi & Yore, 1992, for a review of effective strategies using texts; see Saul & Jagusch, 1991, and Hynd, et. al., 1994a for problems surrounding traditional approaches to text.

[17] Something Roth (1985) refers to as "conceptual change text processing strategy."

altered or overcome their own misconceptions (see also Hynd, 1994b, for a more recent study with similar findings).[19]

Strategies associated with effecting meaningful conceptual change include:

> use of contexts and case studies; discrepant events (when a mismatch exists between the preconceptions that students bring to a learning situation); analogies, metaphors, and similes; examples and non-examples; and multiple representations of verbal and nonverbal information (Kinnear, 1994).

Computer simulations have been found to be an effective method for fostering students' conceptual change regarding principles of motion in physics (Svec, 1985) and the molecular structure of water (Hakerem, et. al., 1993), but even with this format care must be taken to address students' prior conceptions (Olson, 1992).

Concepts like mass, volume, and density often pose a problem for science teachers to teach, as an understanding of them does not typically arise from everyday experiences. Teachers have been able to help students construct such concepts by training pairs of students to use "mediational means," i.e., approaches involving the development students' technical, observational, pattern-seeking, and explanation skills, and related exercises aimed at helping them think about their thinking (Vellum, Anderson, & Palincsar, 1993).

With highly controversial concepts like evolution, some feel that attention to students' prior knowledge must be broadened to recognize the critical role of belief (Cobern, 1994a; Qian & Alvermann, 1995). Rather than trying to convert people, teach more about evolution, or improve instruction -- all of which have been suggested as ways to alter the finding that only 9% of the U.S. population accepts the scientific concept of evolution,[20] Cobern argues that a more effective route is to approach science from a constructivist perspective by leading students to see evolution as "the way science *believes* things to be" (p. 586) and to appreciate the cultural and intellectual climate in which Darwin

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[19] The authors also recommend the use of other conceptual change strategies like an "anticipation/reaction" model and Posner's four-step model for inviting conceptual change.

[20] This is based on a recent Gallop poll (cited in Sheler & Schrof, 1991, as cited in Cobern, 1994a).

lived (Cobern, 1994b). In this way, he explicitly draws attention to the socially constructed frame delimiting the discipline.

Writing-to-learn strategies[21] are just beginning to be used in teaching for conceptual understanding in science, with research still needed in a range of classroom settings to help clarify the principles undergirding this form of instruction (Rivard, 1994). Overcoming teachers' resistance to this approach involves redefining writing as a way to discover vs. simply as a way to display knowledge, and to redefine the role of science teachers away from that of simply grading writing content toward one of facilitating students' problem-finding and connection-making (Peasely, et. al., 1992).

Concept mapping has been found to be a useful way not only to assess students' conceptual development, but also to guide teachers' planning for conceptual change instruction (Kinnear, 1994).

English

Students (Composition)

In writing instruction, some work has been done to map the developmental process students follow in their efforts to make meaning through writing during the first five years of school and how this may help teachers to understand differences in student writing in terms of positions on a developmental continuum of understanding (Kroll, 1991).

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[21] These include having students write what they think they know about a situation, using the writing as a basis for discussion and experimentation, and writing about how and why their thinking has changed as a result of reworking their understanding of the relationships both between their ideas and conventionally accepted ones and among the components of the concepts they are working on.

Methods and Materials (Composition)

Studies of writing pedagogy suggest that process writing is enjoying wider use in English classes, issuing in more attention to conceptual understandings of how adequate language expression is determined and developed (Jambek & Winder, 1991; Tchudi & Mitchell, 1989). For example, through the use of a process called "procedural facilitation" which scaffolds students' essay-writing around intentional use of the strategies expert writers engage in (primarily through the use of modeling and asking particular questions at each stage of writing), sixth grade students have been helped to plan longer, make higher quality revisions in their texts, alternate between knowledge generating and problem-finding in their writing, and transfer these procedures to new writing situations when the scaffolding has been withdrawn (Scardamalia, 984).

In a similar study, 10th grade students given thinking prompts,[22] rather than simple definitions of elements needed to complete a persuasive argument, showed a significant increase in their problem solving during writing, from pre- to post-instruction testing, suggesting they had grown in their understanding of the concepts associated with effective argumentation (Bryson, Bereiter, Scardamalia, & Joran, 1991).

In exploring methods based on differences in the way experts and novices conceive of the composition process, and how teachers may build on these to encourage novice writers to move beyond telling what they know and surface editing toward a knowledge-discovering process, the studies described above offer critical findings for the concept-oriented writing teacher.

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[22] For example: Plan, identify new learning, identify confusions, build an argument, challenge its assumptions, elaborate statements, search for additional ideas and put it all together. This is an example of the "scaffolded instruction" alluded to in the introduction to this section.

Methods and Materials (Literature)

For the study of literature in secondary English classrooms, constructivist approaches like feminist pedagogy, which blends student-generated questions with textual substantiation (Whaley & Dodge, 1993), and shared inquiry, which blends open-ended teacher-generated questions with textual support as practiced by The Great Books program (Criscula, 1994), appear in only some of the PCK studies reviewed here.[23] At least half of the teachers in this group of studies emphasize traditional whole-group discussions over the use of cooperative groups and constructivist strategies such as "writing-to-learn" (see below) and teacher-made questions and interpretations over student-generated ones. With a few exceptions, instruction by all teachers studied does not appear to emphasize a commitment to explore non-mainstream interpretations from sources other than the student, or principled evaluation of a piece of literature's inclusion or exclusion from the canon -- activities which would increase attention to the values undergirding the rules of disciplinary syntax.

Writing-to-learn strategies like the use of the double-entry journal,[24] has been an effective way to enhance students' self-knowledge and understanding of literary concepts, particularly when tasks are centered on the high interest, undemanding texts of Young Adult literature (Nugent & Nugent, 1984). Another writing-to-learn strategy involving writing about a situation or issue before reading the way a published author handles it has been found to increase students' interest in a text and sensitivity to concepts associated with their own and published authors' styles, e.g., concepts like direct and indirect narration, descriptive and non-descriptive language, use of imagery, and voice (Tierney, Caplan, Ehri, Healy & Hurdlow, 1988).

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23 These include Grossman, 1989, 1990, 1991, and Gudmundsdottir, 1990, 1991a, 1991b.

24 This strategy engages students in a process of identifying something they find striking from their reading, writing about it, comparing their thoughts with those of others, including critics' evaluations of the text, then writing a second entry synthesizing insights gained.

In a two-year study of the effects of a "computer-saturated" environment called the "Apple Classroom of Tomorrow" (ACOT) on students' thinking processes as they engaged in writing, computer graphics were found to be very helpful in developing students' writing and thinking by aiding visualization and offering a way to capture ideas not easily rendered by text. The way computers were used prompted a wider array of planning and revision behaviors: From thinking about what students knew about a topic to considering the concept of genre and incorporating the ideas of others; from surface editing to considering the concepts of voice and point of view, and the needs of an audience (Tierney, Galindo, Harris, Stowell, & Williams, 1988).[25] In the second year of the same study, students showed gains in the fluency and organization of their writing, greater confidence and self-expression, and growth in synthesizing of ideas.[26]

Social Studies

Theories

Structuring social studies instruction around core concepts and related facts to enhance students' understanding has been a long-standing recommendation of such theorists as Hilda Taba (Fraenkel, 1992). A giant in the field of curriculum, Taba argued for a three level approach to social studies education: Level one identifying key concepts like "cultural change" and "interdependence" which would be approached repeatedly throughout the grades via different content and increasingly sophisticated treatments; level two comprising "organizing ideas," i.e., explicit links between the components of a concept

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[25] The ACOT environment included a self-contained classroom for 20-some students during their 9th and 10th grade years in an inner city school, computers for every student, some teacher-directed learning, independent and collaborating computer-based problem solving, independent and team-teaching by five teachers representing math, science, English, and social studies. In the mornings students stayed in the room; in the afternoon they would attend classes in other parts of the school.

[26] There were also problems with this learning environment. These included gaining access to computers, equipment malfunctions, difficulty reading screens, lack of physical mobility and isolation from the rest of the school.

(e.g., for the concept of "societal control," Fraenkel offers the organizing idea: "To maintain themselves, all societies regulate the actions of their members through some system of laws and customs." p.173); and level three dealing with the particulars, possibly student-chosen, through which the concepts and organizing ideas would be illustrated. In the last case, to provoke more complex student understandings, Taba argued for "sampling" rather than "covering" detail via a few contrasting cases.

Teachers

I have not found any recent studies of conceptually oriented social studies teachers. One reference linking social studies teachers and teaching concepts appears in Wade's study (1994) of fourth graders learning about the concept of human rights: She asserts that teachers' consider the concept of human rights to be "abstract, complex, and difficult to relate to the real life situations of students" (Wade, 1994, p. 79, citing research by Conley, 1984, Heater, 1984, Lister, 1984, and Molnar, 1986).

Students

Relatively few studies have been conducted in social studies education which address how students develop an understanding of social studies concepts (Wade, 1994). Those that do appear to focus on elementary students. Of the studies surveyed by Wade, none discussed conceptual understanding development relative to conceptual change theory, favoring instead Piagetian and information processing theories. They also neglected to recognize the importance of students' prior knowledge, motivations, and other contextual factors in influencing the quality of student learning. In an attempt to address this gap, Wade conducted a qualitative classroom-based study of the development of conceptual understanding of 17 fourth graders around the concept of human rights. She found that most, after the unit, were able to articulate a concept of rights as "freedoms"; only a few mentioned "legalized privileges or protections" (p. 84). Most did not develop a comprehensive understanding of human rights, which Wade interprets as a function of their prior knowledge (many thought of human rights beforehand as "freedom to do whatever you want"), values, interests, personal agendas, the emotional salience of the topic and the instructional approach. In regard to the last, she realized that she and her partner needed to more explicitly highlight contrasts between students' prior conceptions and the understandings they wanted students to develop, to simplify the concept, create more concrete objectives and use advance organizers (p. 91).

The relationship of traditional approaches to social studies content and "limited change" in students' conceptual growth, as well as the critical role of the teacher in fostering more complex understandings have been explored in a rare longitudinal study of students' concepts of the notion of "representation in government"[27] (Sinatra, Beck & McKeown, 1992). The authors conjecture that the lack of significant gains in students' understanding of this concept stemmed in part from simplistic textbook explanations which tended to emphasize the structure of government rather than clarifying its philosophical base; and teachers who failed to build on students' informal notions of Democracy (e.g., "being free," "having a say") by intentionally asking them to connect their ideas with formal features of a representative government.

Metaphors, analogies, and similes to reinforce explanations is highlighted in a study of students' understanding of social studies concepts, (Tierney, D.S., 1988). Intermingling instruction in reading and writing has been related to greater student motivation to learn; students using this approach have been better able to obtain, discover, focus, and extend ideas; and develop their concepts of authorship, readership, as well as critical thinking abilities (Tierney, Caplan, Ehri, Healy, & Hurdlow, 1988).[28]

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[27] Students were sampled in the 5th grade and again in the 8th.

[28] Conceptual understanding of students in this study, for example, was developed by asking them to respond to an issue like "Students are no longer allowed to congregate in the hall" from a variety of

Other research has highlighted problems in social studies instruction, including pedagogical and curricular reasons behind students' failure to learn map reading concepts and skills (Muir, 1985) and the fact that elementary students are capable of learning more sophisticated concepts (e.g., social perspectives, civic understanding, time and space, and economic understanding) than are usually offered, and consequently the optimal time for learning them may pass before schools get around to presenting them (Levstik, 1988).

Methods and Materials

Research into the concept development of primary school students highlights the importance of analogies to clarify concepts, and stories as places to apply them (Jarolimek, 1991). Kindergartners taught concepts in a manner which emphasized "critical attributes" were significantly better able to generate examples of the concept than those not taught with this method (Burts et. al., 1988).

Fifth and sixth graders involved in a research project designed to measure the effects of computer aided-scaffolded instruction on the development of their self-regulated use of physical geography concepts were successfully able to develop and apply concepts when supports were withdrawn, but only when they showed they were ready for independent problem-solving, not according to a pre-set schedule (Biemans & Simons, 1995).

In another study featuring computers, Hypermedia[29] was found to be an effective tool for conveying complex interrelationships between ideas for the majority of students studied in a partnership between Brown University and three secondary schools (Spoehr

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perspectives (teacher, student, administrator, school board member) and from different stances (pro, con, mixed); then they were given access to writings, films, speeches and panel discussions, and news accounts on civil rights, and asked to reformulate their positions on the original issue.

29 This is Hypercard software using text, audio, and graphics, including video, photographs, charts, diagrams, and animation intended to supplement traditional courses in American history, literature, and American Studies.

& Shapiro, 1991). Addressing concepts in American history, literature and culture, the impact of this software on high school students' essay-writing was to produce in most students a value for and reliance on conceptual structures in their writing: In less evolved essays these included listing attributes; in the more evolved, offering evidence, supplying instances, using abstractions and extended chains of reasoning as derived from students' independent explorations of the data base. The authors suggest that while the software provided access to a rich web of relationships between important ideas for "the vast majority of students," not all students were equally able to internalize them.

In a study of social studies texts at the fifth grade level, it was found that two key ideas (England's role in the colonial struggle for independence and the concept of representative government) were "not strongly portrayed" in four standard texts for this age group (McKeown & Beck, 1990). Stressing, instead, the many countries seeking to establish colonies in the New World and under-emphasizing England's control over the original thirteen, these texts failed to give students a basis for understanding the reason colonists valued representative government so highly and hence, its critical role in precipitating the Revolution. Texts did address the ideas of the country being settled, some notions of freedom, and a few processes, but these are what most students already brought as prior knowledge to their study. The manner in which these ideas were addressed was piecemeal, without an overarching framework clear to the students. Lacking this, they had "no way to judge [the] value [of facts], role or appropriateness for the overall topic and no guidance for how to integrate prior knowledge with what is presented." (p. 723). The implications for teachers' PCK is significant: If texts do not name targeted material and bridge appropriately to students' existing knowledge, the authors assert, it is incumbent upon the teacher to do so via clearly articulated conceptual frames.

Summary

Themes running through this body of literature are clustered by category.

Theory:

1. A more detailed analysis is needed of the substages involved in a theory of conceptual change.

Teachers:

1. High knowledge by teachers of content and learners -- particularly their beliefs and prior knowledge, and the patterns they follow in developing an understanding of target content -- have been found to result in students' greater conceptual understanding.

2. Concept-oriented teachers find that students can learn more than most people think and that focusing on concepts does not result in a loss of factual knowledge.

3. Teachers need intensive staff development to use conceptual methods effectively, e.g., to learn ways to foster greater comprehension of texts, writing-to-learn strategies, and concept mapping.

Students:

1. Students taught with traditional methods (emphasizing number facts and algorithms in math; ignoring prior knowledge and beliefs in science and social studies) do not appear to gain much conceptual understanding.

2. Some work has been done to track the development of students' thinking in elementary math and composition.
This type of research appears to be in its infancy, yet is crucial
if teachers are to be systematic in building it into their PCK.

3. Understanding and responding to the learning context (composed, in part, by students' attitudes, motivations, and agendas) seems key if teachers are to be successful in helping students achieve conceptual understanding.

Methods and Materials:

1. Concept-oriented teaching requires highly interactive and experiential classroom processes, featuring multiple modes and activities emphasizing translations between representations of content.

2. Built-in structures which focus student thinking on their thinking about core ideas (e.g., writing prompts in composition) have been found to foster conceptual understanding.

3. Computers have been helpful for advancing students' understanding of concepts in math (by freeing students from the more routine aspects of problem-solving), science (through modeling ideas), in writing (through the use of graphics), in social studies (through the use of Hypermedia illustrating complex inter-relationships among ideas) and in geography (through modeling).

4. Texts, which are heavily relied upon in traditional science and social studies classrooms, typically ignore students' prior knowledge, beliefs, and misconceptions and thus often fail to bring about conceptual understanding and change.

5. Few studies to date appear to have been conducted clarifying ways to foster conceptual understanding in the areas of social studies and the study of literature.

To iterate a key point -- because of the historical emphasis on didactic forms of instruction, it has been found that even teachers with adequate subject matter knowledge need intentional training in recognizing the way students think, to help them develop the PCK to teach for conceptual understanding, i.e., to know how to unpack disciplinary knowledge into content and processes learners find meaningful (Grossman, 1989, 1990; Hollen, Roth and Anderson, 1991; Lampert, 1989; Peterson, Fennema and Carpenter, 1991). However, adequate subject matter knowledge plus training may not yield PCK adequate to develop students conceptual understanding, if a teacher's epistemological assumptions (Peterson et. al, 1991), values (Anderson & Roth, 1989), or lack of conceptually oriented materials stand in the way (Hollon, Roth & Anderson, 1991).

Representation Systems

Attention to instructional representations has been a major focus of math instruction (e.g., Ball, 1993a; Janvier, 1987; Lampert, 1989). Math is inherently representational in that its primary objective is to portray aspects of the real world through representations like graphs, formulae, equations and manipulatives, in order to aid effective problem solving. Mathematicians discuss representations in terms of a correspondence between aspects of the represented world and the representing world, one or both of which may be abstract or hypothetical (Kaput, 1987).

Representation systems have been catalogued variously. Kaput breaks them into four interacting types:

1. *Cognitive and perceptual,* i.e., those addressing teachers' and students' inner representations;

2. *Explanatory,* involving models;

3. Those addressing the *significant mathematic structures* embedded in particular representations[30] ;and

4. *External symbolic representation*[31]

Lesh, Post and Behr (1987) list five components of representation systems:

1. Experience-based scripts which organize knowledge into interpretive frames;

2. Manipulatives like Cuisenaire rods, Deane's blocks and number lines;

3. Pictures or diagrams;

4. Spoken languages; and

5. Written symbols, including words.

Janvier (1987a) distinguishes between symbols or illustrations and representations, which are seen as a combination of written symbols, real or hypothetical objects, and mental images. Shulman's notion of representation comes closest to Kaput's explanatory representations, Lesh et. al.'s manipulatives, pictures and spoken language, and Janvier's illustrations and objects.

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[30] Examples Kaput gives include morphisms, generic algebraic constructions, internal and external canonical building-block constructions, approximation, feature/property isolation, and logic models.
[31] Examples would include letters, numerals, brackets, as well as Venn diagrams, arrow graphs, flow charts, Cartesian graphs, etc.

To illustrate the range of notions of representation needed to teach for conceptual understanding, this review breaks studies of classroom-related representations into two categories: Those focused on external instructional representations created by teachers and curriculum developers of math, science, English, and social studies; and those of students, based on their understanding of a concept or problem situation. Within this second group are studies of students' external representations (e.g., drawings and concept maps) and mental representations (i.e., evolving conceptions). Descriptors used to retrieve articles for this section included various combinations of content area plus "concept teaching," "representations," "models," and "analogies."

Instructional Representations

Shulman's notion of representation includes an array of methods to convey core ideas about content: Analogies, simulations, demonstrations, examples, models, explanations (1987). All are subject to teacher's internal representations; each conveys messages about the nature of content and in so doing shapes students' experiences of content (McDiarmid, Ball, and Anderson, 1989). Sample studies follow addressing instructional representations grouped by discipline.

Math

Theory

Piaget's assertion (1952, as cited in Post & Cramer, 1989, p. 223) that "Intelligence organizes the world by organizing itself" implies that a one-to-one correspondence between mental representations and reality is less important than the development in students of mental structures which are helpful for solving real-world problems. Such structures can be developed through the use of instructional representations, which provide critical bridges between the learner and mathematical abstractions (Post & Cramer, 1989).

Psychologists and mathematics educators have only begun to map the conceptual models underlying mathematical ideas and how they are related; these could offer insights into designing more effective instructional representations and the ways students might make sense of them (Lesh, 1987).

Teachers

The number of different ways math teachers have found to respond representationally to students' needs has been linked to amount of their subject matter knowledge (Ball, 1991; Leinhardt, Putnam, Stein, & Baxter, 1991). To illustrate, in a card sort exercise associated with the concept of "function" performed by a highly recommended fifth grade math teacher and a college-level mathematics educator, the former used surface criteria related to the type of representation presented (graphs, equations, or ordered pairs) and created simple, non-overlapping categories; while the latter created a single superordinate category underlying a fundamental concept (was it a function or not?) followed by a series of nested subgroups, each illustrating different salient ideas: Distinctions between functions and relations, the role of a rule in describing mathematical relations, and the use of multiple representations for a single concept (Stein, Baxter and Leinhardt, 1990). The nested quality of the latter's thinking was shown in the way a single equation (y=2x) could be sorted in different ways, depending on the feature highlighted: As a function, as an algebraic representation for a particular type of slope; as possessing an obvious rule; and as containing an infinite choice of paired values (p. 651). The authors go on to assert that such nestedness produces "multiple hooks" for each expression, leading to a kind of representational versatility missing from the less differentiated and looser organization of the schoolteacher's inner mathematical landscape. The latter's thinking, by contrast, was heavily influenced by his beliefs about his purposes for teaching functions and graphing to fifth graders, his pedagogical skills, and his text-dominated mathematical knowledge.

Methods and Materials

How problem data are represented by a text or test can be decisive in determining whether students can solve the problem (Young, 1982 as cited in Davis, 1983). Students allowed to use graphs and pictures, for example, can be creative and resourceful in problem-solving situations where they have some familiarity with the concept, but difficulty with the associated mathematical abstractions (Davis, 1983a, as cited in Davis, 1983). In fact, in kitchens and supermarkets, where the representation of mathematical ideas is grounded in concrete situations, students have been found to be ingenious in solving problems that would have stumped them in the classroom (Lave, Murtaugh, and de la Rocha, 1983, as cited in Davis, 1983).

Unlike students' inner mental models, external representations like the Cartesian coordinate system are inert (Lesh, 1987), until modified by teachers and students (Lampert, 1986, 1989) and or manipulated by a computer, which can map successive variations on an equation at the student's will (Lesh, 1987). When external representations become dynamic in these ways, they more readily amplify students' understanding of concepts because they free students from focusing on answers and allow them to attend to what they are doing -- collecting and sorting information, constructing the problem, checking possible solutions -- and why.

With the increased availability of computers to provide students with easy access to a range of representational formats, explicit instruction in crossing between symbol and referent, as well as how certain representations convey mathematical content more efficiently than others is now being seen as a crucial aspect of mathematics education (Kaput, 1987).

Because some representations are better than others for portraying particular aspects of a situation,[32] knowledge of a range of representations is needed, as well as a developmental approach to the ways teachers and students can use them (Verngaud, 1987).

Science

Methods and Materials

Analogies, often accompanied by a concrete model, are a widely discussed form of instructional representation used in science classrooms.[33] In exploring the role of analogies in conceptual change, which some now feel is *the primary* way to promote conceptual change (Dagher, 1994; Vosniadou, 1994) suggests that teachers' use of analogies is valuable not just for developing conceptual understanding, but may inspire more interest by students in science and help to stimulate creative connections across content domains.

For teachers to use analogies effectively, they must: Use those students are familiar with; distinguish an analogy's defining attribute from its other, possibly, irrelevant or inaccurate associations; train students in analogical reasoning; and be systematic in their use (see Glynn, 1994; Treagust, Harrison, Venville, & Dagher, in press). In comparing the understanding of the refraction of light by a group of 15 year-olds taught with an

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[32] Especially, one would think, as one listens to which are helpful to students' developing understanding, my auditor prompts me to add.

[33] Within studies on teaching for conceptual understanding can be found many creative representations using analogies for scientific concepts. A sampling includes representing photosynthesis as a manufacturing process (Hollon, Roth & Anderson, 1991; Anderson & Roth, 1989), refraction of light as like what happens when the wheels of a toy car move from a smooth surface to a carpet (Treagust, et. al., in press), representing the eye as a camera (Glynn, 1994), electricity working like cars in a circuit (Dagher, 1994); comparing the arrangement of electrons in atoms to organizing books on a shelf (Brooks & Brooks, 1993); and natural selection via a process of having students locate colored noodles (imagined grasshoppers) in grass within 5 minutes to show that green noodles are harder to find, hence coloration can influence survival (see Glynn, 1994).

analogy, with another group taught without it, Treagust, et. al. found both groups did as well on a task scored as a conventional test, but the former group offered "higher status" explanations for their actions. Some students in this group, after recalling the analogy, solved problems they initially felt dissatisfied with and most reported liking the analogy and thought it helped their understanding.

A task analysis of the use of analogies in 43 science textbooks found that many authors use them ineffectively (Glynn, 1994). The best seemed to follow a six-step model, which Glynn also found in the practice of 10 exemplary middle school science teachers: Introduce the target concept; bring up the analogy; identify relevant features of each; map similarities; map differences; draw conclusions. Several analogies for the same concept can highlight different aspects of it for students, giving a more rounded understanding, with the long-term goal being to equip students to create their own analogies, and interpret, criticize, and extend the analogies of others (Glynn, 1994).

Working with college physics students, Clement (1993) found that students exposed to a three-part "guided-constructivist" approach (which involved a target concept, "anchoring intuitions," and concrete analogies and models bridging between the two) showed significant gains in both content and process goals, i.e., misconceptions were unseated about whether a table exerts an upward pressure on a book lying on it, and students spontaneously began to create their own bridging analogies, concrete examples, and arguments in support of the principle. His model involves carefully chosen "thought experiments" in which students' conceptions are made conscious, then supported or challenged through a process of wrestling with the analysis of illustrative cases.[34] His

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[34]That is, he begins by developing a "concept diagram" for a lesson on how a static object (like a book) can exert a force (as on the table on which it rests) seen as "the target problem," by mapping out the anchoring intuition (something which makes sense to students from their everyday experience, e.g., that a spring compressed by a hand exerts a force on the hand) which is then demonstrated, then helping students identify shared key features between this example and the book through a set of analogous cases (a book resting on a flexible board, then on a foam pad) in which students are challenged to articulate similarities and differences, followed by presentation of a model of "objects as comprised of atoms connected by spring-like bonds," then a demonstration of a desk's "springiness" by shining a light onto a mirror on a desk which reflects it to a wall, then seeing the light move down the wall when someone stands on the desk.

results suggest that in order to effect deep understanding of core concepts, teachers need to lead students through intentional and *extended* analogical and other kinds of rational reasoning processes[35] *in conjunction with* empirically-based experiments, long thought by physics educators to speak for themselves in asserting the "truth" of a given principle. Simple analogies or straight experiments alone are not enough.

English

Teachers

Few studies were found related to the representations of English teachers. One revealed that different teachers' orientations to content affect the way they represent subject matter to students: One with a language orientation represents literature study as a linear process of linguistic analysis; another represents literature study more as a bridging between uncovered insights into human nature and readers' own lives (Grossman, 1991). Differing orientations, not surprisingly, reflect differences in the inner representations teachers have of their task: One viewing literature study like a hierarchy moved step-by-step from decoding, through literal and figurative understandings, to advanced philosophical and moral conceptions; another conceiving of the task more like the layers of an onion had students circle around a core idea from different angles -- some text-based, some based in the experiences readers brought to the text -- allowing the different viewpoints to layer additional meaning in students' minds (Gudmundsdottir, 1990, 1991a, 1991b).

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[35] E.g., "...generation of extreme cases, arguments by contradiction from lack of a causal effect, generation of new scientific questions related to the lesson" (p.13)

Methods and Materials

Graphic representations of knowledge in texts read by ESL 7th and 8th graders have been found to aid understanding and recall (Tang, 1992; 1993.) Along with organizing imagery and the nature of academic tasks, the kinds of representation a teacher uses have been associated with students' critical thinking development (Grant, 1991).

Social Studies

Teachers

Several studies in this area found that history can be represented in different ways depending on a teacher's subject matter knowledge and on his/her values. For example, one teacher was found to represent the American Revolution as a linear cause-effect event and emphasized memorization of chronological, mostly one-sided textbook facts (Wilson & Wineburg, 1993); another, using Crane Brinton's conflict theory, represented it as a three-part phenomenon based on the idea that revolutions occur when there is a perceived need, leaders, and opportunity (Wineburg and Wilson, 1988); another portrayed it as a two-sided argument, where cases were built supporting the viewpoints of Loyalists and Rebels (Wineburg and Wilson, 1988); and a fourth urged students to construct an understanding of content and interpretation as wed, through careful analysis of primary documents expressing multiple points of view, e.g., those of minorities and women, as well as those of Loyalists and Rebels (Wilson & Wineburg, 1993).

Methods and Materials

Teachers' use of outdated maps to represent the concept of change over time can help middle school students to grasp differences in current and older versions of the way the world has been seen (Hollister, 1994).

Summary

Key points among this set of studies:

1. Instructional representations are central to teaching for conceptual understanding and effective problem-solving.

2. Representations which attempt to capture the vividness of real world contexts support a higher level of problem-solving.

3. Computers can free students to concentrate on conceptual development by relieving them of the more routine aspects of problem-solving.

4. Analogies along with actual experiments in science appear to be a critical form of representation for bringing about conceptual change. Teachers need training in how to use analogies effectively as the texts they employ often may not.

5. Teachers' inner models of content can be a significant influence on their choice of instructional representations.

Students' Representations of Content

For instructional representations to be used effectively, teachers need to be sensitive to the ways students develop their own inner representations (Cifarelli, 1993). Discussions of studies dealing with students' external and mental representations of content follow, grouped by discipline and by focus.

Math

Theory

A constructivist view of students' representations treats them as organizers of actions students have taken in the past in real problem-solving situations and as interpretive frames for subsequent problem- solving (Cifarelli, in press). Students' internal representations are seen as evolving conceptions, rather than depictions of external reality (von Glasersfeld, 1987). Some feel that the PCK of teachers committed to teaching for conceptual understanding should include knowledge of students' internal representational processes, and have their development through carefully scaffolded interactions as an explicit goal[36] rather than simple recognition or rote learning of rules, which many traditional textbook exercises emphasize (Cifarelli, in press; Goldin, 1987). Ball (1993a) sees a need for representations to be co-constructed by teachers and students, and that the core of conceptual teaching in math is the teacher's design and use of such constructions.

Students

The adequacy of external representations learners create and modify for themselves as they make sense of the information and relationships within a problem has been linked to the success of their problem-solving (Cifarelli, 1993). Cifarelli (in press, 1993) found that students' interpretations of problems and their subsequent representations could be grouped into three levels of understanding, all of which some students were able to attain in the course of solving a problem set with somewhat similar features: "Recognition," where similarities between parts of a current problem and others like it were identified, so that students could apply the relevant algorithm; "Re-Presentation," where students mentally anticipated a result based on their own mental representation of the problem and spotted potential problems with their solution path; and "Abstraction," where students reorganized their conceptual understanding by anticipating a result and making inferences based on it, without actually having to solve the problem.[37]

Differences in the ways students' represent problems for themselves can contrast starkly: One "below average" eighth grader faced with sequencing fractions on paper rulers he had made, used memorized relationships between fractions (e.g., 2/4 = 1/2) to

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[36] including built-in metacognitive activity

[37] This ability in students is similar, in my mind, to the PCK of teachers who can plan for supporting some students through the "rough spots" and unfamiliar aspects in solving particular problems, based on their assessment of what students already know, and their familiarity with developmental patterns students seem to follow in learning the content.

place the fractions, seldom checking that spaces between units were sensible; another lower-performing student carefully looked at the strip and using her fingers as a ruler, accurately estimated divisions, only later seeing how these divisions related to the fractions she placed at each point (Tierney, 1988). Throughout their talk about fractions, the former spoke in terms of numbers and rules and thought he knew more about fractions than the latter; the latter spoke more in terms of parts of cakes or sets of cookies; both had trouble solving problems that involved switching from their preferred mode of representing, though the visual approach was more accurate than the former's rote use of equivalencies. The author concluded that both approaches need to be cultivated in both students; the former could benefit from the meaningfulness of visual representing and the chance to check computation this way; the latter needs to tie intuitive knowledge to formal manipulation of symbols in order to handle a wider range of problem types. Yet, teachers must *start* with students' own conceptions.

Misconceptions in math stem in part from students' mental representations based on the inappropriate assembling of simpler ideas through concrete metaphors like up, down, heavy, and light -- concepts first experienced in early childhood (Davis, 1983a, as cited in Davis, 1983) that some have called "phenomenological primitives" (diSessa, 1981, as cited in Janvier, 1987b). These are the building blocks constituting prior knowledge, the effective manipulation of which, some feel, is at the heart of mathematical competence (Janvier, Ch. 13, 1987).

Elementary math students often do not regard instructional representations as tools to help them problem-solve, but as more mathematical content to learn (Dufour-Janvier, Bednarz, & Belanger, 1987). Faced with multiple representations for the same concept, students often learn how to make one correspond with another using the syntactic rules of math, but without developing a sense of the underlying concept being represented (Dufour-Janvier, et.al., 1987). Premature or inappropriate use of representations can cause frustration and misconceptions in children and place undue focus on the representation at the expense of the target concept; thus, effective representations for the younger student must be based on students' own drawings and codes (Dufour-Janvier, et. al., 1987). Sensitive to the way representational contexts influence student understanding, Ball (1996) arrived at the same conclusion with her third graders: She encouraged her students to create their own drawings to illustrate their investigations of fractions, as these afforded a clearer view of what and how they were thinking.

Maps of modifications to students' internal representations as they are engaged in problem-solving suggest that learners construct new knowledge when their old structures prove inadequate (Cobb, 1988, von Glasersfeld, 1987, and Johnson-Laird, 1983, as cited in Cifarelli, 1993) and that they may use a variety of representations to address different aspects of a given problem, realistic problems being inherently multimodal to begin with (Lesh, Landau, & Hamilton, 1983, as cited in Lesh, Post, & Behr, 1987).

First graders initially engaged in problem-solving involving adding and subtracting typically model the action embedded in the problem (joining, removing, comparing, part/whole relationships); if the problem can't be modeled or represented, they cannot solve it (Fennema, Franke, Carpenter, & Carey, 1993). The developmental sequence of their problem-solving moves from direct modeling, to counting strategies which involve some modeling, to manipulating relationships between number facts, to using memorized facts. Some evidence exists that young children can come to understand some fractions if they can first be stated in monetary terms (Fennema, et. al., 1993).

Teachers

Some have found it fruitful to divide mathematics educators into two camps: Those who look at students from the outside-in, that is, tend to think about math in terms of ideas which students learn to represent, and those who look at students from the inside-out, i.e., feel that students' "inner experiences *are* their world, not merely a representation of *the* world" (Mason, 1987, p. 207). These different starting assumptions result in different educational practices, with the latter far more concerned about the nature of students' current conceptions and how to work with them effectively.

Studies of math teachers' engaged in training for "Cognitively Guided Instruction,"[38] reveal that research-based knowledge about children's thinking and ways of representing it allowed teachers to raise their expectations for student understanding and performance (Fennema, Franke, Carpenter, & Carey, 1993).

Science

Students

A number of studies have been conducted in recent years to explore the ways students understand and represent to themselves various science concepts, e.g., notions of light (Shapiro, 1994), electrical currents (Shepardson, & Moje, 1994), and weight and free fall (Bar, et. al., 1994). Shapiro makes the important point that valuing the ways students make sense of content not only allows them to feel validated as thinkers, but also offers important insights into effective instructional approaches and ways to empower students to contribute to their own learning (1994). In her study of fifth graders learning about light (1989), she discovered "The Classroom Profile" -- a chart indicating how each student in a class was thinking about the target concept -- to be an engrossing and effective way for students to develop self-awareness, awareness of the scope of others' thinking, and the plausibility of explanations shared by scientists. She also found that how students represent themselves to themselves as science learners (as competent, as bored, as not competent) interacted powerfully with the success of their learning processes.

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[38] Teachers learn to differentiate problem types, observe students' problem-solving strategies, and encourage variety in solution paths.

One study dealing with the conceptions of students in grades 1, 3, and 5 in their mental models of the Earth's shape, found children were inclined to have one of six different inner representations -- Earth as a flat rectangle, a flat disc, as both flat and round, a hollow sphere, a flattened sphere, a mixture of various models, and as a sphere -- with the majority of first graders holding dual earth or mixed representations; third graders, a hollow sphere conception or sphere; and fifth graders, the same as third graders, but weighted toward the latter (Vosniadou & Brewer, 1992). Most influential in shaping students' conceptions appeared to be where they were in the process of interpreting two everyday experiences: How something flat (the ground) could also be curved; and the nature of gravity's pull (down vs. in).

Methods and Materials

Concept maps have been a useful way for teachers to gain insight into students' alternative conceptions and changes in their mental representations of content in science; students' maps have been found to represent more concepts, be better organized to explain phenomena and more hierarchical -- mirroring currently held scientific conceptions more accurately -- after instruction emphasizing their use (Fellows, 1993).[39]

Computer-based concept mapping (a graphic way students can describe the way knowledge relates within a particular domain) has been used to facilitate students' external representations of key concepts (Zeitz & Anderson-Inman, 1993). Successful concept mapping (number of nodes, complexity, correct label-link ratio) was found with female high school science students with strong spatial ability, inner locus of control, and, paradoxically, low elaboration skills as measured by *The Schmeck Learning Styles Inventory* (Zeitz & Anderson-Inman, 1993).

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[39] This instruction was accompanied by the opportunity for students to talk over ideas with others, have meaningful/useful experiences with concepts, and access to instruction which modeled useful scientific explanations (Fellows, 1993).

Writing

Students

Novice writers have been found to have mental representations of their writing as a place to demonstrate knowledge in already composed forms, rather than as a process of on-going analysis and reflection, in which they alternate between discovering and refining knowledge and adjusting it to their purposes for writing (Scardamalia, 1984). Research into 10th graders' internal models for tasks associated with persuasive-essay writing suggests that as students become more expert, their representations of argumentation move from the idea of a fight, to a back-and-forth verbal exchange, to integrating opposing arguments via fuller analysis (Bryson, Bereiter, Scardamalia, & Joran, 1991).

Social Studies

Students

Studies of students' internal and external representations of social studies content are scarce (Ball & Wilson, 1996; Sinatra, Beck & McKeown, 1992), possibly because, as Sinatra, et. al., point out, social studies concepts are less clearly defined than in those in science.[40] Students' understandings of the political world, for example, have not been studied extensively (Furnham & Stacey, 1991, as cited in Sinatra, et. al., 1992); nor have the ways in which more complex understandings of political institutions evolve, as these entail longitudinal studies inconsistent with the '"one-shot surveys"' on which social scientists seemed to have relied (Palonsky, 1987, as cited in Sinatra, et. al., 1992).

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[40] I wonder whether this is because social studies concepts are, in fact, intrinsically less well defined, or because they haven't been subjected to the same "unpacking" that some math and science concepts have been. I'm reminded here of the challenges to performance- based assessment coming from the fact that most teachers have been inclined to think less in terms of their deep content goals for student learning than in terms of activities (Willis, 1996); the former requires more rigor (and practice) in clarifying targeted concepts.

In a study of third graders' reasoning about government, it became clear that students equated the concept of leadership with ownership, as in the president "owned" the country and the governor "owned" the state (Ball & Wilson, 1996). In the same study the authors reflect on the critical necessity for students' representations to be developed in a social context characterized by debate, akin to that of disciplinary scholars, and that, from a moral standpoint, students' ideas must be subjected to the same kinds of evaluation as those applied to scholarly thinking in order to assure that students have the "access to knowledge" to empower them with "cultural capital" (p. 183). The authors argue that the norms, focus, and direction of student discourse must be grounded in the teachers' best judgment of what will most serve students' interests. They conclude that when teachers begin to take greater risks in allowing students' conceptions to become the center of discourse,

> [teachers] become more and more dependent on their students -- on what they contribute to the conversation, in what directions they steer the class explorations, on what they are willing (or not willing) to do. (p. 185)

So the balance of power shifts, requiring a certain flexibility and courage in concept-oriented teachers, who must believe that the directions taken will become mutually enlightening, and be ready to respond with PCK apt for the unplanned circumstance.

In a comparison of the ways eight historians and eight high school seniors with a mean GPA of 3.5 responded to primary documents and school texts, historians were found to read and represent materials to themselves very differently from the way the students did (Wineburg, 1991). For the historians, the main question for any text, whether primary or secondary, was not "what it [said], but what it [did]" (p. 498). They were acutely aware of written documents as human artifacts and constantly looked for embedded subtexts -- the "convictions authors may have been unaware of or may have wished to conceal." (p. 499). As such, they represented the nature of historical texts to themselves, not as conveying

> information, ... tell[ing] stories, or even to set the record straight. Instead, they [saw them as] slippery, cagey, and protean, ... reflect[ing] the uncertainty and disingenuity of the real world. (p.500)

By contrast, school texts typically present themselves as authorless, unproblematic records of what happened. The seniors, who read in epistemologically simple ways, gave the school texts more authority than primary documents, believing them to tell the past like it was -- "just reporting the facts" (p. 501) with "immaculate perception" (Alan Megill, 1989, as cited in Wineburg, 1991), unlike the historians who regarded them as a human construction designed to serve some ideological end. In a far more complex process, the historians became both "mock readers" (who pretended to believe the rhetorical devices authors use) and "actual readers" (who stepped outside the frame of the text, and questioned it, seeing the devices for what they were) -- who recognized that, in the many ways one might interpret author intention or the context in which something was written, texts also "decode[d]" their readers (p. 507). Typically untrained to read any other way, students believed textbooks uncritically because they represented the task of reading to be about collecting facts. Without explicit training, such naive reading does not subside in adulthood, asserts Wineburg, and, in fact, may be perpetuated by teachers whose approach to history is epistemologically simple, i.e., who, harking back to Schwab (1962), exclude attention to disciplinary syntax and only stress substance.

In a study of the prior knowledge of fifth and sixth graders about the Revolutionary War and its effects on learning, it has been found that in addition to the unique ways students' structure their prior knowledge, it can also fall into several general patterns: as a "stew," where students' ideas are not accurate for a particular question, but speak to a related but more general question; as overly simplified general concepts rather than expressed as an understanding of particular instances of the concepts (e.g., the nature of freedom, the features of government); as overly narrow associations, resulting in an inability to generalize; and, as somewhat sophisticated, but missing a salient attribute (McKeown & Beck, 1990). In the same study, the authors found that student knowledge did grow after instruction, even though it still contained misconceptions and was "characterized by simple associations and a lack of connected structures," which showed up in "a lack of flexibility in students' use of concepts" (p. 719).

Summary

Many more studies of students' models of content in math and science education exist than those in English and social studies. Major themes running through these studies are

1. Students' mental models of content can fruitfully be thought of as evolving conceptions which directly impact the adequacy of their thinking and problem-solving.

2. These models may involve pictures as well as numbers.

3. Students' mental models can be influenced by or even echo instructional representations, but only when these are meaningful and do not require additional work to master. Ideally, instructional representations should be co-constructed by teachers and students, i.e., be a blend of students' inner models with teacher-made representations.

4. Students' external and mental representations can reveal much about their misconceptions and the developmental patterns of their understanding. Teachers' PCK should include knowledge of the developmental patterns in students' inner models for optimally effective instruction.

5. Inappropriate use of instructional representations may stymie the development of inner models of content of younger students.

6. The PCK of teachers should include sensitivity to which adult-made representations are most interesting and meaningful to students, and how to shift students away from exclusive reliance on their preferred representational mode.

7. Concept mapping appears to be a useful way for students and teachers to track students' understanding of core ideas.

8. Students' inner models of content must be valued as the building blocks that they are; however, they must also be worked with critically in order to bring them into line with accepted content structures or students will be deprived of developing necessary "cultural capital."

9. Tools like the "Class Profile" (Shapiro, 1989) can offer students valuable insights into the many inner models of content held by classmates. These, in turn, can stimulate in them different and potentially more effective ways of thinking.

10. Students' inner models of history texts tend to be simplistic and unambiguous, reinforced by the unproblematic treatment of content by textbooks, and by teachers who view (school) history as epistemologically simple. Thus, students come to view the act of reading history as a process of "fact gathering," rather than as an interpretive act requiring critical thinking about which content is presented and how.

Conclusions

The major thrust of researchers responding to Shulman's call to explore PCK (1986, 1987), has been to uncover the crucial role subject matter knowledge plays in shaping the different ways students experience ostensibly similar content in the hands of different teachers. This focus has brought needed attention to the subtle and shifting interplay between content and pedagogy which happens with particular students at particular times. This interplay has been hard to capture because the types of questions researchers had been asking (What traits do effective teachers have? What processes constitute effective teaching?) have tended to freeze dynamic classroom action into static teacher attributes, or to decontextualize it by emphasizing generic classroom events (Shulman, 1986). We can now see that the quality of student understanding has a great deal to do with, not just what teachers know about content, but how they know it and the goals they set with and for students. With this observation about teaching geometry, Ball (1991) makes a similar point:

> What you need to understand about shapes or proofs depends on what you think the point of teaching geometry is, which is in turn connected to our larger understanding of mathematics in general, and geometry in particular. (p. 22)

More subject matter knowledge will not automatically result in more complex understandings of content by students if teachers fail to give disciplinary syntax its due.

Based on many of the practices found in the studies discussed, with a few exceptions, attention to the discipline as a discipline, which explorations of syntax would bring to the surface, is seldom highlighted. Looking at the deep structures comprising a discipline reveals both the frame delimiting the picture and the way parts of the picture are cropped or enlarged over time (Ball, 1990), aspects of knowledge constructivist educators committed to teaching for conceptual understanding are attempting to make clear to students. Inviting students to participate in the growth of disciplinary knowledge, not simply in its acquisition -- to experience what novelist Cynthia Ozick (1988) calls "the hinge moment," where they become creators of culture not just consumers of it -- requires a different belief and PCK about the nature of content and the purposes of schooling than the Realistic practices dominating public schools have stressed.

With research in science, math and writing education having unpacked some of the deep structures underpinning content, we now know much more about how to help students develop a clear understanding of taken-as-shared disciplinary concepts. Marks (1990) has recommended that research be conducted in the different content areas and grade levels, then combined to form an overarching view of PCK, as well as a particular view of the similarities and differences in this knowledge base for different teachers and contexts. Research tracking developments in teachers' choices of instructional representations for particular content over time could provide one useful focus for this potentially unwieldy enterprise.

Through case studies highlighting the development of the instructional representations strand of PCK in experienced teachers dedicated to teaching for conceptual understanding, this study attempts to augment existing studies of PCK in general, and those of conceptual teaching strategies, in particular. It provides needed examples from English and social studies, which others have called for (Brophy, 1991; Marks, 1990), and begins to sketch developmental patterns in these teachers' understandings of their PCK of methods and objectives for teaching particular concepts, as students interact with the representations depicting them.

CHAPTER 3

DESIGN OF STUDY

General Research Model

The general research model used for this study is a qualitative case study design. Case study gives an "intensive, holistic description and analysis of a bounded phenomenon" (Merriam, 1988, p. xiv). Here the bounded phenomenon is the development of an individual teacher's PCK in the area of instructional representations associated with a curriculum unit. By comparing several versions of the chosen unit for each participant, for the purpose of further clarifying this aspect of the knowledge base of teaching, I try to create a descriptive and interpretive account of the evolution of the professional knowledge of four teachers. The focus is on self-report as I believe this clarifies the way teachers make sense of their own process. Two classroom observations supplement these data.

Merriam supports the value of case study for this kind of educational research, suggesting that

> research focused on discovery, insight, and understanding from the perspectives of those being studied offers the greatest promise of making significant contributions to the knowledge base and practice of education. (p. 3)

A non-experimental case study approach is well suited to explore veteran teacher development of instructional representations because it is designed to acknowledge the difficulty of isolating particular causes of behavior and influences on knowledge in particular teaching contexts. Casting a broad net for gathering evidence, it offers a glimpse at an inner landscape seldom systematically described. Each participant is unique, yet may have patterns of development in common with others.

As the primary instrument of data collection, I have adapted my interview questions to circumstances, processed data as soon as possible via a reflection log, and followed up on confusing responses. My main goals have been to gather insights into ways to enhance the teaching environment so as to encourage preservice and inservice teacher development and for clarifying growth patterns in expert teachers to guide the thinking of teachers new to working with particular content and students.

I have generated meaning through a process of creating categories, patterns, and themes from the data.

Sources of Data

Four sources of data inform this study. The first is a set of three semi-structured interviews conducted with four veteran teachers, each teaching one of the following content areas: English, science, math, or social studies. They span grades 6-8 with at least 9 years experience each and come from schools in central New England. They were identified by their principals and at least one other source (teacher educators, teachers, or myself) to be committed to teaching for conceptual understanding.

A second data source is documents related to the unit of study, which I used to clarify some of the instructional representations a teacher has used within the selected piece of curriculum. Two audio-taped classroom observations provide a third source.[1] These were conducted with an open focus, using a running log technique, to provide additional contextual detail. In observing, I looked for clues to the following questions: What does the participant's classroom look like? If there are displays, who are they created by? What do they emphasize? How do students behave? How actively involved are students in the class? What is the atmosphere like? Are boys and girls equally involved? What seems to

[1] not necessarily related to the unit in question, as this was not always possible

be the core idea or ideas addressed? Are representations being used? If so, what are they like?

A final data source are transcribed interviews and classroom observations of another set of four teachers, this time at the high school level. In the original research plan, I had hoped to compare and contrast the PCK development of middle and high school teachers, but time constraints made this unrealistic. Still, I was able to use the data from these teachers to supply a backdrop for the cross-case analysis of the middle school teachers in Chapter 4.

Gaining Access

Having been involved with education in my region for almost twenty years, I was familiar with many of the teachers and administrators in area schools. I called superintendents in six districts in two states to locate possible policies regulating educational research in their district schools. Only two districts had policies, which I obtained. Most superintendents left the decision to have teachers participate in the hands of building principals. I composed a letter to area principals asking for their recommendations of middle and high school teachers who met criteria associated with teaching for conceptual understanding (Appendix B). I also asked the head of a local independent teacher education program for the same, knowing his organization had a roster of local master teachers with whom he placed his interns.

Participant Selection

From these letters and calls, I received five nominations which I corroborated with at least one other qualified educator. A sixth teacher was referred by his former colleague and supported by his former department chair, who saw him as an evolving thinking teacher with clear goals for his students. Another I selected, based on my familiarity with his teaching, gained through his work with student teachers I had taught; I confirmed my selection with his principal, who felt his emphasis on teaching math in the context of real life problems made him a strong candidate for this study. The last was located via a referral from the former assistant director of the teacher preparation program mentioned above and corroborated by his principal as meeting the targeted criteria.

I wrote the original eight participants (Appendix C) who came from five districts in two states and gave them background information about the study (Appendix D). All agreed to participate (Appendix E). After conducting twenty of the twenty-four interviews, I decided to narrow the study to the four middle school participants, all of whom began the study teaching in the same district. Three of the four taught in the same school and had been former colleagues of mine.

Procedures for Data Collection

The primary sources of data for this study are three semi-structured interviews: The first addresses the teachers' personal and professional history (Appendix F); the second, the contents of the available versions of a unit of study (Appendix G); and a third, knowledge surrounding representations of core content within the selected unit (Appendix H).

The types of questions for each interview break down as follows:

Table 2: Types of Questions Used in Interviews

Question Type	First Interview	Scnd Interview	Third Interview
Experience/ Behavioral	6	12	2
Opinion/Values	4	1	0
Feeling	0	0	0
Knowledge/Facts	1	5	25
Sensory	0	0	0
Background/ Demographic	8	2	4
Hypothetical	0	0	0
Devil's Advocate	0	0	0
Idealizing	2	0	0
Interpretive	5	2	2

The majority of questions for the first interview pulled for demographic information, experiences, and interpretations of experiences, with the intention of creating a context for understanding subsequent data. Those for the second interview dealt mainly with knowledge and experiences. My assumption here was to pull for descriptive detail and let the interpretations come out of it during data analysis. Questions for the third interview were mostly knowledge-based, aimed at checking the nature of representational choices used in various unit versions (UVs) and influences, where appropriate, on how they had changed over time.

Procedures for Data Analysis

For data analysis, I used a constant comparative method (Glaser and Strauss, 1967, as cited in Merriam, 1988; Strauss and Corbin, 1990). All interviews were transcribed, then analyzed for categories. Audiotapes of classroom observations were condensed into descriptive accounts, then analyzed similarly. Categories were a combination of pre-set, based on semi-structured interview questions sensitive to the literature on PCK and concept teaching, and emergent, based on unique responses. Consolidating related categories, I began to look for patterns. I integrated these into three chronological narratives for each participant: The first portraying key points in each participant's personal and professional history; the second, the history of a curricular unit taught at least four different times; the third a depiction of the knowledge development surrounding selected instructional representations, along with a table presenting the core ideas associated with each teacher's unit and some of the ways these have been represented in the unit over time. When data echoed findings from the literature, I wove these in. I conclude individual cases with a discussion of influences on PCK development and conclude the chapter with a discussion of cross-case patterns in unit revisions and the PCK surrounding instructional representations.[2] In Chapter 5, I discuss implications for perservice and inservice teacher education suggested by apparent developmental patterns.

Reliability Measures

In Chapter 1, I laid out my biases and orientations to teaching, learning, PCK, adult development, and viewpoints which differ from mine in an attempt to clarify the filters through which I describe and interpret data. Others, with their own filters, will read my

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[2] Instead of trying for generalizations, *per se*, I try to aim for "working hypotheses" (from Cronbach, 1975 as cited in Merriam, p. 174).

descriptions and interpretations, and make of them what they will; my viewpoint exists as one among many.

All three interviews were transcribed verbatim. The course of the second interview deviated somewhat from the protocol, because respondents were sorting through materials related to earlier versions of a given unit -- hunting for information in some cases -- and searching their memories for the ideas and feelings they had at earlier points in teaching the unit. I corroborated some of participants' descriptions by obtaining copies of and examining the materials myself. Since I transcribed five of the twelve interviews myself for the primary four participants, I was able to get in closer touch with almost half of the data, noting key ideas and my thoughts about them while listening to the respondent's voice. These ideas were added to classroom observation data to supply the raw material for subsequent categorizing and analysis.

Since an assumption of qualitative research is that reality is multidimensional and evolving, the primary way this study's validity can be assessed is through interpreting the clarity and logic of my interpretations as I attempt to describe and analyze the experiences of my respondents. To help with this I have used an auditor (informed outsider) to encourage clarity and logic in my interpretations of the way respondents appeared to be constructing their experiences. I try to convey enough detail so that she and others can assess whether I have an adequate basis for my inferences.

In addition, I have an audit trail by which others can trace the steps I took to collect data, create the categories, and refine them in the form of a dissertation log which I used to chronicle what I did and thought at each step of the process (see Appendix MM). Finally, I provided participants with copies of their cases to critique and went through two rounds of critique and revision for each.

Rationale for this Design

Why qualitative interviews? The interviews allowed teachers, in the presence of their materials, to review the history of their instructional decision-making with regard to content of their choice. Giving teachers a rare opportunity to talk about what they did activated tacit knowledge and allowed not just me, but the teachers themselves to become aware of the depth of their PCK. In a political climate which underestimates teachers' knowledge and underfunds teacher education, contacting the depth of their professional knowledge appears to have been an empowering experience.

Why have teachers discuss a favorite unit? Allowing teachers to choose a favorite unit to discuss provided a window into themselves, students, and their particular "take" on their discipline, which is something seldom addressed in discussions of teachers' content knowledge (Gudmundsdottir, 1990), yet a significant indicator of a particular teacher's values, hence which aspects of the discipline they used to develop their PCK.

Why four content areas? Choosing to address four content areas instead of one allowed me a chance to notice similarities and differences in PCK across disciplines. I felt that finding similarities across content areas could rescue PCK from being so context-specific that it could not be generalized to other content with similar students for use by team teachers and other grade level teachers. I couldn't reach this level of understanding without a basis for comparison.

Why highlight representations and not some other aspect of PCK? Despite variations in the ways PCK has been defined (see Chapter 2), instructional representations are common to most schemes, so can be viewed as a basic component of PCK. For me, they are the creative core of teaching -- part of what students remember most from their schooling. Why not try to collect and built on brilliant ideas, so that the profession progresses beyond the waste and myopia of unnecessary reinvention?

Liabilities and Virtues of the Case Study Design

On the down side, it is hard to predict from case study data, as only a slice of the whole is presented. It is time and cost intensive. Results may be too lengthy and detailed to be quickly processed. Depending on the researcher's skill, sensitivity, training and ethics, it can oversimplify or distort a situation. As Merriam (1988) points out, there may be political commitments of case study evaluators triggered by concerns about gaps between what people *think* they are doing, *say* they are doing, *appear to others* to be doing, and in fact *are* doing (p.34). Thus, case study lacks the kind of generalizability, reliability, and validity associated with quantitative methods.

On the up side, study of the developmental patterns of experienced teachers dedicated to teaching for conceptual understanding invites a situation-specific treatment because teachers' choices of representations will, presumably, vary with the nature of their content and their students. Case study offers an in-depth portrait of the development of one individual and his or her unit history. This study supplies four such portraits, one each in math, science, English, and social studies. It tries to describe characteristics of complex phenomena in real-life settings with the hope of helping readers -- teachers, teacher educators, administrators, researchers, student teachers -- to make sense of their experiences. The tentative hypotheses it generates add to the knowledge base of teaching and teacher education, because they are based on rich descriptions of the way real teachers believe that they have evolved, thus others may find them relevant and usable.

Assumptions Undergirding this Design

This study uses ethnographic methods (interviewing, documentary analysis, life history, investigator diaries, observation) and is concerned, in part, with a socio-cultural interpretation of events, that is, a concern with the context in which development occurs. Contextual elements include socio-economic factors; a school community's racial and ethnic make-up; the possible influence of parental attitudes, residents and school officials toward education; and generational changes in the experience base and orientation of new groups of students. This study also borrows from psychology in that assumptions about knowledge (orientations toward epistemology) provide an analytic category for data analysis; and from sociology in exploring teachers' notions of their role.

The product I have aimed for is interpretive -- providing conceptual categories to support and/or challenge theoretical assumptions about the teaching of concepts held prior to my data gathering. In the absence of a theory of PCK development, I have generated descriptions and continua which reflect different facets of the PCK developmental process, highlighting knowledge about representations in particular.

Appropriateness of Data Collection Methods

Semi-structured interviews allow participants some latitude in responding according to their own sense of the world. They have allowed me to gain access to feelings, thoughts, and intentions about the ways teachers have organized and understood their experiences over time. Having spent many years in area classrooms as a teacher, supervisor and teacher educator, I have some familiarity with the cultures of my respondents. In the process of interpreting data I have tried to notice when my familiarity with the teachers in this study might have inclined me to "go native" in my observations, since I have known all four respondents as colleagues and/or friends.

Relying on document analysis as a second data source has required accessing earlier unit versions (UVs). Teachers purge their files from time to time, so not all of these were available, thus some had to be reconstructed from memory. The majority of materials were saved, some dating back twenty years. I shifted between using the documents to create categories and fitting them into categories I had already created from the interviews. Authenticity, usually a concern with documents, was not a major a concern here, since I was dealing with materials (commercially-made, teacher-made, and student-made) which teachers intended others to see and use. There was no benefit to them in falsifying the origin; more often it was an issue of forgetting where something came from.

Ethics

While in-depth interviewing can open both participants and interviewers to buried feelings which may or may not be pleasant, my sense is that this process has been one which respondents found valuable. The process of being carefully listened to -- having their professional knowledge respected and taken seriously -- seems to happen rarely for these teachers and felt a lot like therapy for some. I have been asked to keep some material off the record and to omit names (always using pseudonyms), which the agreement participants signed stipulates and by which I have abided. I have tried to be conscious enough of my biases to neutralize my reactions when needed, so that participants could speak freely. I don't think I was always successful, as I find it hard to hide my value for concept-oriented teaching, and when I wasn't able to see it, I know I kept pushing for more evidence than some participants were able to provide. In fact, one of the main issues to emerge from this effort is that although two different people supported each teacher's candidacy for this study of concept-oriented teachers, participants were, in fact, in varying degrees of consciousness and intentionality about this goal.

Pilot Study

I undertook a pilot study to field test my methodology. I wanted to know:

1. What kind of records would teachers keep of the materials used and steps taken in previous years to help students reach the goals within a selected unit of study?

2. Would teachers be able to reconstruct their thinking about the content and process of earlier versions of the unit, so that I could attempt to track the development of their PCK through their choices of instructional representations?

3. Would the amount of time I had allotted in my original estimate (see Appendix D) be enough to capture their PCK in the detail I hoped for?

Most of what follows are the steps taken in data collection for a science teacher named "Kit," along with what I learned about this process. I conclude with preliminary comments on data analysis, and recommendations for adjustments I subsequently made to my initial research design.[3]

Participant Selection

Kit had been teaching middle school science in semi-rural New England for eleven years. During the last two years she had been worked half-time, as she was the mother of two young children.[4] Kit was a former colleague of mine and the cooperating teacher for a student teacher I had instructed and supervised as part of a teacher preparation program at a local liberal arts college. Her principal strongly endorsed my initial inquiry about her as a candidate for this study. Because of these reasons, and the fact that Kit was excited to participate and willing "to be practiced on," I selected her to be the respondent for this pilot.

Data Collection

Using the protocol in Appendix F, my first interview with Kit took place in a local coffee shop near her school. Teaching half time in an overcrowded junior high left her with no classroom after eleven AM and no other options for an adequate on-site meeting area. The interview lasted forty-five minutes, which I audiotaped and later transcribed. I

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[3] Kit's case is reported in its entirety in Chaper 4.

[4] Because she is such a valued teacher, her request for part-time employment was granted, although she had to threaten to quit first.

did not finish asking my last two questions before Kit had to leave. I realized that I needed to schedule a full hour or more for this session and find a quieter location for our next meeting.

As Kit wanted some help deciding which unit to select, our next meeting (5/4/95) was "unofficial" and took place on a park bench, lasting forty-five minutes. This and all subsequent sessions were audiotaped and interviewer impressions recorded in writing, following the session. First, I asked Kit the last questions from the first protocol, then we discussed which unit she might want to pick. She seemed torn between one on meteorology, which was highly developed and clearly one she was proud of; and another on astronomy -- the one she was currently teaching. I realized that rather than ask teachers to select their favorite unit and a second one students typically found challenging which was part of my original design, I should ask for units teachers were most attracted to, as teachers would probably remember more about these than others. At this point, I still hadn't yet realized that exploring one unit per person would consume all the available time. Kit decided to collect materials for the astronomy unit to bring to our next session. I gave her the protocol for the "official" second interview, to help her organize her thinking.

The second interview, Session #3 (5/18), took place in a quiet downstairs room of the local library where we were the only occupants. Although I had provided Kit with a copy of the protocol for this session, we soon left it behind, in a flurry of astronomy handouts and packets she had assembled for the current unit version (UV-1995) and from the first year she had taught it (UV-1988). The bulk of the session, which lasted an hour, was spent giving me a sequence of the activities in the most recent UV, which had evolved from a two-week unit in1988 to a six-week unit in1995. On a 24" x 36" piece of newsprint I penciled-in a grid -- the X-axis for the UVs and the Y-axis for the steps taken in each. While Kit spoke, I filled this in as well as possible, drawing arrows and inserting afterthoughts, as her memory made adjustments to what she'd said before.

Kit realized that she wasn't able to piece together the sequence of UV-1995 completely using her memory and her plan book, which contained mostly reminders to herself and general plans for her 8th grade Earth science class. So we agreed to meet the following week, at the same time and place, and she would bring her "Log Book" -- an invaluable resource containing student-supervised pages for every day of class, detailing homework, classwork, and reminders. It had come into existence the preceding year, as a way to keep absentees organized in the face of Kit's part-time status. Kit also realized that she needed to bring plan books from as far back as possible, to jog her memory of the UVs between 1988 and 1995.

This session taught me that piecing together the sequence of even the 1995 version was very hard for Kit -- partly, I believe, because the unit was so long and contained so many parts. Shorter units (say four weeks), I realized, would be preferable, the richness of this one notwithstanding. I also learned that plan books may be useful in a general way for capturing what teachers have done, but not necessarily the details of their thinking. Assuming teachers have even saved them from previous years, how helpful they might be was hard to predict.

For Session #4 (5/25), using the audiotape of Session #3 and the newsprint grid, I cross-referenced unit packet pages for UV -1995 with steps taken, then transformed what I thought was the completed sequence into table form using the computer. My intent was to show Kit my understanding of the sequence of steps for UV-1988 and UV-1995 for her to check. I brought this to Session #4 and made corrections as Kit went through the pages of her log. This process actually doubled the steps taken in UV-1995. Kit also gave me additional handouts not included in the packets given before. After this session, I recorded my impressions of the session and updated the table on computer.

In preparation for Session #5 (6/14), I created a simplified chart blocking out the activities in UV-1988 and UV-1995. At this session, I also asked Kit to indicate in what year each item in UV-1995 had first been introduced, and in this way was able to map back the probable contents of the intervening UVs. Because I had begun to look for themes in the changes, the content of this session was very rich -- moving away from the nuts and bolts of what was in UV-1995, to a reflection on its origins and the major influences on its development. Kit concluded with steps she'd like to take next year to refine the unit further.

Summary of Insights Gained from Data Collection

1. The first interview needed to last from an hour to ninety minutes.

2. Planbooks from previous years didn't necessarily provide a lot of clarity about the content of earlier unit versions (UVs).

3. Divergent thinkers like Kit seemed to need a lot longer than I anticipated to work out the details of sequencing. I saw these as an important prerequisite to understanding the ways a particular representation fit in with other aspects of the unit and earlier units taught; however, I believe we got bogged down in more detail than needed to sketch the major drift of the unit's development.

4. Given the requirements that the unit have at least five years of history and last at least three weeks, I felt participants should be encouraged to select units they were most interested in, as I believed they would remember their evolution more easily. Teachers should also be encouraged to choose units in which the total number of days is less than six weeks, as the length of Kit's unit had proven unwieldy.

5. A matrix on newsprint for the first session on UVs (Second Interview), to be filled out on the spot, was helpful. At the follow-up session (Third Interview), I thought the interview protocol should focus generally on why a representation was added or dropped; supports or constraints on unit evolution; the source of the idea/materials for a UV ; changes in the ways the same materials were used in different years; the core ideas of each UV; how they were represented in each UV; and why were they changed, if they were changed.

6. The process of mapping the contents of the UVs took many more meetings than originally planned. Many of these were work sessions, rather than interviews *per se*. Again, it was hard to predict how representative Kit would be, but the overall indication was that I should limit my design to one unit of study per participant, rather than the two I had originally planned. In this case, three hours for unit-interviewing had not turned out to be much time for data collection; yet, along with the initial interview and anticipated critique sessions, it represented a significant commitment from a busy professional.

Data Analysis

Because I had not finished transcribing the initial interview by the time I began data collection for the astronomy unit, I failed to use the categories I subsequently identified from it as a starting framework for recording my impressions of the unit and our meetings about it. Instead, I immediately zeroed in on the content of the astronomy unit, and in so doing, was too narrow in my understanding of the core content Kit was representing. From the start, Kit had stressed affective goals (students feeling positive about having questions, feeling confident about their ability to gather information and make decisions) and generic thinking skills (e.g., categorizing and predicting). However, I was thinking primarily in terms of cognitive goals dealing with specific subject-related concepts, as this is what my reading of the literature in teaching for conceptual change had stressed. In this respect, I was falling into the same narrow view of teaching Ball and Wilson (1996) address in suggesting that the moral dimensions of teaching cannot be separated from content.

I came to see that the notion of "concept" was too limited for Kit -- that her goals included targeted concepts, skills, and attitudes, all of which she worked at representing. I had to decide whether to limit my study to subject-matter concepts or to include a broader notion of concept -- one which would more fully portray the nature of Kit's commitments. I decided to collect data based on the broader definition, but ultimately analyzed only representations related to content-related concepts as these were the most concrete, thus easier to spot stages of use.

I also realized that it was difficult to capture many of the representations Kit used, as they were fleeting metaphors and illustrations inspired by a particular student's face, a chance comment, or other transitory influences that stimulated an on-the-spot idea in her for a way to connect with students' realities. I realized I had to limit my study to those representations that were most planned for, *most concrete*, most at the surface of teachers' memories (like Kit using "oobleck," a gooey/caky substance, to simulate both the solid and liquid properties of the earth's crust.)

In a first effort to analyze large scale changes in the nature of the Astronomy unit, I began by describing the extremes of Kit's unit development, contrasting the last UV with the first in terms of content, then qualities, core ideas, and representations, for her to check the accuracy of. I gave these data to her in table form a day in advance of our next session (#7), so she could bring them to our meeting (6/21) having already looked at them. At this session, Kit told me she was not comfortable with the emphasis I had placed exclusively on cognitive concepts. Consistent with her first interview, she re-emphasized that her primary goals were affective (helping students to feel confident in their abilities to separate fact from fiction, ask questions, gather information, and make decisions) and science content was just a means to reach these ends. Her core ideas included not just concepts, but core attitudes and skills, which she felt had remained consistent throughout the years she'd taught the astronomy unit and, to her mind, throughout all her other units as well. To her it seemed that the number of ways she represented them had grown, as she had added more and more activities within the unit, but the core outcomes had remained the same.

Using the transcription of her first interview (which had been buried below the unit materials), I pulled out the skills and attitudes I heard her emphasize, then reviewed the tape logs of our work sessions to check if I had left anything out. This is as far as I went with data analysis for the pilot study. For the primary study, I used Kit's data, continuing a process which included, at our next session, asking her to indicate which skills and attitudes she felt she stressed in this unit, which I compared with my sense of the same. Next I showed her how it seemed to me she had represented these and the academic concepts we had already worked out, for her to edit as needed. At this point, we were ready to discuss all her representations, guided by the categories listed in the protocol for the "Third Interview" (see Appendix H).

__Summary of Insights Gained From Data Analysis__

1. I realized that I needed to stay true to the steps of the constant comparative method and not be too quick to jump into unit analysis before I had allowed the background data of the first interview to inform the emerging descriptions of UVs.

2. Starting with the most recent version of a unit and moving backward seemed to allow easier reconstructing. Initial categories for all versions could be built off the most recent -- the assumption being that it was the most complete and showed the most developed stage of the teacher's thinking about unit content and objectives at the current time.

Conclusions

As result of the pilot, I gained a clearer sense of the difficulty of carrying out my design as originally conceived. In terms of record-keeping, my first question, I found that Kit could locate with relative ease copies of various activities she'd used over the years. The hard part for her was remembering the sequence of her activities. I came to question the amount of sequencing detail I had gathered, and made less of an issue of it with other respondents because it seemed secondary to the knowledge I was trying to collect about the representations themselves. I chose to focus on where representations appeared in the unit and whether/how they were coordinated with other representations.

My second question regarding teachers reconstructing their thinking about the content and process of earlier versions of the unit remained to be answered fully; Kit was clearly able to revisit her earlier thinking in broad terms (major changes; major influences on changes); how specific we could get (the small insights one has after individual class sessions) was not clear. At this point it was clear to me that Kit did not think in terms of "representing" core content -- whether academic concepts, skills, or attitudes -- yet her work was filled with representations (e.g., having students shift Styrofoam lollipops in front of a light source to illustrate moon phases) and her students were quite successful at learning and using knowledge, skills, and attitudes they had constructed for themselves --

based, in part, on the effectiveness of these representations.[5] While Kit fit the description of a teacher committed to teaching for understanding, it seemed she was not fully conscious of what she did or why. [6]

In this regard, I saw a basic tension between my theoretical framework -- the notion of PCK of concept-oriented teachers and representations as part of it -- and the way Kit thought. I was trying to name and analyze teaching knowledge that existed for her in a holistic, web-like form that was neither fully articulated nor conscious, yet still had some intentionality. Describing, understanding, and naming the directions of Kit's largely tacit professional knowledge in terms of an unfamiliar theoretical framework seemed strange to her; she was surprised that anyone would find what she shared to be interesting or useful, much less able to be theorized about. For my part, I needed to find a balance between the theoretical framework I was using for conceptual teaching and the arrangement of her and others' knowledge as it naturally occurred.

The answer to my third question: "Would the amount of time I had allowed be enough to capture teachers' PCK in the detail I aimed for?" appeared to be "No." After meeting with Kit seven times -- six times related to the astronomy unit alone, involving over six hours of interviews, we were just about to take a look at the nature of the representations themselves. Part of the problem certainly had to do with my inexperience at data collecting for this project, part with the length of Kit's unit, and part with her difficulty with sequencing. I also wonder if part stemmed from the fact that teachers are seldom asked for such detail, thus the opportunity to share, while gratifying, can be overwhelming. At the same time, Kit seemed to be making some connections for herself

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[5] I base this belief not only on Kit's principal's original belief that she met the criteria for teachers committed to teaching for conceptual understanding (see Appendix B), but also on such factors as a majority of high grade-point averages; Kit's assertion that students' could critique misused terminology in recent news articles on earthquakes; their evident interest in and enthusiasm for figuring out moon phases during class the day that I observed (just two days before the end of the school year); and end-of-unit evaluations citing various activities involving some of Kit's most creative representations as among their favorite and most memorable parts of the unit.

[6] Perhaps a continuum of consciousness exists along with a continuum of PCK, and one can be at different points along each.

about her deep goals as a result of this process, which prompted me to believe that this project, however difficult, was both feasible and worthwhile, given the amendments outlined above. For this reason, I decided to include Kit as one of the four middle school participants in this study.

CHAPTER 4

DATA ANALYSIS

"Instruction must recognize that students are not blank slates, even in domains they have not formally studied. The design of instruction must consider not only what knowledge students lack, but also the character of the knowledge they already have and the role it may play in representations of new information..." (McKeown & Beck, 1990, p. 722)

Introduction

Four experienced middle school teachers with a commitment to teaching for conceptual understanding -- one each in math, science, English, and social studies -- shared with me their professional histories, the history of one unit which they had taught at least four times, and their knowledge about particular representations associated with the unit. My intent was to capture a broad overview of their sense of the developments in their practice over time before narrowing the focus to ways these may have affected a particular piece of curriculum, and within that context, to examine concrete examples of PCK in action surrounding specific teaching events.

At the start of the study, all four teachers taught in the same town of 13,000 (97.5% white; median family income of $40,500) in semi-rural New England. Half-way through the study, Dar, who taught English, switched schools to teach in a neighboring college town of 9,000 (91.6% white, with a median family income of $65,500). Three of the four teachers in this study (Kit, Dar, and Ben) taught at the same junior high school of three hundred fifty. Divided into three instructional teams, the school places equal emphasis on extra-curricular activities and academics, rendering it more like a middle school than a typical junior high. The faculty are mostly veterans, with an average tenure of over ten years at the school.

The facade of this brick building built in the early twenties boasts two floors of eight large many-paned windows, divided by a central cement staircase topped with a portico. Once inside, one sees magenta, purple, bright yellow, and kelly green halls decorated with student artwork, individual photographs of team members, posters of the up-coming Christmas fair, a poster about collecting food for holiday baskets for the needy, and murals of moonlit cityscapes from the last school dance. The carpeted halls are free of graffiti and debris. Walking past the cafeteria, I glimpse many brightly colored student-made papier-mache fish suspended from silver streamers attached to the ceiling.

Within the same district, Ted's school of 214 houses grades four through six and dates from the same era. In the halls, gleaming wooden floors and wall-flanking multi-colored lockers are joined by multiple displays of student work: posters of life in Egypt, charts about mythology, a strip of paper running the entire length of the hall with one million zeroes on it, photographs in the stairwell of Ted leading the school in a conversation about the national debt in front of a flat bed truck with this figure illuminated by a huge digital display, and artwork by students depicting the moods certain colors evoke in them. In both schools one senses economic modesty -- these are old buildings lovingly cared for. One also senses a value for the whole child and encouragment for creativity.

Because many of us spend so much time as students when young, I make the assumption that professional development begins with the "apprenticeship of observation", which Lortie (1975) calls our long tenure as students. This apprenticeship blends with the values and experiences gained from our parents and siblings -- our earliest teachers -- so I begin the story of teachers' professional development in childhood.

Case One: "Ted" (Math)

"I think that a lot of knowledge is tinkertoyish. You plug in concepts and then you build off those. I mean I think it's got to be constructed." -- Ted

Professional Development

Introduction

The youngest of three children, Ted, now 49 and a parent of three boys under 8, has been teaching sixth grade for nineteen years, all at the same elementary school in semi-rural New England. Most of his time has been spent on the East Coast, punctuated by vacation trips to Europe and the Caribbean and a two-year stint in Colorado.

Childhood

Ted recounts that his father taught him to want to do things well and to want to understand how things work.

> I remember as a kid always wanting to know why, always having a questioning mind. It comes down to playing games well and understanding. It applies to all facets of life, and I don't think it's just purely about being competitive, although I am competitive. I don't mind losing. It's just you want to know, and you want to do well.[1]

Ted has no recollection of teachers who inspired him to teach, but does have memories of powerful male teachers at the middle school level, "all characters," particularly an English teacher, Mr. N., who broke through the role-related barrier between teacher and student to connect with his students as people:

> He was a hot ticket. He was real. There were no games being played, what he said was the truth; if he wasn't very happy he said so. He related to us as kids, not in the old authoritative top-down style. His

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[1] Quotes have been edited for clarity. All participants have exercised their member check rights to evaluate the appropriateness of these edits.

> delivery was pretty traditional [but] he seemed to make the subject matter and us students real.

Subject Matter Preparation

Ted majored in English at an Ivy League institution, but has always enjoyed math, though he didn't realize he was a "mathematical person" until after he left school. Math in college was "pretty minimal and not very fun." Freshman year he mistakenly took a calculus course intended for math majors. He credits the experience with giving him compassion for the student who struggles with math. It appears to have been the seed for helping him develop the PCK associated with confirming students' confusion and prior knowledge, reading their needs, and reframing the problem in familiar terms:

> I was lost in this course. It didn't come. None of it. I know what it is like to just not get it and to continually not get it. So, when I teach kids who aren't getting it, I quickly drop back, scoop underneath wherever they are to find some comfort zone, then start them from that point, trying to draw as many connections as I can, bringing them as close as I can get to where they need to be. At times I can't, but I at least explain, 'This is not going to make sense to you right now, but it will later. Try to remember this discussion when we look back.'

Entry into the Profession

After graduating from college, Ted held a variety of jobs including Wall Street banker, carpenter, waiter, truck driver and accountant. Responding to a newspaper ad announcing a last-minute opening in a local teacher preparation program one September -- the same program, interestingly, through which two of the other three participants in this study were certified -- Ted found himself in a classroom that afternoon and has never looked back.

> The day before school began, somebody dropped out of the Program. The opening was with Dave Bradley and Anna DeLeo at the Hillyard School, for 5th/6th grade. So literally, I got up that morning before coffee with no plans for the day, let alone for the rest of my life, and by one o'clock I was in the classroom planning with Anna.

When he got in the classroom, it "felt right." Only years later, after discovering a copy of his college application, did Ted realize that he had predicted that he would be teaching some day.

Ted doesn't perceive practice teaching to have much to do with the way he teaches today:

> As far as modeling goes, my master teacher modeled a way to teach math that I followed for the first ten years of my teaching which, I think, at the time probably was as well as it could have been taught, but now looks archaic and primitive. It was very compartmentalized and very skills oriented. No melding, welding and putting together the pieces. No fabric of mathematical understanding.

Professional Influences on Teaching

Ted found his first year brutal; out of desperation, he leaned heavily on his master teacher's materials.

> I pirated everything my master teacher did to start. I had her whole program so I could literally go and copy all of her units. The first unit of the year was, "Reading and Writing Large Numbers," followed by "Rounding off", followed by "Roman Numerals," followed by "Addition," "Subtraction," "Multiplication," "Division," "Introduction to Fractions," "Fraction Equivalencies," etc. There were sixteen units -- bang, bang, bang, and bang. I had let the kids work through them sequentially at their own pace. So, I'd have one kid sailing forward on unit number twelve and one kid still back on page twelve of the first unit.

Four years later, Ted earned his Master's in Education from an in-state teachers college. In one course he had to create a unit from scratch. He decided to focus on prime numbers and use his own ideas.

> Prior to that I'd pulled from lots of sources, thrown in an instruction here or there, but basically just stitched together various workbook and ditto pages and my own breaks for a puzzle page that would be on the same concept as the topic... . Pretty grim.

Based on a self-directed approach, his unit began with an instruction sheet containing steps like, "Play a game; come see the teacher for an interview; then go review a filmstrip."

> I began to understand what students needed to know as they progressed through the topic, how they best acquired certain knowledge so that another piece would make sense. For example, I

> could see that a game they were trying to play made no sense, if they didn't know the rules of divisibility first. So, I would have them learn the rules, then have an interview with me and perform a little: they would have to recite prime numbers using the rules of divisibility before a panel of other kids who would tell them if they were right or wrong. From that, they were then allowed to go play the game.

Taking the time to create this unit seemed to develop Ted's PCK in many ways. It allowed him to see the need for "a relevant path of learning that was interesting, but sequential"; showed him that "You could make math into anything!" and that students have to construct their understandings themselves. Ted also seems to have had an instinctive understanding of the importance of creating roles for students to teach each other in order to reinforce their own learning and increase their ownership of the learning context.

It's striking that Ted's awareness of patterns in students' learning and how to design lesson plans with these in mind, appears to have sprung from his own observations rather than from his earlier teacher education, in-service staff development, curricular materials, coursework or some combination thereof. Perhaps because he lacked sustained reinforcement for his insights, much of the PCK Ted developed from designing the unit on primes did not become an integral part of his practice until ten years later.

In spite of including more manipulatives and games in his seventh through tenth years of teaching, because of continued heavy emphasis on worksheets and teacher-dominated assessment, Ted gradually choked out any desire to teach math. By the time he saw the first working drafts of the NCTM Math Standards (1989), despite being "a mathematical person," he was sufficiently bored by what he thought were the limits of the content that he asked his principal if he could teach something else.

> We went through a population change. There was a new teacher coming onboard and my principal asked, "So how are we going to reconfigure and what do you want to teach?" At that time I had taught social studies for three years and loved it. It is a wonderful curriculum: the Greeks, the Romans, the Egyptians, the Middle Ages, and the Age of Exploration. This is great stuff. I went to my principal and told her I wanted to teach social studies, not math; and that I wanted us to hire a math teacher. The reasons were obvious to me: that I could make the social studies interesting. I could make it real. Whereas with math, I was focusing on skills and artithemetic, not the language of mathematics itself. I was saying, "What the hell can you do with math? It's math!" It's stunning to me to recall my point of view,

but I remember saying it because it was in defense of the position I was holding. I don't remember what her response was. I don't think it was anything like, "Well have you thought about how you teach math?"

The Math Standards would eventually have a powerful impact on Ted, breathing life into his teaching and his identity as a teacher by validating that a lot of what he really liked doing instinctively made sense pedagogically.[2]

> Having made the case clear that I didn't enjoy teaching math, the working draft of the NCTM standards came up that same spring. The high school math chair got us a small grant and had us meet to talk about the standards, and give written feedback to the NCTM. Reading them was like, "Oh, my God. You know, if this is what the teaching of math can be ... this makes sense to me.'" Because if we are going to talk about the way I used to do things, it was "Grunt Work City." It was the epitome of everything it shouldn't have been, and just seeing that piece of work was liberating because I am mathematical. I love to play with the numbers. I realized I could teach these kids math the way I saw it, and we could do anything we wanted to and make it mathematical. The Standards were enlightening because they allowed me to change and have an impact on students' mathematical understanding. That was an important turning point in my life as a teacher.

Two years after reading the Standards, a sub-committee of a district long-range planning committee came up with a recommendation that there should be an individual education plan (IEP) for every student in the district.

> Everybody went, 'Ha, ha, ha. That is absurd. That will never happen.' Well, of course, it hasn't happened, but in a sense it should be happening continually.

This conviction prompted Ted to establish individualized goals with all fifty-some of his sixth grade math students, "shining a spotlight" on each by offering very specific feedback on their progress in conferences, so that students knew exactly where they stood.

> I think probably my greatest strength is, for every one of these kids in my classroom now I have already told his parent the two things I want that kid to work on this year. If the parent thinks that their kid is not capable of that or I am not seeing this kid clearly, I want to know that. When they leave, I want to know that I have boosted them in the areas they needed most. I want them to know what their strengths are, and what they can rely on.
>
> I think a lot of teachers don't give kids that honest feedback: 'This is the way I am seeing who you are as a person operating in this classroom.' When I do, a lot of them are blown away. The analogy I use with them, when I talked about it earlier in the year was, in a lot of classrooms you are under a floodlight that lights up the whole classroom.

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[2] See Appendix I for a summary of NCTM recommended changes in content and emphasis for grades 5-8.

> In my classroom it is nineteen separate spotlights, and you are alone in that spotlight. Everything I talk to you about is going to be based on a conversation you and I have had before, about your organization or about your willingness to study for tests or whatever the piece is. That is intense. It is intense for some parents too, but my feeling is that if more teachers were more rigorous in assessing kids and giving them honest feedback, these kids would benefit educationally.

Such goals and the Standards forced him to sharpen the PCK surrounding his purposes for instruction.[3]

Finally, perennial complaints of teachers at the junior high that his students weren't capable of "doing fractions" after leaving his classes provided the final nudge to prompt a major overhaul of Ted's practice.

> So often teachers in later grades have said, "You know these kids just can't do fractions" -- and about four years ago I said, "Well, bull! They CAN do fractions, and next year when you get them they'll be doing them in their sleep!"

Ted took this as a personal challenge, prompting him to integrate fractions and all other relevant math topics into everything students did all year -- a major change from the compartmentalized approach he had taken before.[4]

During the early to mid-nineties, Ted took 15 -18 credits in mathematics education.

> Not undergraduate courses for math for content, but more for teaching the math: A course on discrete mathematics, courses on problem solving and teaching algebra to young kids... .

Ted feels that these broadened his knowledge of subject matter and his sense of the choices available to make mathematical literacy a possibility for all his students.

Perceptions of Himself as a Teacher

Ted currently teaches language arts to his homeroom and math to the entire 6th grade (about fifty students). He very much enjoys the interdisciplinary possibilities of teaching at the sixth grade level.

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[3] They also bring to mind the teachers of high performing groups of students in Peterson, et. al.'s study (1991) who had much more specific knowledge about the individual ways their students thought than did the teachers of lower performing students who tended to think about their classes as a whole.
[4] The section "History of the Fraction Unit" details this process.

I think it's true that although I teach both sixth grade classes one hour a day in math, my homeroom class gets exposed to a hell of a lot more math than the other class does, simply because they are with me all day and I think that way. They listen to me think, and I ask them questions constantly. For example, whatever the book is that I'm reading to them ... I'll hold it up edgewise to them and say, '"Okay gang. It's a four hundred page book. What page am I on?'" And they'll have to tell me, and I'll say, 'How did you figure that out?' And they'll say, 'It's a half and so, 200 pages.' That happens all day long.

Ted seems to think of teaching like baseball -- throwing questions out to the team to see how they will field them, as the this exercise where he had them construct the value of pi:

They'll come in and we'll focus in on what we were doing before. Today I reviewed pi with them. Yesterday, they took coffee cans, measured them, then used a calculator to determine how many times larger the circumference was from the diameter. They shared all their answers in a list of 36 numbers from both classes. We looked at them in terms of mean, median, and mode. They came up with 3.19 as the mean average and also the median, and the mode was 3.20. They decided that the relationship was 3.19 to 1. Then we went to pi which is up there [pointing to a poster bordering the ceiling showing pi worked out to 100 digits after the point] and talked about how close they came to that. They were upset that they weren't right on it, but they were pretty damn close, a percent and a half. Today I reviewed that, elicited responses, then I threw a problem at them based on the numbers they had generated.

Ted sees himself as hardworking and committed to rigor. This showed up repeatedly in the two classroom visits I made. Ted's room is immaculate and brims with visual information. Two walls of ten-foot windows in his high ceilinged corner room illuminate the other two walls, which are densely covered to the ceiling with posted material: colorful math-related laminated posters; circle graphs depicting how students spend their day; pictures of family; collages inside students' profiles; various carefully done book projects and posters. Charts of various kinds also abound. One is titled "Mastery of Basic Facts" with a list of students' names beneath and stars next to them in various columns. Another offers a guide to problem-solving, a third, steps to "Check Your Work". One depicts occupations and the kinds of math they use under the heading, "When are we ever going to use this?". One has guidelines for listening and speaking during meeting time, another, "Benchmark" numbers for every student to learn.

Students sit in clusters of three or four at tables arranged around the periphery of the meeting area in the center of the room. Girls and boys seem equally willing to volunteer. Everyone is on-task and focused on the overhead which Ted used at points during each observation. One day, for example, using only the digits in the year 1995, students demonstrated different ways to produce the numbers 1-100 e.g., "1= 1 x 9 minus the square root of 9 minus 5," which Ted would write on the overhead, have students think about and then vote on whether the solution worked. Discussion led into areas like what is an integer and how negative numbers operate.

Ted expects students to speak precisely:

> 'You times it,' says a student.
> 'You what?' replies Ted.
> 'You multiply it.'

In another case, "What verb do I want? What do I do with this number?" and when a student calls a number "minus nine," Ted holds out for him to say "negative nine." Ted pushes students to reason for themselves and gives time for this. To students working in pairs he says:

> Make separate decisions and then check with each other; two heads together, not two heads into one beforehand.

And he constantly reminds students that their work "deserves more," asking them, in one instance, to paraphrase the very specific evaluation criteria for the stock market units:

> Dots must be placed very carefully between points on your graphs. Use an art gum eraser and a fine line No. 3 pencil... Readability has to do with the size of your print and how you form your letters.

As a result of this careful outlay of his expectations, students seem to self-evaluate pretty easily. Upon receiving some returned circle graphs related to his stock market unit, Ted's sixth graders were intensely interested in the feedback they received -- the room's quiet softly punctuated by comments related to the assignment and "Ohs!" as students figured out what they had or hadn't done.

While constantly pushing for high quality work, Ted also sees himself as caring. This came through not just in having high expectations for every student and giving students tools to reach them, but also in empathizing with their experiences:

> "Let me give you time to process that."
> "Thank you for trying."
> "My feeling is that you had something right, and in a panic you dropped it."
> "We haven't done integers. That may not make sense."
> "I don't want to embarrass anybody."

He commented on the "Jeckyl and Hyde" quality to his teaching style, alternately the taskmaster and the gentle supporter. During the second observation, just before parent conferences, Ted commented to me that it was time "to rattle their cages a bit" since it was November and the group was sliding into complacency. Ted observed that, after a talk of this sort, his gentle supportive side means so much more, and students "start looking for it." His rigor is somewhat controversial: Many parents "love how demanding" he is; others become protective or defensive with regard to their child's progress in class.

The issue of "realness" is one to which Ted often returns.

> I will come in and say, 'You know, this is one of those days, gang, where I am asking myself why am I doing this job. I feel like I am alone in here. I am spending my time giving you feedback on something which you put no time into.' I try to confront them with that, but I think that probably the kids feel like I drive them too hard. However a lot of kids, as the years go on will come back and tell me that sixth grade was a very powerful year, and they never had anything like it before.

He struggles to sort out the appropriate mix of positive and critical feedback, feeling that children need encouragement, yet can benefit from the honesty a constructive critique provides:

> I worry that giving positive feedback is something I don't do enough of. Yet there is nothing I like less than somebody telling me that I have done a great job when I haven't, or some baseless platitude about good work.
>
> Look at that poster up there. Look at the contrast in colors and how that jumps out at you. I can point out to Karl [its creator] how that poster has that vibrancy and eye appeal, but then I am going to tell him four things about it that are not so good. Every piece of work deserves credit for something, and a wish for the future. I call this feedback system "plusses and wishes."
>
> Some kids appear to come from classrooms where they are always told that everything is wonderful. A lot of them may be more

> inclined to remember the wishes and not the plusses, so I have to be gentle.

Realness also shows up in Ted's commitment to move away from abstract manipulation of numbers in a computational or algorithmic application toward helping students develop true "number sense." He tries to accomplish this goal by playing up stories from life to illustrate mathematical thinking, underscoring the comment of one of his students, that "Mr. S. can turn anything into a math problem."

> I become a bit of a stage actor ... set the situation for them, 'I was driving to school this AM, and I was listening to the radio, I heard the news about blah, blah, blah.' They are listening. I have fun doing that, because I am creating something for them, teaching them some completely disconnected piece of knowledge. We were in here last week and talking about the relative position of the sun and earth and talking about leap years. Some kid has a relative who has a birthday on a leap day. So I immediately turned that into a question. As soon as they started talking about this leap year thing, I realized none of them knew why they occur. There's a lot of math involved there. I think you can connect almost anything that happens to what you are doing in math. And I find that the fun part.

Algorithms, consequently, play a minor role in Ted's practice. His priority is encouraging students to use their intuitive approaches with life-based problems like how to build a birdhouse or a bed. Ted occasionally brings in stories about the way his eight year-old solved a problem to try to free students to use their own invented strategies in order to engage more genuinely with the content:

> When I presented my students with real life problems my third grade son had encountered and solved, I told them that the only way they could solve these problems was to solve them as a third grader would. They couldn't get fancy on me. 'This kid has not been exposed to any of the things you've been exposed to.' Some kids who are good at computation don't like this math class because they are not allowed just to demonstrate their rote knowledge; they have to get right down in the dirt with the rest of us and think and reason and debate. I don't see it as disadvantaging the bright kids because it stretches them and forces them to think through things they've never had to think through before. They are so facile learning the didactic method. I am leveling the playing field and suddenly all the roles start to shift. The reason I like that is that it forces them to let go of thinking they understand in the first place. You go back to their basic thinking: 'Does this make sense? What would you do next? Keep your eye on the problem and how to solve it. Deal with fractions that happened. How do you think we can solve it?'

Ted's value for students' prior knowledge and his sense of the constructivist nature of learning come through clearly, resembling the beliefs of the teachers of higher achieving problem solvers in Peterson, Fennema and Carpenter's study (1991). His admonition that students think for themselves (for perhaps the first time in their school lives) brings to mind the point Hofer and Pintrich (1997) make that in many epistemological schemes a key point in development occurs when people shift away from viewing knowledge as originating from experts and begin to see themselves as creators of knowledge in collaboration with others. In this respect, Ted deliberately attempts to foster a more sophisticated relationship to knowledge and knowing. This isn't easy. His experience describes a path through this time of transition, when math teachers adopting the approaches espoused by the NCTM standards are working with possibly resistant students who have been taught in traditional ways. He is attempting to disable routine "programming" as a result of earlier rote memorization and stimulating personal knowledge construction by (re)activating students' own invented strategies.

At the same time, at certain points in instruction, Ted sees a place for using algorithms. He is almost apologetic about it, empathizing with what different students might be feeling as he does:

> In order to accomplish what you need to do for the task at hand there are times I'll say to the kids, (I did this for constructing the circle graphs) 'Okay we are doing equivalencies with a circle graph here.' They needed to be able to say that 5/24ths = 75/360ths. So they had to do an equivalency there dealing with equivalent fractions between hours in the day and degrees in the circle. 'If you are going to spend five of your 24 hours watching TV, how many of those 360 degrees are going to have to be colored in?' ...To get them to do an equivalency is absurd because to get them to do '5/10ths = how many 20ths?' is where they're at for the most part. So I didn't tell them how to do it sensibly. I simply said, 'There's a little cross multiplication thing that works for this. You're not going to understand it at all, but I'm going to teach you how to do it and it works! And if you don't trust it, add it up when you're done and see if you get 360 degrees.[5] Probably, some of you are going to go, "Oooh, I think I get that."

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[5] Having students check the rightness of the algorithm honors their sense-making over knowledge of disciplinary procedural knowledge, bringing to mind the way five year- olds have been empowered in "Writing to Read" programs. Having first used phoneme-based spelling to write, when they eventually do encounter (often nonsensical) standard spellings, the children are positioned to respond, "The person who invented spelling must have been crazy to spell it this way," instead of feeling small because they spelled something wrong (Asbell, 1984).

And others of you are going to go, "Huh? I have no clue what's going on here." Don't feel bad. Because about the fifth time I do this, those of you that are saying, "Ooh, I think I get this" are going to say, "I get this" [with confidence], and those of you that don't have a clue are going to say, "I think I'm getting this." '

I frequently expose them to some thinking process that they are not ready for, but it has a context. I keep giving it to them in contexts. Then by the time I come around to it in March to teach it in depth, they have a basis for it. It has an "Oh yeah, we've talked about this before" aspect. So that works a little.

In this respect, Ted's practice supports the conclusion Tierney draws (1988) that students need to integrate their intuitive knowledge with formal manipulation of symbols and with seeing math in contexts.

Another overriding theme in Ted's descriptions of himself as a teacher is helping students to develop autonomy as learners -- to conceive of themselves in the way Vergnaud discusses (1987) as able to act effectively based on accurate predictions about size, space, numbers and approximations within the real world. He works at this in a variety of ways; first is by looking at his own needs as a learner.

I have to learn by figuring things out on my own. I have discovered that it is very hard for me to take someone else's template or system of explaining or looking at a complex situation. As soon as I am aware of the problem, I am trying to solve it. I am trying to give it meaning. Working in the algebra class with some of the teachers last year I discovered that it was terribly difficult for me to listen to other people's explanations of the way they solve problems if I hadn't solved it myself first. ... If I had, then I could relate. This goes very deep into all of the teaching I do.

Second, echoing findings in motivation research, is by understanding how content is relevant to students' personal goals and empowering them to hold teachers accountable:

I don't want anybody doing anything that is pointless. All of my kids should have the right to ask two questions: 'Why are we doing this?' and 'Why is my grade the way it is?' ... I should be able to give them answers to those. So we do a lot of self-assessment. I want them to walk out of here knowing that education isn't something that just happens to them ... that they have a part in this process. I want them to be able to ask questions of their teachers and feel comfortable about that.

Third is by freeing all students to fully exercise their native math powers within a narrative context, echoing the belief of teachers committed to teaching for conceptual understanding that most students can succeed at this given the right supports (e.g., Lampert, 1986, 1989):

On the silo problem, a student who didn't view herself as a successful math student got it right and knew she got it right. One of the things I did to free her up was to give her the calculator. She took those five pieces, the diameter, pi and got the circumference, 100 foot rolls, subtracted and got it right. And she KNEW it. The beauty of it was she KNEW she got it right. She was so excited. I didn't give her any support at all. She was determined -- got the whole thing herself. The calculator freed her up on that.

Undoing the notion that math is mystical -- a perception Ted feels students pick up from media portrayals and from teachers and other adults without strong subject matter knowledge -- is another way he encourages autonomy:

So many of these kids are taught mathematics that many of their teachers aren't comfortable with. I want students to know that they are capable, that they can understand the world mathematically, that mathematics is not a foreign language, or some sort of a bizarre construct that other people understand and you don't.

Yet another way Ted frees students to be more autonomous is by nurturing multiple paths to solution while using his PCK of the tough spots embedded in different approaches and ways to support students through them.

Once I came to class and stated, 'I'm taking forever correcting these stock market units and they're not so good. As a consequence, you have to tell me how long it is going to take me to finish correcting them!' So they took that very real problem: 'It took me 3 hours to correct the first 10 units. How long will it take me to correct all 37?' They spent 20 minutes stumping their way through it, and then we spent the next 40 minutes on the overhead projector sharing those different approaches. There was an hour's worth of discussion just in the four different ways they took to solve that problem, and we went through all of them. We got into fractions, proportionality, set theory, decimal/time conversions...

The kids who were good at arithmetic said, 'Three hours times 60 minutes an hour is 180 minutes to do ten units. 180 minutes divided by 10, 18 minutes per unit. 18 minutes per unit times 37 units, 666 minutes. 666 minutes divided by 60 minutes per hour, 11 hours and 6 minutes.'

Another student took 37, divided it by ten, and wrote that she discovered that I had three and seven tenths times as many units to go as I already had corrected, took the three and seven tenths, multiplied it times three hours and got 11 and one tenths hours which is 11 hours and six minutes. A lot of the kids were just blown away that the same answer resulted. As soon as I said, 'This is what Vanessa did,' and I wrote 37 divided by 10, and, you know, blank faces, and I said, 'What was she doing? She was dividing 37 units by 10 units. What is that telling her?' The three and seven tenths threw them. So I used simpler numbers and changed the 37 to 40 to get a whole number up top which freed up the majority. Just as soon as they did that, seven or eight kids went, 'Ah yeah, that will work.' So that real-life-context problem ended up as a good class on proportionality, problem solving using simpler numbers, different avenues, and all that.

In his careful exploration of different students' thinking, Ted's practice is reminscent of that of first grade teachers exposed to the methods of "Cognitively Guided Instruction," with higher achieving problem-solvers who spent more time asking students to explain their thinking processes than did those with lower achieving students (Carpenter, Fennema, Peterson & Carey, 1988; Peterson, Carpenter & Fennema, 1989).

Underscoring the effects of professional isolation, Ted wonders if anyone else has come upon the insight that proportional thinking is integral to common sense problem-solving:

> ... I've spent time thinking, 'Am I the only person that feels that way? Are there articles out there that talk about teaching kids how to think proportionally?' It's woven throughout all your reasoning in math. We are reading *Danny Champion of the World* as a class right now. I might ask, 'Danny's going to drive 30 MPH and travel 6 miles. How long will it take him?' Rather than go through all these distance equals rate times time things, you can think it through with basic proportional thinking. It allows you to do a lot of things.

Ted sees proportional thinking as a central tool for helping students reason for themselves because it provides "a framework, a tinkertoy, a way to work it out." Rather than prematurely introducing the abstract thinking associated with a memorized algorithm, Ted's PCK of instructional strategies permits him to encourage his son and his students to use concrete thinking tools like using simpler numbers, finding common equivalencies, doubling, and the distributive property as building blocks with which to construct a doable and meaningful solution path.

Another tool Ted has found valuable in helping students reason for themselves is giving them benchmarks for appreciating the relative size of numbers in order to gauge the accuracy of their solutions. He asks students to conjecture about and then learn particular quantities like the size of the US population; the distance across the USA; the population of their hometown; and the old standards such as day in a year, feet in a mile, etc.

> New this year is that in my unit on developing number sense, I require that [students] memorize benchmarks against which to judge other numbers and the sensibility of other numbers. This year, those benchmark numbers have all evolved from classroom discussions. I then add them to our list. Students have to record them in their notebooks, then I'll throw them into a quiz sometime. One of the

questions on division might ask, "How many USAs it would take to circle the world?"

Equipped with these benchmarks, students grapple with problems like the one Ted sprang on them one day, inspired by the news on his car radio while driving into work:

> AT&T announced they would downsize by 20,000 employees. So I came into the classroom that morning and asked, 'A really large corporation (this is where their number sense comes in) announced they've downsized, and they say that they made a significant cut to their workforce. How many workers do you think they cut? 20; 200; 2,000; 20,000; or 200,000?' If you know that the US population is 250 million, and our town's population is 12,000, which of these numbers seems relevant to the workforce of a giant corporation?' Then they had to work it through. Different kids picked an answer and told why. At the beginning of the year they would have had no clue how to answer that question.

Ted's commitment to creating viable frameworks for students to build on extends to his unwillingness to arbitrarily chop off studying parts of the curriculum because others asked him to:

> At this school our social studies curriculum says, 'Go from the geologic age of the earth, to Egypt.' I couldn't do it. The first year we were asked to drop The Stone Age from our curriculum the other sixth grade teacher and I were planning together, and the night before we were supposed to start I went to her and said, 'I can't do it. I have no clue how I'm going to start my unit on Egypt in a manner relevant to these kids. What do I use as a connection? How do I give them a piece to work from?' I had to spend a week -- I cut it to a week tying in Stone Age people, to bridge that gap, so when we got to Egypt the students knew that it was built upon a new Stone Age culture. I just had to do that. I thought it was a complete disservice to the kids to say, 'Okay, today we're going to start Egypt. Here it is. It is here in North Africa.' It would have had no context. I think that every single thing you teach, you need to be able to tie into prior knowledge and make that connection clear to the kids from the beginning.

In a striking departure from the "robotic" use of pre-made materials from his master teacher which made no attempt to build on students' prior knowledge, Ted's PCK of students' knowledge construction now morally obliges him to provide the bridges students need in order to relate meaningfully to the material. If the school's curriculum is deficient, he fills the gaps.

> I see frames of reference as the key to all of it. My own frames of reference are terribly important to me.

At the same time that Ted is committed to fostering student autonomy built on a sense of themselves as logical and capable thinkers, he is also interested in creating a community of learners. Experience has taught him of the power of communal problem-solving for challenging material like math contest problems:

> I try to make sure that the kids own the problems. The Continental Math League is a formal meet, and you get five of these every year to give to the kids. They do this contest individually, as they always have, but with the knowledge that the next class they come in they will be grouped with two other kids who have also done the contest, and they will bring to that group their own experiences, frustrations, understandings, misunderstandings -- whatever they have gone through on these questions. When they come together as a group nobody is left in the dark. They come in with a little investment, so they can say, 'Wait a minute. I did it this way,' or they might go, 'Oh my God I missed that. You are right.' But they come with some sense of ownership.

Recalling a finding of Ball and Wilson (1996) that sometimes it's students' relationships rather than an interest in the content that motivate them to participate in class, Ted believes that math becomes more meaningful for high and low performing students alike when it becomes a social experience.

> Any problem that you have created for them is, by definition, irrelevant; but when you put it in a community setting, it becomes relevant because you are communicating. It's not just you and the problem about barn silos; it's you and your friend arguing about 'Do you use pi to derive the circumference or what you do?' Then you have ownership of ideas; you use listening skills. It really does make an incredible amount of difference. And it spreads the wealth... because some of the kids get it, and when they are forced to explain it to the kids who don't get it, it's frustrating but energizing for them. And for the kids who don't get it, if it's done well, it's a chance for them to start to pick up some of the skills the other kids have.

Thus Ted finds ways for autonomy and community to arise mutually.

For Ted the elements of good teaching include strong subject matter knowledge, understanding students and, especially, having good communication with parents -- convictions strengthened by having a family of his own -- as such communication extends his knowledge of how to work with students:

> You have got to keep your eye out there on the class and know how they are responding to you. I usually feel as though I have a good handle on all of my kids with maybe one or two exceptions. I think it is real important in these cases to talk to parents and tell them to call me immediately if they have concerns, because as a parent myself, I view the school as an extension. I say to the parents, 'I frequently appear very busy, but make sure that if you need to talk to me you just tell me. I will stop no matter what I am doing.'

Ted feels that becoming a parent has been a powerful influence on the development of his PCK. First, by the birth of his third child, he was working two jobs. Increased demands on his time forced him to economize in his planning, prompting him to look for ways to accomplish more than one thing at a time, as in this example of integrating math with language arts:

> When they do their book activities in poster form, they have to put margins in and measure them -- stuff they should know from 2nd grade. We go for balance. See that poster up there? [He flashes his laser pen pointer.] We talk about the fact that you should be able to take a line and bisect the poster into four quadrants and each quad should be visually weighted the same as the others so it's balanced. Then we use these paintings [artwork by professionals whose posters adorn the walls] and we talk about how they are balanced. When they share their paintings, I ask them to tell me what is pulling the eye to each one of the quadrants in that painting ... how it's balanced. I think that's math.

Becoming a parent has also allowed Ted on-going opportunities to observe and develop his own children's sense of number using the natural events in daily life.

> With my oldest son, I have influence on aspects of his math education over which I have no control with my students, and I feel very good about that. I am not pushing him at all. What I am doing is encouraging him, asking him questions and exposing him to concepts when he is ready for them. It is a lot of fun. He's developed his reasoning ability and isn't stumped by something no matter what the situation is. It is wonderful.
>
> As I watched him learn as a little boy, all I could think of was tinker toys, because everything he was exposed to he would relate to something else, and plug it in, so he never forgot anything. Everything was connected.... it wasn't linear, but it was logical.

His understanding of learning styles has been deepened by the striking contrast presented by his second child's developmental path.

> On the other hand, my middle son has no frames of reference, none. He has never viewed the world from a fixed point where other things plug into it. He has always experienced the world [as] a set of random events. He brings to it a lot of his own creations and a lot of his own context, but he doesn't view [the world] analytically. So it will be interesting to see him as he gets up [in the grades] what's going to happen to him in school. Will he begin to integrate and systematize his knowledge?

Observing his middle son's way of learning developed Ted's PCK of the need to establish fixed reference points like benchmark numbers to guide students' quantitative thinking.

Before teaching, the exposure Ted had to youngsters was mainly through his niece and nephew and the three young sons of a former girlfriend. He thinks he still has a tendency to treat kids like "miniature adults," although now having his own children (ages 8, 6 and 3), he's clearer about how young his sixth graders really are. "I realize only three years ago they were Tim's age, and so I think my own perception of them as developing human beings is always changing."

Teaching for conceptual understanding takes longer and requires patience, which Ted feels he has more of now than when he started. When he first began teaching, the challenges of reaching slower students frustrated him terribly. Because he had not been trained to develop the PCK of bridge-building between targeted content and what students do know, he only saw students as either 'getting it' or not:

> I remember sitting there my first year of teaching with the left wing of my desk pulled out and a student sitting next to me. She didn't have a clue what I was trying to tell her, and I didn't have a clue how to get her to see. It became this perverted exchange where I knew that what I was saying wasn't making sense, but I didn't alter it. I thought sure I didn't change it because I didn't know how to change it, but the reality was I didn't WANT to change it! I was angry! I remember looking at her thinking, 'She is so thick she is never going to get this.' In all my teaching moments that are hard to look back on, that is probably the one that I feel the worst about. There are occasions now where I will be thinking in the back of my mind, 'My God I can't believe he's not getting this by now!' But I now firmly believe that students all know something. They've got something there that they know and understand, and it is my job to figure out what it is so I can use that knowledge in developing an understanding of the concept I'm trying to present.

Today, as a result, Ted deals with students who are stumped quite differently. His PCK has taught him to ask key questions at key times:

> When I sit down with kids now I have a much different sense of timing. I remember back in my college psychology class learning that long-term understanding is better gained by leading students to the trough, but letting them do the drinking. If you are going to have somebody learn something, don't present them with solutions. Have them do it themselves. Give them the tools (the background information) adequate to build the knowledge on their own, and they'll internalize it; it will become their own.
>
> I have a student in my class right now who really is struggling, and the temptation is to explain something so he can see it, and then let him do it. But that approach has no stick at all. It was just Teflon learning: in and out. You really have to sit down and present him with the situation and then leave him alone. Keep him on task and maybe nudge him a little with a question. When he is done I can ask, "Now what did I do to help you there? I didn't do a thing. I didn't tell you anything. I asked you some general questions, but you got there

> on your own." It is slow, but I think it is more valuable. I think that lesson, once learned, will be there when he is in seventh grade.

Ted is like the teacher Wood, Cobb, and Yackel (1990) describe who realized she needed to stop talking, let students learn "in spite of" her, and use their errors as guides to discover how they were making made sense of the problem (p. 606). Having the PCK of when to intervene and make suggestions and when to withdraw results in a complex and demanding form of practice -- one at which Ted has become adept.

Reflections on Professional Development

Early on, Ted needed the time and encouragement of the graduate course in his Master's program to devise a more intentional and multi-modal approach to math instruction than his original teacher training provided. His instincts for shaping his own first unit were both constructivist and collaborative. What is striking is that the PCK of how to help students build necessary prior knowledge in meaningful and interesting ways en route to mastering the concepts of primes did not transfer to other units. When Ted did create activities for other units more in the spirit of the unit on primes, he tended to discount them as interstitial play-breaks between "real" math activities -- often sandwiching them in before vacations. An abundance of available skill and drill-oriented materials reinforced his cultural notions of schoolwork, which, in the absence of support to teach otherwise, alienated him from his teaching potential.

It seems that one of the most powerful effects on Ted's PCK development has been his analysis of himself as a learner. The Math Standards gave him permission to act on these insights so that now Ted builds relationships among various math topics in a carefully sequential though different way each year. He seems to be moving away from curricular units *per se,* toward the ill-structured problems of life, but uses his considerable disciplinary knowledge to underpin them. Putting problems in context necessitates learning how to translate messiness into content one can intentionally strategize about. Like the teachers trained in "Cognitively Guided Instruction" in Peterson, et. al.'s study (1989), the contexts for word problems are often situations of interest to students, as in the leap year example on page 113. But Ted also goes beyond the merely familiar, stretching students to learn about real world events they hear about in the media, such as corporate downsizing and the deficit.[6]

Also like CGI teachers, Ted establishes norms like having students listen to and try to understand each other's reasoning (Fennema, et. al., 1993). Pulling a day-dreamer back, he offers overt appreciation of students' thinking.

> Jane, you're not part of this. I think it's important that we listen to each other's solutions.

Thus everyone becomes responsible for their own learning and a part of everyone else's.

Ted expects and encourages multiple solution paths and expects students to persist in their problem-solving with just enough support from him to keep them engaged. In this respect, Ted's practice more closely resembles that of his Japanese counterparts who give students a problem and spend most of class having students explain the different ways to solve it.[7]

Ted sees his next steps to include being less teacher-centered, but he is unclear how to do this under the current constraint of short class periods.

History of the Fraction Unit

First Version: 1977

In his first year, Ted inherited a system of math instruction called IMS, which he integrated with copies of his master teacher's math packets.[8] The IMS materials consisted

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[6] See the section on Instructional Representations for more on this point.
[7] Based on results from the Third International Mathematics and Science Study (Wingert, 1996).
[8] He was not able to remember what these intials stood for. We conjectured that it might be "Independent Mathematics System," as students worked individually with laminated erasable worksheets, but this was not confirmed.

of one math topic per laminated erasable packet of worksheets. Ted regarded students' use of these sheets as "robotic," but as a first year teacher, he also considered these materials a "security blanket" to rely on if needed. After the first year he did away with them, relying, instead, on his master teacher's dittoed lessons on fractions (see Appendix J) along with games and puzzle worksheets he devised. Lessons were collected into individualized packets which consisted of a

> linear progression through the concept...page two...basically a repeat of page one with different numbers ... All computational -- add, subtract, multiply, divide fractions.

Typical pages might include activities designed to have students recognize "halves" and "fourths" using different divided shapes, use fractional parts of words in puzzles, learn fraction vocabulary, add and subtract like and unlike fractions, practice finding the least common multiple and lowest common denominator, rename mixed and improper fractions, practice multiplication and division of fractions. The lone departure from ditto completion for students' math work was a hands-on experience where students made a "fraction kit" out of construction paper and used it to solve computation problems (see Appendix K).[9]

Ted adapted his master teacher's packets by color coding them so that he would know at a glance which unit students were working on.

> That was an advance I made. My units were color coordinated, so if you had the pink unit in front of you I knew you were doing multiplication. Blue was rounding off ... Pretty sophisticated, eh?!

For ten years Ted's teaching consisted of having students engage in independent work with dittoes. He would invite students to come up and sit with five others at his large semi-circular desk, where he would correct their work, occasionally engage them in individual conversations, send them off, then invite another round of students to "settle around him like birds:"

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[9] The history of the use of this representation is described fully in the section on "Instructional Representations."

I would start over here on my left, and I would just take the unit, correct things, and say, 'Okay, you have a little problem here,' hand it back, and you would get up and leave. I would go right around the table, and the kids would come and go. Some days I could wipe the table out -- everything had been corrected -- and there would be empty chairs. I would say, "' have an empty chair here. Does a'ybody need some help? Does anybody want to talk about whatever?" If nobody did, I would say, 'Okay, Ellie, why don't you bring that unit up here? I want to talk to you.' I would get in a minute or two of teaching time. I would sit there, and I would talk to Ellie about why she needs to borrow here or something. It was usually very computational, very number oriented.

Ted's next advancement was to use different colored pens for each day of the week, so that he could track exactly when students last received feedback from him and thus, how quickly they were progressing through the materials.

I could tell that, since it was light blue when I made that X, that was last Monday and then I could say, 'You haven't corrected that since last Monday. What have you been doing?!' Meanwhile, you would have about two or three kids over there who were sailing through this thing like a hot knife through butter. They couldn't be happier: ' I can go my own pace. I don't have to wait for the slow kids.' Those kids didn't need the stuff in the first place. They already knew it. Then you have the other kid over there who was a daydreamer, who never would finish the first unit no matter what you did.

The fraction unit took a few weeks for the average student, who then took a test and moved on to the next unit.

Reflecting on the messages about math embedded in the materials and methods he was using, Ted observed that students and teachers were being encouraged to think of math as a very individual and computational process with the emphasis on answers, rather than a collaborative process with the emphasis on questions and discussion. Connections across math topics were not stressed.

T- ...You just sit there and focus, and you and your own little experience will never cross paths with anybody else's. Because all we want to know is if you get them right or wrong. I could have been a robot. I could have been a scanner. I was a scanner.

R -IMS: "I Am Scanning."

T -That is it. 'I am a scanner.' 'What do you do for teaching?' 'I scan. I scan with multiple colored pens.'

Influences on Development

At this early stage, refinements of the fraction unit were based solely on easing Ted's management responsibilities: Color coded packets and marking pens allowed him a quick visual method of tracking who was working on what and how hard.

After fourteen years of teaching fractions without major changes and vexed that the teachers of seventh grade continued to complain that his students couldn't "do" fractions, Ted "decided to make sure that these kids learned fractions so that they owned them."

Second Version: 1991

Departing from his individualized program, Ted began his new approach by implementing a six-week fraction unit as a class, beginning with building up students' understanding of "just what a fraction means in terms of its relationship to the whole." This was something he felt they had seldom developed due to the piecemeal and abstract nature of their earlier math experiences, echoing findings of Davis (1983) that most students do not understand the math that they are learning.

> What we have in this district is hands-on math in the lower grade levels, but it's not systematic. A lot of the teachers have said, "We are doing thousands of activities. We go to workshops. We've got lots of stuff on the table here, but we don't feel like we are moving in a certain direction and at a certain pace. That is being dealt with now because of the Standards, but that is the situation as it had been. There was very little transfer from this nonsystematic hands-on early elementary education to the abstract which abruptly occurs when these kids hit fourth and fifth grade. So the kids go off the deep end on me. They get to sixth grade, and they have learned symbolic manipulations, but they're disconnected from their earlier, concrete experiences, so they have no lasting effect, no roots. At sixth grade, students are mature enough that I can talk to them and say, 'You kids have been doing stuff abstractly, but with no understanding. Let's get real!'

Ted finds this admonition marks a turning point for many students in their experience of themselves as learners.

Ted began with hands-on materials from a commercially made program called "The Fraction Factory" involving a careful sequence of drawing and manipulating area models to help reinforce in students the ways different fractional sizes compare.[10]

> I spent six weeks teaching the fraction unit, moving from that very sequential piece to some more manipulations of other models of fractions besides area models like sets of beans... .[11]

Then Ted had students go though a series of worksheets to reinforce concepts and develop a basis for more abstract understanding:

> We did a lot of page by page work to establish the concept of equivalency. From then on, once those kids had played with that kit, anytime later in the year that I would say, 'What color were your 10ths? White? Yellow? What color were your fifths? Blue!' So it gave us a commonalty that we could constantly refer to as we worked into the abstract later.

Ted feels that this approach helped solidify his PCK of students' prior knowledge.

> I did the unit as painstakingly as I could without feeling like I was being condescending to the kids or making them do stuff that they knew. I tried to make sure that they weren't feeling, 'Ah, this stuff is really getting boring.' They loved it, much more than I did. It was pretty slow.

While students' responses to the unit forced Ted to see what they actually needed in order to construct a strong understanding of fraction equivalencies, he was left feeling frustrated that he was doing work with them that easily could have been accomplished in earlier grades.

> At the same time I did this I'm thinking to myself, 'I shouldn't be doing this work with sixth graders. This is ridiculous. But these kids are thirsting to do this stuff,' so I moved the program down to the fourth grade, and I said, 'Use this kit.' After two years of having those teachers do a lot of the things that I was doing with the sixth graders, I then gave my program to another teacher in fifth grade who wasn't doing anything with fractions. I've got four fourth grade teachers, but I only managed to get to two of them with any effect. My goal was have them lay the groundwork so in the future when I got my sixth graders, they had some of that hands-on that made the concepts click for them, and indeed it worked.

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[10] The history of Ted's use of these materials is detailed in the section on "Fraction Kits" under "Instructional Representations".
[11] See Table 3 (pp. 137-138) for examples of various ways Ted represented fraction concepts for students at this time and later.

Influences on Development

This was a watershed year for Ted. Departing from exclusive reliance on individualized instruction, he backed into a concrete, constructivist approach with the whole class out of frustration and a sense of challenge. At this point, he still relied on dittoes, though now for coloring and labeling as well as for computation, adding plastic manipulatives to reinforce them. Still not content, however, he passed most of his materials and ideas on to teachers in earlier grades, hoping subsequent classes would be prepared to go further with him.

Third Version: 1992 - Present

For the last four years, heavily influenced by the Math Standards, Ted's practice looks quite different:

> Factions live in the classroom from the first day of the year. We do a "fraction unit" in the spring, but by the time we get to [it] we have developed a vocabulary and a way of understanding fractions that has been there since day one. For instance, we will start doing probability exercises in the beginning of the year as simple as discussing the chances of your name coming up if you and four other kids want to stay in at noontime and do a favor for me. We'll express the probability in terms of fractions, and I won't point out that we are using fractions. You can do it percent form as well. Another example: I want a third of the class to assemble themselves there, a third here, and a third here, so when we are teaming up for different things I use fractions and they have to sort out what a third or a sixth or a half of 18 is.
>
> Fraction concepts flow into common mathematical situations. Students are required to keep records of their scores for all quizzes. They have to learn that 13 out of 15 equals 13/15, a fraction, which equals X%. Also students have to maintain a reading graph for a contract book and be done with it by the end of the month. The kids don't pace themselves well when reading these books each month. I've got kids choosing 116 page books, and kids choosing 516 page books. They don't have the experience yet to know that a 500 page book is over 25 pages a day for 20 days and if you miss a day that's 50 pages the next day. So I started having them graph. The vertical axis has the pages in the book, and the horizontal axis is the number of days in a month. If they choose the book on the fourth of the month they put the starting point there. If they decide they want to finish on the 31st or the 30th or 29th or whatever, they put the end point there at the number of pages in the book. They draw the slope that they have to maintain and then they start plotting their progress which gives them a visual way to see how they are doing. How does that deal with fractions?

> In conversations with them I will say to them, "About what fraction of the book do you think you have read? Or what fraction of the month have we gone through? So by the time we get to the unit we have done a lot of work with fractions.

From these examples, it's clear that the notion of a curricular "unit" has become somewhat passé because concepts are so thoroughly integrated throughout the year.[12] Pushed to identify his core goals for students around fractions, Ted reveals that he has two: To develop a "panoramic view" of them as an integrated part of a variety of useful ways mathematical thinking can help with everyday questions, and within this, to understand the core concept of equivalencies. These goals begin to be addressed well before the unit starts in both planned and spontaneous ways and reflect the connection-making reminiscent of the practice of high knowledge teachers Leinhardt and Smith (1985) studied.

A planned example of addressing these goals is the stock market unit Ted has taught each October since 1991, in which eighths are given meaning through the profit and loss activity of stocks students "buy." Inspired by a local newspaper contest, Ted has students work in threes to trace the activity of eight stocks they select, then compile their data in the form of several graphs (see Appendix L). Data are aggregated within math classes; the group with the healthiest overall growth wins. In the process, students become practiced at converting eighths into dollar amounts, reinforcing equivalencies between fractions and decimals -- knowledge they must use to help them think proportionally on their final test (see Appendix M). Throughout the unit Ted tries to stimulate students'

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[12] This integration is a direct reflection of the recommendations of the Math Standards, where a math topic like fractions is never isolated as a single focus for instruction. For example, Standard 5 (Number and Number Relationships) calls for such goals as helping students to "understand, represent, and use numbers in a variety of equivalent forms (integer, fraction, decimal, percent, exponential, and scientific notation) in real-world and mathematical problem situations; develop number sense for whole numbers, fractions, decimals, integers, and rational numbers;...investigate relationships among fractions, decimals, and percents" (p. 87); Standard 6 (Number Systems and Number Theory) calls for students to "understand and appreciate the need for numbers beyond whole numbers; develop and use order relations for whole numbers, fractions, decimals, integers, and rational numbers; ... [and] understand how the basic arithmetic operations are related to one another" (p. 91); and Standard 7 (Computation and Estimation) calls for students to be able to "compute with whole numbers, fractions, decimals, integers, and rational numbers; develop, analyze, and explain procedures for computation and techniques for estimation... [and] for solving proportions; [and] select and use an appropriate method for computing from among mental arithmetic, paper-and-pencil, calculator, and computer methods" (p. 94).

higher level thinking and personal motivations to learn, like the meaning-oriented teachers Brophy (1991) and Brooks and Brooks (1993) describe.

In addition to letting go of an emphasis on curricular units, Ted feels that a major difference now in his teaching of fractions and all other math topics is a shift away from individualized instruction toward whole class discussions. Students at different levels can tune in, in different ways, at the same time, because Ted's PCK no longer views learning as the lockstep process implicit in the format used by curriculum developers of worksheets.

> T - It's interesting that in the beginning, the way that I taught I wouldn't have wanted to teach the whole class... because it would have been painful for the kids who had it, to have to sit through explanations. So you had to individualize because learning was so step-by-step, so rote, and now it's not rote at all. It's easy to do the whole class together, and I've just realized in the last five or six years that the class is a community and I can teach Laura who is like this [snaps fingers] with Jessica, who's clueless and have no trouble with that."
>
> *R - Because? What are you doing differently?*
>
> T - Because of the kinds of problems you pose, the kinds of discussion you have and the questions you ask. Sometimes Jessica may come to a conclusion faster than Laura will, because Laura is still hung up on whatever her rules were that she was taught and she hasn't been able to figure her way through it, while Jessica is starting to think and starting to see connections here. Laura's spent so long performing that she hasn't done much thinking. That's part of it.
>
> The other part is you can ask a question and have a kid respond to it at all sorts of different levels, patterning questions, and things like that. For example, I will throw out a thought question and two hands will go up. I address the girl -- ' can see that you are really eager to explain and have a clear understanding, but the class is not ready to hear it yet. You are going to get called on, just not at this time.'
>
> I then direct a discussion designed to foster a broader awareness, so that six or seven students might now understand. We talk about what's relevant to the problem. We examine background information, which the two who understood from the start can confirm. By explaining to the others, the girl who first understood it, more firmly establishes her own understanding. I won't say if she is right or wrong; I leave that to the rest of the class to decide. At this point, there might be five or six who are satisfied that they worked through it or are ready to see why she is right, or disagree and say why they are right. They have a chance to experience the problem on a personal level.
>
> Some students still won't have gotten it, but they will have been called on for some relevant piece of the conversation, which allows them to begin being involved in the group by raising their hands. Our train is leaving the station. You might be in the engine, the passenger cars, or the caboose. But it's not leaving until all are on board. Not all will arrive at the same place or at the same time, but all will be further down the line. Over time, students become more

willing pasengers. It's a socializing experience. I say, 'You can't run and hide. If I see you aren't listening, I'm coming back to get you.'

This set of responses shows that Ted's PCK now permits him to encourage students' reasoning despite (and sometimes because of) lacks in their formal knowledge and to accommodate diverse learners at the same time. Like the CGI teacher "Ms. Miller" in Peterson, et. al.'s study (1991), Ted now uses everyday opportunities to make math "real" in an enjoyable and organic way. Coming to see knowledge as something one constructs by identifying core concepts and linking them, he has shifted in his understanding of students, his ideas about teaching, and his goals.

A life-long student of numbers, Ted's subject matter knowledge is packed. He is now free to use it fully, which allows him to see various ways to create a logical sequence for developing learners' conceptual understanding. His PCK of which interconnections between math topics will most help students understand fractions is evident in how he times the unit:

> I don't touch fractions formally until I do prime numbers, and magnitude and number sense and all that stuff. When we come back from Christmas vacation, I'm going to go into primes, composites, and fractions from there. Fractions is probably the piece we'll talk about the most. It's a piece that just simply needs to get done and it will improve their multiplication knowledge and will improve their ability to do some of the other things that they do in problem solving.
>
> Currently the big picture is, throughout the year my aide and I have tried to have students think in fractions and do fractions without saying we're doing fractions. So that when we finally get to the unit usually in late winter we've already got the whole rich history of dealing with the concepts. The ground will be fertile, so to speak.

Only after Christmas is there a concentration on fractions *per se,* and this is done in the context of at least three formal prior opportunities to develop a "sense" about them: a timeline of students' lives done in August, the Stock Market unit in October, and the on-going opportunity to graph the fraction of pages students have read each day of the month for their reading contracts.

Once students begin the actual fraction unit, which lasts about four weeks, they are given a chance to play with the manipulatives from the Fraction Factory[13] in order to

[13] The use of this representation is detailed in the section on "Instructional Representations."

refamiliarize themselves with the way particular fractional parts visually relate. From this exposure, Ted gives students a variety of representations to show fractional relationships,[14] such as using apple corers to divide apples into different fractional amounts and the opportunity to build on students' knowledge of coins (see Appendix N). After the unit, which usually takes place in late winter before students take standardized tests, Ted will offer advanced fraction problems as a group problem-solving challenge (see Appendix O).

While Ted's PCK allows him to help students link earlier learning about fractions to the unit, spontaneity characterizes a lot of students' experience, both during the unit and at other times. Twice this past year, Ted brought in problems which had cropped up at home. He asked his students to solve them without relying on the algorithms they'd learned, i.e., to think like a younger child might and in the process honored their own mental representations of content. Many students found this unexpectedly empowering:

> My oldest son had to build a birdhouse for cub scouts. He went down cellar and found some scrap wood. He needed to know if the piece of wood he had would produce two pieces, one 16-1/2 inches long and the other 9-7/8ths. So he asked me, 'Dad, how much wood do I need?' In my typical fashion I said, 'Why don't you see if you can figure it out?' He needed to add 16-1/2 inches and 9-7/8ths, and he did it in his head. He was in first grade at the time.
>
> This is what he did: He added 16 plus 9, forgetting the two fractions. Then he picked up the half from the 16-1/2 and he added that in, so now he is up to 25-1/2. He did this thinking out loud, and I wrote it down right after he did it so I could use it as an example for my classroom of how a young boy, who doesn't know what my students know, reasoned it through [see Appendix P]. I tell my students this is the part of themselves they can't let go of. So he gets 25-1/2. Now he has the 7/8ths to deal with. He knows that 7/8ths is almost a whole, so he rounds it off and goes to 26- 1/2. Then he realizes that 7/8ths is one eighth less than a whole, so he takes the 1/8 off. So the 26-1/2 minus 1/8 is 26-4/8 minus 1/8 which is 26-3/8. Because of previous discussions we've had, he knew that one half is 4/8ths. Whenever we get pizzas, we just kind of dealt with that, so he wasn't unfamiliar with equivalencies.
>
> I used that example and I had reasonable success with it. I asked my students, "How do you think he solved this problem?" They said things like, "He probably found the lowest common denominator." I said, "No, no. He simply reasoned it out. See if you can figure out how." I tried to pull that from them, and some of them were able to do it. A lot of them heard the message: 'Gee, it's not really that hard to do if you just do it in a way that makes sense to you, as opposed to doing it the way you've been taught.'
>
> Another example this year was when I built my youngest son's

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[14] See Table 3 on p. 161.

> bed. We had a 16-5/8's span. We needed to put two 5-1/2 inch pieces in the middle of it, and I wanted to get the three spacings equal. I gave that problem to my oldest son and watched him solve that. He did the same kind of a construct, and giving [the problem] to my sixth graders later, they tried to solve it symbolically and got themselves completely screwed up. Then I gave them the story itself, and said, "We're measuring wood. Draw yourself pictures. Work in groups and see what you can come up with." By approaching this computational piece through a problem-solving mode that I work hard all year to develop -- stay loose, draw pictures, talk about it, get comfortable with it, ask questions, answer the questions -- they could solve it.
>
> And again that is establishing the confidence in them that fractions aren't mysterious, really arbitrary and not understandable. It breaks down that sense that they have gotten from two years of math education that they have to learn how to do this because it is on page 267 and they've been assigned it for homework.'

The idea of undoing the disservice nonmeaningful approaches to math have done to students pervades Ted's *modus operandi*, cropping up even at home in his efforts to keep his oldest son's math reasoning alive in the face of what he encounters in school:

> As my oldest has gone through different classes, I have really been able to maintain with him from the beginning an inherent sense of number which hasn't been screwed up by the school yet. There have been a couple of times where it has been close, and I have been able to nip it in the bud... .

One sees how the nature of the task for educators in later grades who are committed to implementing the spirit of the new standards becomes this kind of careful rekindling of students' native reasoning abilities by shifting their expectations of what it means to "do math" in school.

In the last year, Ted has come to appreciate proportional thinking as a core idea for helping students develop or rekindle their informal problem solving capabilities with fractions and other math topics. For example, during the stock market unit, students need to be able to assess the relative return on investments as seen in problems like, "Which is better -- making $0.25 on a $5 stock, or $3 on a $50 stock?"

> This year I've realized that proportional thinking is more critical than I ever realized. I am spending time on this in the stock market unit. We talk about whether to invest $1000 in this company vs. $2000 in that company and what might occur. At the end of the contest, one of the problem-solving questions I asked was: "In which company would you have preferred to invest all of your $10,000, if you could have known what you do now?" We discuss that the company that had the greatest number of dollars profit was not where you would have put all your money, because it turns out this company gained $500 on a $2500

investment -- a 20% return. This other gained $250, a 25% return. That the company with the largest profit was not the best performer is a difficult concept for the kids to grasp. They were okay with it because we had discussed proportionality. They' re getting it and I'm hoping this is going to help when we get to fractions.

Influences on Development

Several major developments in Ted's PCK of teaching fractions have occurred in the last four years. The first is recognizing the need to integrate fractions into many situations throughout the year, not just during the fraction unit itself. Seizing opportunities from his own life, from the news, or within the framework of the class, Ted allows students to manipulate fractions and represent them in multiple ways, so that they become not just meaningful, but genuinely useful "on a personal basis." Second, Ted has augmented his PCK of instructional strategies to include whole-class discussion and small-group problem-solving as a far more effective way to accommodate heterogeneous learners. Third, he has realized that a critical part of making fractions meaningful is helping students to understand the core concept of equivalencies. In reviewing some of the dittos he had used in years past, he stopped at one page (Appendix Q) and talked about how students always stumbled over it. Now he understands why.

> I have come to understand that it doesn't matter if students know how to add, subtract, multiply and divide fractions if they haven't truly internalized the concept of equivalencies, and the concept of improper/ proper which is not a tough one. My number line on the wall above the blackboard starts there at negative 20 and goes to 100. In the middle of the year if I asked, 'Would you please go to the number line, take this pointer and show me where 2 and 4/5ths is?' 75% of my class would have no clue. Last year we were talking about the number .75, or 3/4ths. The first three or four kids who went up to that number line could not place 3/4ths. They wanted to go to 75 out of 100. Now that shows something, but I said, 'No no, we're not talking about 3/4ths of the number line. We're talking about 3/4ths as a number, albeit a fractional amount. That's a number I want you to show me, just like if I asked you to show me "14." ' It was a stumbling block for them.

It was somewhat agonizing for Ted to slow himself down, in effect shifting his expectations of students' needs and his task, in order to help them truly develop a grasp of equivalencies. Students' needs and teachers' calendar limitations don't always coincide; Ted's PCK has evolved to allow him to begin to address both:

> Faced with either slowing down and linking the concept, or speeding up to cover all the material, my imperfect solution is to engage in mathematical activities and discussions which can hopefully do both. In each exercise I try to offer a buffet of concepts for the class to "taste."

Future Versions

Ted would like to design his teaching to include less time center-stage:

> Right now I feel good about what I do, but I think I spend too much time talking, too much time leading discussions. They are good discussions: educational, relevant and helpful; but I wish I wasn't the center of attention so much. I have been aware of that for three or four years now and have been trying to back away from that, but it comes at great expense. It just creates all sorts of havoc in my efforts to cover different areas and content during each exploration. The one thing I do know is I wish I had them in a math lab where I could keep them for the whole day and we could play around.

Reflections on the History of the Fraction Unit

It seems that what constitute the core ideas within teaching fractions (the notion of proper and improper and, especially, the idea of equivalence) only became clearly visible to Ted after he adopted the constructivist approach of the last four years. It also seems that the foundation needed to develop students' native thinking requires careful coordination and cooperation across grades over a sustained period of time.

The history of the fraction unit suggests that over the years Ted developed his PCK of teaching fractions by learning

1. To integrate fractions with other math topics as espoused by the NCTM Math Standards and with (often inherently multidisciplinary) opportunities posed by everyday life.

2. To take more time to help students construct an understanding of fractions and analyze where they are stuck so that he could ask strategic questions, but leave them to work out the problem themselves.

3. To see the concept of "equivalence" as a core idea.

4. To foster an atmosphere for problem-solving by balancing individual with community thinking, by devising ways to engage students at all performance levels in community problem- solving.

5. To intentionally link students' previous knowledge with new learning.

6. To counter rote approaches to math by encouraging students to use their intuitive mathematical abilities supported by basic thinking strategies like doubling, adding, breaking hard numbers into easier parts, thinking proportionally, and using benchmarks to gauge the accuracy of their problem solving with fractions.

7 To take advantage of the power of color and manipulatives to create memorable representations of core ideas like what it means when two quantities are equivalent.

Based on the fraction unit, if one were to construct a continuum of PCK relative to curricular knowledge and instructional strategies, it might look something like this:

Stage One: Teacher uses others' materials which involve drilling students individually in how to manipulate computation problems using worksheets.

Stage Two: Teacher still uses others' materials, but supplements them with personally made and commercially made creative puzzles and games to reinforce computational accuracy in a more interesting way.

Stage Three: Teacher still uses others' materials, and adds manipulatives, because they break up the monotony and students seem to like them. Some whole group discussion begins. Creating a social context for essentially unmeaningful problems creates extrinsic meaningfulness because content becomes a medium for social interaction, which most people find interesting.

Stage Four: Teacher begins to shift goals toward problem-solving and begins to integrate math topics using real examples from the classroom, students and teacher's lives, and current events. Classes are more discussion and small-group based. Finding problems students can identify with increases intrinsic meaningfulness.

Stage Five: Students generating their own problems for each other to solve might be highly compelling. Potential exists to develop students' knowledge of metacognitive structuring,that is, thinking like a teacher about such things as problem types and the prior knowledge needed to solve each, particularly if teachers make this explicit for students beforehand.

The Evolution of Ted's PCK of Instructional Representations

Because of the intrinsically representational nature of mathematics instruction, Ted employed a great many representations, not all of which will be described. Table 3 (next page) shows some of the representations Ted has used in the service of teaching fractions over the years.

Table 3: Selected Representations Associated With The Fraction Unit

A = Analogy (auditory/visual); D = Demonstration (hands on, visual, auditory);
E = Example (auditory, writing); I = Illustration (visual); M = Model (hands on, visual)

CORE CONCEPT	REPRESENTATION	WHEN USED	SOURCE
Kids own the problem: Are capable	(M) Used to make own fraction kits	1977-1988	Master teacher
	(E) Continental math league contests: Now done in groups as well as individually	1989	Ted's perception that kids found it irrelevant; social interaction.
	(D) Give kids tools, have them reason themselves	1992	Standards; own intuition
Operations involving fractions	IMS - Independent laminated sheets from a cart. Added color coordination to clarify what day a page was corrected.	1977	Colleague in same school
	Ditto packets -- pulled together	1978-1988	Math workbook (Cleveland); and some tchr.-made
Number Sense	(D) (E) Prime Number Unit activities (6 wk, individualized)	1980	Own unit based on reqs. for grad. course
Proportional Thinking	Eg., (I) Timelines (personal, Earth) Bar graphs of stock performances	1994	Tinkertoy connections
	(I, E) Benchmarks for reference points	1995	Frameworks for how math works
Probability	(D) e.g., Having some students line up and conjecturing about what the probabliity is of being picked.	1991	Own idea
Percents & Everyday fractions	(I?) Common math situations like tracking quiz scores; charting reading progress	1992	Own idea: Growing awareness of how much oppty there is to bring math into daily lives.
	(D?) Teaming: 1/3 class stand here etc.	1992	Own idea; math standards inspired
	(I) Balance in art (what in each quadrant pulls the eye?)	1993	Poses problems all day long; inspired by the Math Standards
	(D) Rulers	1994	Saw kids didn't know how to use

Table 3, Continued

CORE CONCEPT	REPRESENTATIONS	WHEN USED	SOURCE
Equivalencies	(M) Geoboards (open question: How rep. 2/3? Working in pairs.)	1988	Made first ones; later obtained from catalogue.
	(I) Fraction Factory: Black whole (trace and label); blues for 1/5; browns for 1/3; yellows for 1/8s, etc. (w/in a 6 wk. unit)	1991 1992 - on	Creative Publications. Used one year.
	(M) Plastic Pieces from F.F. above	1993 - on	Used differently each year
	(M) Scrap paper only (area reps)	1994	Used w/ fraction factory.
	((M) Strip of paper divided into fractions and decimals in response to figuring out how to convert stock price fractions into dollars	1991	Technique gotten from workshop "a long time ago," resurrected bec. relevant to stock mkt. unit
	(I) Pie Graph for Events in their lives (first concept of scale)	1993	Own idea
	(E) Age of the Earth in calendar format using LASER POINTER -- (1'=1 yr.; 11' long life; then 1" = 1 yr.)	1993	Saw kids needed to understand concepts of scale and equivalencies
	(D) Toilet paper roll for siting the height of the flag pole	1993	Ames catalogue
	(D) Pizza Game	199?	Bought from catalogue
	(M) Coins	1994-	Ted's idea of way to make equiv. more concrete
Common Sense Problem-Solving	(I) Building a birdhouse	1994	Opportunity from everyday life observing his own son.
	(I) Building a bed	1994	Same
Adding /Sub. Fractions and Multiplying fractions and mixed numbers by whole numbers	(M) Fraction kit	1977-on	Master teacher
	(D) Game involving estimating and fraction calculators (2.12)	1993-on	"Shower" idea of Ted's
	Computer program: Fraction Practice, Fraction Action	1993	Used one year; from catalogue
	Fast Food Units: Decimal Dog, Fraction Burger	1994-	Dale Seymore, Creative Publications; not used much; brought home for own kids (attractive, but not that easy to use).

Two representations having longer histories with distinct stages of use are discussed next.

Fraction Kits

Fraction kits are a way to anchor students' images of various fractional parts so that they have a shared basis from which to work with target concepts. Initially, Ted had students make their own kits using his master teacher's materials, but found that students might not adhere to a common standard for determining fraction sizes (see Appendix K). A student's thirds might end up smaller than her quarters, thus losing the gift of the representation to show equivalencies visually. Thus the representation was inconsistently effective and used only as a means to getting a right answer.

Because students worked independently in the first years of Ted's career, their kit-building was staggered which he found difficult to manage. After about three years of frustration, Ted decided to give his class the best student-made kits from earlier years and made the rest himself. Kits were used to solve computation problems involving adding, subtracting, and renaming fractions. At this point, Ted controlled the consistency of the representation, but students were less invested in them because they hadn't made them themselves.

In Ted's fourteenth year, he decided to buy a commercially made product called *The Fraction Factory* and had the class use these fractions kits as a whole. First students traced, colored and labeled dittoed area models divided into different fractional parts, then used brightly colored plastic manipulatives to help them touch and build equivalent fractions as they solved problems. In this way, the class developed a color-coded common language for referring to particular fraction sizes.

> In the beginning I did the whole program. When I bought *The Fraction Factory*, they had mimeo sheets that you would run off, and the kids would work their way through. We were going to go back to square one and what I anticipated was that these kids, these cool sixth graders were going to go, "Oh God, we're playing with these toys. This is stupid!" But they loved it. The Fraction Factory program is very sequential. A lot of tracing and labeling: page one - this is a whole region. Take your black whole, trace it and label it. Page two, take these whole region representations and trace your blues (1/8ths) and your browns (1/4s) and your yellows (1/16s) , etc. Label each piece: 1/16, 1/16, 1/16, 1/16, etc.

The next year Ted cut back a bit on his very sequential approach because he had given the mimeo materials to interested teachers of fourth and fifth graders. But he retained the manipulatives -- plastic color-coded pieces students could assemble into area models with each fraction size, to refresh their memories of fractional relationships.

> What I want them to do is become more familiar with each piece of the kit, so that they know the shape, the color, and what fractions is represented. Then we start discussing them. Later when I say, 'Okay, hold it. We're talking 1/16ths here. Picture 1/16ths -- What color are they? Yea, those are those long skinny yellow ones. Right. Remember the blue ones? Well those are 1/8ths.' They can refer to their memory of the concrete, yet it's also somewhat symbolic, on the way to the abstract.

In this way, Ted's approach is similar to the developmental sequence found by researchers studying the problem-solving of first-graders (Fennema, Franke, Carpenter & Carey, 1993) which moved from direct modeling, to counting strategies involving some modeling, to manipulating relationships between number facts, to using memorized facts.

This past year, Ted modified the use of this set of representations even further, as most students, thanks to his initiative, had been exposed to the kit in earlier grades.

> These are used differently each time. Don't know what I'll do this time. Try to make it fun for me! I don't assume when these kids come in that they know everything. First of all, they are coming to me from four different fifth grade classrooms with five different fifth grade math teachers. So I don't assume that they had these fraction factory experiences and I don't assume that those who had them remember them enough. Even now, in the fourth year of my crusade to make sure my kids know fractions, they get these out and play with them.

Recognizing that students were missing a valuable part of instruction by not making the kits themselves, Ted has come back to wondering if he should have students construct their own and if the resulting investment of time could be worth the trade-off:

Before I return to student-created kits, I'm going to have to think about how I 'm going to overcome potential inconsistencies.

His PCK of this representation involves recognizing the value of associating colors with different fractional parts, then discussing and manipulating these parts as a way to make their identities and relationships to each other more memorable; and urging students to use their memories of these colors and relationships as a platform from which to solve subsequent problems well beyond the end of the unit.[15]

Stock Market Equivalencies Strip

Another representation Ted has used in the service of teaching fractions is a strip of paper for converting between the fractional movements in stock prices into dollar amounts for the stock market unit.[16] A technique he picked up at a workshop "a long time ago" involving labeling a three foot piece of adding machine tape at appropriate intervals with various fractions and their decimal equivalents, Ted only used it once or twice before the 1990s; but when he began the stock market unit in 1991, it assumed new significance as a powerful tool for a real-world use:

> The stock market is rich in fractions because of the prices. These kids don't have a clue what the decimal equivalent of 1/8th is. They have no idea how to figure it out, but they certainly know what a quarter [coin] is, and they know that a fourth is a quarter and is written as .25. So I work a lot with eighths off that. We have this simple exercise where they take a strip of paper and fold it, open it, label it. It's basically reviewing something they already know, but it's another actual manipulative representation of it. They label the "zero" [at the left end]; they label the ".5'"at the top of the fold in the center, and they label "one" at the [right] end of the number line. Point 5 is 1/2, so they label that 1/2. They fold [the strip] in half and in half again, unfold it and now they do the decimal again for the folds that haven't yet been labeled for decimals, which would be the .25 and the .75 and then the fractions --1/4 and 3/4. For the fractions I have them do: 1/4, 2/4,

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15 This last point brings to mind the goal of teachers committed to teaching for conceptual understanding -- to foster independent use of content and skills beyond the immediate setting in which they were learned (Prawat, 1993; Anderson & Roth, 1989).

16 This is similar to the number strip Tierney (1988) describes, in discussing how two students' inner models of math influenced their use of the strip.

> 3/4, 4/4. So now [at] the center line, they have .5, the 1/2 and the 2/4 fractions, as well. Then we fold again and they label their eighths.

In addition to building on students' prior knowledge of monetary decimals, Ted's PCK of students' prior knowledge strengthened the power of the representation in several ways. First, he couched its use within a context of other experiences students already had with linear representations in his classroom.

> Students had done number lines with me in a language unit in September, where they lay out events of their life on a time line, and they have also done it in their "Age of the Earth" calendar dealing with the Earth being 4 and 1/2 billion years and figuring that into a calendar- year format, so you can see which month of the year the dinosaurs were in, and which month of the year the tortoise showed up and so on. So they have [encountered] concepts like this before. Now we do it in a pretty abstract form. Meaningless in that sense, but it is based on the same process that they've gone through twice in a way that did have meaning to them, so the leap to the abstract is smaller and hopefully more grounded for them.

Second, recognizing the importance of timing, Ted's PCK of instructional strategies inclined him to wait until students discover that they need to know how to convert eighths into a monetary equivalent before he introduced the strip.

> They open up the paper and it says AT&T: 74 and 7/8ths. They have to convert that to money, and they don't have any idea how many cents 7/8ths is. I don't have them make this conversion strip until they've asked, 'How do you do this?' After the groups have gotten frustrated by that is a good point to introduce the concept.

Third, his PCK of instructional strategies prompted him to layer its use with other representations of fractions. For example, in one classroom observation, he asked students to locate 87 1/2 cents on the number line above the blackboard, assuming the line numbered 1-100 represented one whole dollar. He pulled coins out of his pocket to help them understand the concept.

A tough spot for students, Ted has found, is when they get to the point of having to halve 25 cents, and then convert 12 and 1/2 cents into its decimal equivalent.

> When they do their decimals they get the .5 which is already labeled and the .25 which is already labeled, but they don't have the eighths labeled. When they get to the eighth, they're stumped. They can turn a 1/4th into eighths, in terms of a fraction. Many of them know that it is half of a 1/4th, especially if you help them with a question or words like "pizza." But to take .25 and cut it in half, there is absolutely no way that they understand that 125 thousandths is

half of 25 hundredths.

> I have them do this in groups and usually the groups say, 'Well if that's .25, then half of it has got to be 12 1/2.' It doesn't come quickly, but they can work that out. What they don't understand is why .125 is 12 1/2 cents. Decimal place values beyond tenths are difficult for them.

We see Ted's PCK in action both as he understands patterns in students' development and as he identifies the point of confusion and uses students' prior knowledge to help them over it (pizza in the above example, money in the following):

> So then what I do is use that 12 and 1/2 and I say, 'Well here it is. We all know that if I take a dollar, what do I have if I cut it in half? Fifty cent piece. Well if I cut this 50 cent piece, what do I have? I have a quarter.' So we look at its label, ".25." And then I'll say, 'What if I want half of this?' And they go, 'Huuuh?' (They can't do half of a quarter if I say, 'point 25.' But if I say these words, they can do it: 'How much is half of 25 cents?' For the most part, they can show that it's 12 and 1/2 cents using this strip. So there's a connection that can be made, and then to go from there to 'How would you write 12 and 1/2 cents?' Well of course, they don't want to mix decimals with fractions, but they will usually write "Point 12 and 1/2." To get them to go from that, which is not that hard for them, to ".125" is something that they are just not ready to do. Because then you are dealing with that next place value -- the thousandths -- which has no meaning to them whatsoever, and it shouldn't. Where in their life is it found?

One sees how clear and compassionate Ted is in understanding how inappropriate it is to expect students to understand something they have no experience of; he has no current basis for building a bridge to thousandths. However, as an avid sports fan, for years he has wanted to create a unit on baseball which offers representations of thousanths in the form of batting averages, to address this particular stumbling block. It hasn't happened because he has had neither the time to do it during the year, nor the financial incentive to do it during the summer. So students continue to struggle with the unfamiliarity and logic of the decimal equivalent for 12 and 1/2 cents.

While Ted doesn't formally assess how much students are able to convert on their own as they make the stock market strip, in the process of using it, he feels that almost all students build an understanding of monetary equivalents for eighths. If he were intending to teach the concept of equivalencies formally, he would go about it in a different way:

> The conversion strip is being developed in its current context as a tool, so I don't look at it in the same fashion as I would if I wanted

> students to generate the concept of decimal/fraction equivalencies specifially. If I did, I would spend more time on it. I would give the instructions differently. I would work it out so that students had to problem-solve more on their own and process through it. I would watch them, process with them and interact with them on how they are doing it. Now I present it to them, discuss it and it's done. Then it gets used. By virtue of being used, it's a tool, and students become familiar with it. If there are breakthroughs, I'm not aware of them, because I'm not assessing them. So there may be some kid out there who says, 'Hey, I got this!' and she'll never forget it, but it's not the primary focus/purpose of the exercise at the time we do it.

Even though his current use of this strip distances Ted from insights students may be having about equivalences between number systems, it creates an opportunity for connection-making while students are using it and fertilizes the soil for a future understanding of thousandths.

> Believe me, when the stock market unit is over, these kids know how much 5/8ths is. These kids know that 5/8ths of a dollar is 62 and 1/2 cents. Now do they know that 5/8ths is 625 thousandths? Probably not. But they know that 5/8ths of a dollar is 62 and 1/2 cents. When they are ready to understand the 625 thousandths, they'll have that connection to build on. Therefore it will tinkertoy into prior knowledge.

Because the representation is so straightforward, Ted has not felt the need to tailor it to special needs students. Its concrete hands-on simplicity is part of its beauty. It becomes a handy tool which students keep in their math folders for use throughout the year.

> This strip has their name on it. They have created it -- it is part of their background. When we start getting into equivalencies during the fraction unit later on, I can draw on it. We can look at the patterning and write on the board some of the equivalencies that this paper tells them and that they already know.

Reflections on the Nature and Use of Ted's PCK of Instructional Representations

In general, the last four years have seen a greater emphasis on representing the core idea of equivalence visually and tactilely. Many of Ted's representations are different from year to year, based on what's happening in his and his students' lives. Timing is important; he stresses a flow-like quality to what will be introduced next where serendipity is possible because of a deep clarity about his objectives for students and his PCK of sequencing for developing students' conceptual understanding. The representations discussed above are constantly being adapted to changing circumstances -- new problems, new areas of student need, different student interests. Yet, Ted sometimes sees this organic quality, instead of being responsive, as a liability, as flying by the seat of his pants because no one has given him "50,000 and a year off" to codify what he's doing. He sees it as engendered by the crowdedness of the day -- he can't really do anything else.

Summary of Influences on Ted's PCK Development

<u>From Himself</u>

His Upbringing

Ted's father stressed rigor, which pervades Ted's standards for student work. In both classroom observations, I found a great emphasis on precision in language and thought. Thus, he chooses representations that de-emphasize what he knows and empowers students to think for themselves.

His Experiences as a Student

Early experiences with his junior high English teacher seem to have impressed on Ted the value of being "real," by which he seems to mean being honest with students about their performance, as well as by offering real problems through which to develop their math reasoning. Ted's disorientation in his college calculus class seems to have been a catalyst for developing his compassion for students who have no frames of reference on which to build an understanding; and for developing the PCK for creating such frames to help students become more independent, confident, and accurate problem-solvers, after the Math Standards validated his instincts that these were important goals. Both representations discussed above are concrete, hands-on opportunities for students to develop frameworks for understanding.

His Subject Matter Knowledge

Ted has more math subject matter knowledge than most elementary teachers through his on-going fascination with the quantitative aspects of life. His evident pleasure in numbers and his creativity in finding opportunities to conjecture about them from the real world have prompted other teachers in the building to look to him for insights into math instruction. Thus, his representations are used with the flexibility high subject matter knowledge provides, allowing him to help students wrestle with the complexities of real problems not typically found in the pre-made materials on which less confident teachers tend to rely.

His Teacher Education

The skill-based emphasis of Ted's practicum inhibited an understanding of effective ways to make his own intuitive relationship to math an outcome for students. Subsequent graduate courses gave him an opportunity to broaden his approach to teaching math, but didn't seem to take hold in any systematic way until the Math Standards validated a more integrated and discursive approach to math instruction. Thus, his representations are used in the service of developing traditional disciplinary knowledge around fraction equivalencies, but his ends now also include wanting students to think deeply about the dimensions of a problem and empowering them to solve problems in a community setting with the tools he's helped them develop.

His Philosophy of Education

Ted's PCK seems influenced by both the Classical and Pragmatic traditions -- Classical, because of the emphasis on Socratic dialogue in his classroom; the fact that he is often at the center of attention, controlling classroom dynamics directly; and that, despite his concern for students' personal meaning-making, he sees times when using approaches like handing out an algorithm as the most effective way to get from Point A to Point B.

> The Saxon Press[17] just says, "Don't spent your time telling them why, just do it. Teach them how to do it rotely, and when they are ready to understand how the rote works, they'll understand it." Well there's some relevance to that.

The rigor of Classicism echoes in Ted's concern that students learn a particular body of knowledge which should be pre-defined; at the same time, the Pragmatist in him is quite concerned that the knowledge students develop should be useful.

> There is no overt pressure from others that, 'You haven't done geometry yet.' There is my own internal pressure that, number one, the system should have some idea what it wants us to do, and if we are not doing it we should be held accountable. Number two, I focus a lot on mathematical constructs, problem solving, numbers and number theory so students can see how arithmetic fits in. Geometry doesn't have as much meaning to me. I think that if I had a little more training and spent more time learning from the far end where the geometry is taking these kids and what they need, I would spend the time to do it.

Ted's Pragmatism comes through in his emphasis on constructivism via problem-solving in groups and his choice of content. While he used to select content based on whatever pre-made materials he could find, now he begins with "something relevant" -- integrating math with social studies, current events, and students' lives whenever possible. If content isn't connected to students' realities in some way, Ted doesn't see it as worth doing.

> In the beginning of the year we get into the unit on large numbers. I also start off the year with discussion of number sense, just some common sense applications of what you already bring to a discussion of math to the numbers that you're running into in social studies. Then from that I'll throw in a quick unit on reading and writing large numbers and then I don't know. It can go anywhere. I start into problem solving frequently because then you can go anywhere after that. I try to mesh everything together and teach that panoramic view of math. When we get to the

[17] which espouses a very sequential skill-based approach to math

point where we actually spend two or three weeks discussing proportions or something like that, it's not that this is the only proportion section of our program and then we'll never talk about it again. I mean if we don't talk about it all the time, it's not worth knowing from their perspective, nor mine really.

His Inner Representations of Core Ideas

Ted thinks of knowledge as connected, as tinkertoy-like: his need to help students build conceptual nodes linked to others is more evident than in any other case presented in this study. Is this partly a reflection of the nature of the content? Stodolsky and Grossman (1995) would suggest it is, by virtue of math being intrinsically more sequential than other "conceptual contexts." Is it partly a reflection of Ted's way of thinking? It seems likely. His emphasis on building multiple connections between math topics and revisiting topics from different vantage points is marked. Thus representations like the fraction kits and the conversion strip are referred to repeatedly for the rest of the year. Both are primarily visual aids, the former, more concrete, colorful, and hands-on; the latter more symbolic. Both deal with the core idea of equivalency -- how a fraction relates in size to another fraction or decimal -- Larger? Smaller? Or Equivalent?

His Epistemological Commitment

From Belenky et. al's standpoint (1986; see Appendix A), Ted has shifted his commitment from one emphasizing *Received Knowing* with himself as the sole authority for determining right and wrong as the adult representative of disciplinary authority to one in which he empowers students with the help of representations to determine among themselves what seems to be correct, and then to be able to defend their answers. In this respect, he now seems to stress *Separate Procedural Knowing* in Belenky et. sl.'s scheme, according to existing syntactic conventions within the discipline for determining the validity of solutions. He also seems to value *Constructed Knowing*, however, as when students invent their own paths to solution in a process which involves personal creativity, as well as a willingness to understand and (often) incorporate the thinking of others.

Ted's view of school mathematics has shifted from unintegrated math facts to interrelated propositions, paralleling a shift away from Perry's *dualism* (1981; see Appendix A) which in students Ryan[18] studied was associated with information processing oriented toward the "knowledge" level in Bloom's taxonomy, towards *relativism* which Ryan found in students oriented toward Bloom's higher levels of "comprehension" and "application" -- outcomes to which Ted's PCK is clearly oriented.

From the Context

School

Being in a self-contained classroom where he was responsible for teaching several different subjects seems to have had contradictory effects on Ted's PCK development. Initially, Ted saw little relationship between math and other subjects, math and the students, math and the world. Math class consisted of rigid, linear, individualized, abstract worksheets which he feels uncomfortable recalling today. Influenced by available materials, Ted found social studies content to be intrinsically more meaningful than the materials and approaches he used in math. In this respect, one might argue that his PCK development in math was slowed down by the apparent contrast in meaningfulness between available curriculum materials in math and social studies.

Later responsibilities (family and a second job) forced Ted to economize in his planning. This resulted in trying to accomplish more than one thing at a time, which showed up in the greater use of interdisciplinary approaches (e.g., art and geometry; reading and percents), which the Math Standards supported as a powerful approach to

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[18] 1984a, 1984b as cited in Hofer & Pintrich, 1997.

developing true numeracy. He links his representations to real world problems which, like the real world, usually have interdisciplinary dimensions, and takes advantage of every content situation (whether "math" or not) to locate mathematical dimensions.

Students

Like other adherents to Classical assumptions about the purpose of schooling, Ted sees students, in general, as waning in their ability to think critically; yet it has only been recently that he has asked them to do so in math. At the same time that his high standards sometimes frustrate him, he also has the PCK to recognize a developmental pattern in students' mathematical thinking. In December, he perceives their mathematical knowledge as still unconnected.

> I lose perspective each year. You work with these kids and right around March, April, and May, it starts to happen for them. It takes forever -- this panoramic view of math, number sense and all that. Right now I'm in the frustrating part of the year, just at that point where they don't seem to be integrating it, getting it, using it, accessing it, so it's discouraging. But the beauty of it is that you know that once springtime rolls around, this constant exposure to that way of thinking allows them to start to do it: they start to see the light. They start to get it. It's very confirming to me as their teacher.

Having this overview of students' development helps Ted to sustain his high standards throughout the year by selecting representations which push for this panoramic view of math -- a view he feels many eventually gain.

Collegial Collaboration

Ted yearns for better cross-grade communication. He has functioned as the unofficial math chair in his building and tried to address this issue out of an interest in the common good, though he worries he could be perceived as pushy. He does this without remuneration for the extra time and effort:

> We don't have a vehicle by which I can say to the fifth grade teachers and fourth grade teachers, 'These kids don't have any true sense of number patterns, for example. What are you guys doing?' I have actually started round-robin discussions in the building, which our principal has never picked up on. I used to have monthly or bimonthly discussions on math topics. We used to discuss how the people in the building taught them. 'How do you teach basic facts? How do you teach fractions? Where is the beginning point? What do we want to do here?' Those were wonderful and should still be happening on a regular basis. One hour a month on a focus topic would be wonderful. I could organize it, but I don't want to be pushy, and it just kind of died out.

A nest of issues crops up here: competing priorities, lack of administrative initiative, the great need many elementary teachers have for help with mathematics instruction, the leadership some teachers are capable of providing, lack of compensation for teacher initiative, the potential for improving the level of student preparation by coordinating more closely across grade levels.

What is the impact on Ted's PCK development? Perhaps the need to use representations to develop skills which could have been developed in earlier grades, if more communication had taken place.

> Every year, you start over again. I'm just desperate to find some way to get the teachers below me to teach these kids how to think mathematically, because they don't.

Potentially, he has been cut off from learning things he knows he would like to know such as how others manage to stay effective while being less center-stage or how one might make 1000ths more meaningful; as well as from things he doesn't know that he doesn't know.

Synthesis

Despite the child-centered philosophy of Ted's teacher preparation program, it is striking how much the fragmented lower-level skill-oriented materials of his master teacher slowed Ted's PCK development. Lack of administrative support for fostering collegial ties has also been an impediment, if not for Ted's PCK development then for that of his less mathematically confident colleagues. Lack of remuneration for curriculum development has forced Ted to use summer for other things, a pursuit which would have allowed him to advance his PCK by putting some of his creative ideas for developing units on baseball and bicycles into concrete form.

On the positive side, parenting appears to have been a huge source of insight for developing Ted's PCK, providing an on-going climate-controlled learning laboratory for exploring the ways children think and what they need in order to think better. Ted has used this opportunity to unfetter his creative impulses and nurture in his children some of his own love of numbers. Early access to the Math Standards through the initiative of the high school math chair also had an enormous impact on the development of Ted's PCK. Notable is not just what the standards said, which Ted found liberating, but how his chair involved Ted and other teachers in critiquing the standards before he was encouraged to adopt them.

Connecting topics within math and between math and the world at large, as the Standards espouse, are critical in Ted's mind for understanding and solving problems confidently because he sees knowledge and learning as tinker-toyish: sequential, but not necessarily linear. He has become increasingly spontaneous, hence less linear, but always carefully sequential, in attempting to help students link earlier concepts with current applications and with new concepts. In this respect, his conceptions of knowledge have evolved from "absolute" and "isolated" to "interrelated" and "evolving" as characterized in Schommer's scheme (see Appendix A); but it was only when an external authority, the NCTM Standards validated this shift, that Ted was able to act on it. To this extent he seems to resemble the attitudes of teachers Loevinger found scoring at the *Conformist* stage; yet his values for autonomous thinking comes across as more reflective of the *Individualistic Transition* or *Autonomous* stages.

Ted thinks of his curriculum as an ever-changing river with islands comprised of topics which may not recur the same way from year to year, as he's always negotiating a new river with a new group of swimmers. Whether in the shower, the car, reading the newspaper, or interacting with his family, he is often planning for instruction. The constant backdrop of Ted's thinking about his teaching reminds me of the incubation all creative projects go through and the lack of time most teachers have for this important process. Ironically, it can also be lack of time which prompts invention, forcing teachers like Ted to accomplish more than one thing at a time, developing, consequently, more interesting and pedagogically powerful approaches to teaching.

Ted's flexibility is reminiscent of the curriculum scripts that have been discovered in other experienced teachers of math (Leinhardt, Putnam, Stein & Baxter, 1991).

> A teacher who has rich and flexible knowledge of a particular domain may have a curriculum script whose overall goals are clear but whose subgoals and actions are much more loosely ordered. Goals may be organized as a network, rather than as a more linear sequence. Such a script permits following up on various inputs and ideas by students. Because of the uncertainty in where the lesson will go however this kind of script requires considerably more accessible content knowledge on the part of the teacher. (p.95)

Yet the spontaneity of this approach also feels to Ted like it is lacking some intention, as if there should be an ideal sequence.

> The stock market unit, for example takes up the majority of a 6-week period. We may discover in the stock market that kids don't understand anything about adding and subtracting decimals so we'll work with the decimals. But I don't think it should be that organic. I think I should have it figured out.

Perhaps it is only when PCK is sufficiently developed -- when teachers have such full command of their subject and objectives that they can recognize possibilities in seemingly random and unplanned-for events -- that teachers like Ted can perform instantaneous syntheses and act on direction from deep intuition. The resulting flow creates a feeling of aliveness in the classroom toward which Ted constantly aims.

Case Two: "Kit" (Science)

Good teaching is like the ideal parent/child relationship. It involves hand-holding, pushing gently and letting kids take their falls -- a very hard role for a parent and for a teacher. -- Kit

Professional Development

Introduction

At the time of this study, Kit, 41, had been teaching for eleven and a half years. For two of those years, Kit and I were colleagues on the same academic team; several years later, she became the cooperating teacher for a student teacher I supervised for a local college. She is the oldest daughter of six children and the mother of two girls, 7 and 3.

After retiring as a colonel in the marine corps, Kit's father earned his Master's in education, became a business English teacher and then the assistant principal of the high school in a town near where she lived. Her mother, a gifted student who skipped several grades and graduated at16, loved the arts, especially dance. She attended a two-year college, completed a nursing program, then stayed home to raise her children.

Childhood

Because her father was in the military, Kit's family moved to China for a year when she was in preschool, about which she has only a dim memory. Then her family briefly lived in California before settling in a mill town in northern New England where Kit attended grades 2 - 12. Kit saw her father as a stickler for high academic achievement: five of his six children graduated from college, and the sixth, now 40, is just finishing. For him, academic achievement was the key to success in America. Kit's mother supported her children's academic lives by editing and typing their papers for school and encouraged each to play a musical instrument. Kit strove to be well-rounded: Along with academics, she marched in the band and played sports.

Even though Kit was always among the top three students in her class, she did not enjoy school:

> It was generally boring unless I was given individual projects and choice, or when I could do artwork and theater. In language arts I remember making a booklet on humor, and that's really the highlight of my schooling. I was recognized for this project. I remember using some kind of glue to make a wart on a witch's nose... . I loved learning, but I did not really enjoy education. It was very much lecture format, and you don't speak to anybody near you. I was miserable.

Her experiences seem to have spurred her to create a learning environment for her own students with the opposite characteristics of those she had encountered when young:

> I'm always curious. I like to do innovative things. I don't like to sit and just read, even though reading is one of my favorite pastimes. I want to use my hands and have some exploratory time. I want to socialize. I work best with others. Those are all the kinds of things I try to integrate in my classroom.

Underscoring the stereotyping girls have faced in science and math classes, Kit relates an incident with her biology teacher whom she remet as an adult.

> I was working as an island staff member at a marine biological laboratory when my high school biology teacher was a student there. He yelled at me across the island, 'You're in science? You were only a "B" student.' He said he thought I'd be an English or psychology major because I was very interested in people -- why they think and do what they do.

Interest in people and their needs turns out to be a central theme in Kit's discussion of her teaching.

Subject Matter Preparation

Kit studied for two years at a selective liberal arts college, then took a year off. She resumed college at a state university and, in another example of her well-roundedness, spent a summer in France her junior year, which peers teased her about because it seemed odd for a zoology major. Kit's initial attraction to science was her perception of it as a stable and organized body of knowledge:

> I went into the sciences because I saw it as structured and easy. I couldn't deal with all my raging emotions, so I pulled this wonderful structure called science over them. Structure exists in all the different disciplines, but you have to find it. Zoology was the easiest one for me. I switched from a psychology major to a biology major and ultimately, into zoology. There's no question I looked at science as more black and white than I do now.

It appealed to her curiosity about everyday physical phenomena:

> Science is one of these wonderful eye-openings of life. I was just fascinated about what makes a burp or hiccup. Why does your stomach growl? What's a sneeze? How can you tell the weather? --- all these little things that you could know.

Entry into the Profession

Kit pursued a variety of jobs before turning to teaching, including aerobics instruction, ghost writing, tutoring heroin addicts, setting up a weekend alcohol rehabilitation program, and working as a research assistant in physiology at a medical school. For three years she also worked for a syndicated educational video series called "Young and Special," which entailed interviewing the parents and therapists of special needs and gifted and talented students in her region and helping to videotape thirty programs built around the children in classroom situations. This opportunity allowed her to observe how some exceptional children act and think and how their parents feel about them and their learning. Kit feels these experiences sensitized her to the range of learning needs all students bring into regular education classrooms.

> I spent many of the years until I was thirty dealing with what I considered "not mainstream society" -- people with a special need of some kind. I went into teaching because I wanted to work with more normalcy. I'm not sure that that's what I got! (Laughs)

When she turned thirty, Kit enrolled in the same independent teacher education program Ted attended -- which emphasized immersion in teaching from the start of school. "Interns" attended seminars in educational theory and practice once a week and spent the remainder of the week in school working with a master teacher. The program lasted a year and involved two different semester-long placements. In an artful pairing, Kit's placements emphasized opposite ends of the teaching spectrum. The first was oriented toward process-thinking, low teacher direction, and lots of noise and activity. Its openness challenged many of Kit's assumptions about teaching, including the notion that teachers are the source of all information:

> My master teacher didn't have all the answers which I thought you were supposed to have, and yet it was wonderful to be in a classroom where I didn't have to be in total control, where the kids were given a lot more freedom. My master teacher said, 'Kids usually do well with change.' That was a new concept to me.

Having a less structured learning environment was at first disorienting, but Kit found that it permitted a kind of intellectual curiosity in students that her experience with more traditional forms of schooling had not and helped her see that this was one of her real goals in teaching.

> It was hard because I didn't know what was okay and what wasn't and how much time students should spend socializing. It was also hard because it opposed traditional educational thinking which is what I was familiar with. Feeling that the kids were applying their learning to their lives, how curious and interested they were was dynamic for me. I realized that's what I wanted to nurture, and that if you could overlook the distracting behaviors, kids were actually building confidence to try.

Kit feels that her sensitivity to cultivating students' confidence was first nurtured here. This placement built her own confidence and, she feels, made her aware of the need to be a good listener in order to be responsive when change was called for.

> My master teacher always listened. I just remember thinking, 'How am I ever going to reach these kids? I can't do anything right.' He made time for me and believed in me. That was a real turning point.

Her master teacher gave Kit license to be real with the students and express displeasure if necessary, telling her,

> 'You can be angry as a teacher. Just act angry before you really are, because then you can still remain in control.' That was liberating. You generally think that you can't be that way, but it's the whole process, the whole picture that I want kids to come away with. The reality of all these multi-facets ... the light and the dark are all part of what's good.

That her master teacher had taught his own children in school was an eye-opener for Kit, because she felt that it helped her see that teachers are whole people, not simply their jobs, and that students are also whole people, with lives outside school.

Her second placement complemented the first in offering a very orderly environment which addressed a different set of learner needs:

> My second placement gave me what I didn't have in my first, which was a series of appropriate behavior criteria and consequences and a child-centered way to generate them. I saw the kids needed that right up front.

Together, Kit feels the placements offered hert a "wonderful balance" by helping her learn that

> ... you don't have to have all the answers and can leave things open-ended, and, at the same time, structure things so the kids feel safe. I felt my two master teachers were really polarized and yet both were very loving and giving of their time. They remain close to me and accepting of the fact that I was different from them.

Another insight her practica gave Kit, undoing a notion she had garnered from her own years as a student, was the awareness that teaching, like learning, is an on-going process, not a series of finished performances.

> The fact that I could reteach something because students didn't get it the first time -- that was another turning point for me. It was eye-opening that anything that went wrong for the student or the teacher usually could be corrected.

She realized that being open about her own learning could be dynamic for her students.

> At first I felt very uncomfortable being up in front of a classroom all the time, being the dictator of what you are learning and how you are going to learn it. Over time I have given myself more and more permission to be a student, too. I can share my enthusiam when I have one of those "Aha!" insights, which is part of what good teaching is all about.

While she received what she felt was excellent modeling in two different teaching styles, Kit feels there were gaps in what she received in her professional training, particularly in regard to designing curriculum units:

> I didn't feel I knew how to plan a unit. I didn't know how to find out what the objectives were, or how to go about teaching content in a systematic way. It seems like it was a total blank in my teacher education.

Like many respondents in studies of PCK development, in her first months Kit started with the text as her curricular authority. Unlike many novices, however, she didn't stop there.

> I would rely on anything that seemed like it was working from the textbook. I would literally go through the textbook and come up with the main concepts in question form and write their answers on a sheet. Then I would sit down and go through any materials I could get my hands on,

> anything that could make the concept stick in students' heads. It could be talking to a partner to do a mnemonics for their vocabulary, or a lab where they could see this happen... .

From her own experiences as a student, Kit knew early in her teaching that students needed a more multi-modal approach to content than simply using the text allowed.

Professional Influences on Teaching

Kit's first teaching assigment was in high school biology and physical science. She found it difficult, however, to relate to the attitudes many students had already developed about science and after the first year decided to apply for a position at the junior high level. She has been teaching at the same junior high for the last ten years.

Having to teach herself how to make science content understandable to students has been a significant trigger both to Kit's PCK and to her overall understanding of her subject:

> I have learned how to approach things systematically, to become more detail-oriented and how to make content able to be digested by somebody else. You have to know where the pitfalls are and how to help students over them. In order to do that, you have to assess what it is in yourself that you found tricky. I remember when I was first teaching high school and trying to teach osmosis and diffusion. I could not make it make sense. I was missing the tiny little details, such as, in this case, that osmosis is only the movement of water molecules. Salt and nutrients don't move; you simplify it to that point. There's no question that becoming a teacher made me understand science. I never understood it the way I understand it now:

Observing patterns in students' experiences with material Kit feels motivated her to gather information about students' prior knowledge, information she used to develop her PCK.

> If students kept missing something, or a request I made seemed very foreign, I was mad at myself initially. Or, I would notice that I was really successful at some things and realized it was because students had worked on this kind of thing before. So, I found it really helpful to go into earlier classrooms and see where students came from. That opened my eyes so much. I talked with their teachers who were generally very willing to show the best of each student -- even kids they had had challenges with -- and offer something helpful for teaching that child.

Kit's initiative also included investigations of the classrooms of later grades, not just those in her district and not just in science. This gave her an appreciation for the continuum and breadth of students' academic lives:

> It was really interesting for me to see how elementary schools differ from high schools. I have forced myself to take professional days to visit all the school districts in the area and seen the different philosophies. I make sure I see what is being done in language arts, math, social studies -- any place that offers something I think I am interested in. I love listening to the whole gamut.

As Kit became clearer about her objectives and students' needs, it seems that her growing PCK of instructional strategies inclined her to become more intentional about sequencing activities and finding multi-modal ways to reach different students:

> First you observe, then you do some comparing, then you can do some contrasting, and then you do some jumps of applying information. I began to realize that those were the steps you had to take, because if you tried to have students compare and contrast, and they hadn't observed yet, they couldn't do it. They didn't have the foundation, so it taught me how to get at little pieces and build on those. As I found the kids didn't understand, I kept backing up [repeats three times] and realized that I had to go with these really simple little pieces, including identifying the lingo. Then I would come up with different ways to help kids understand: Models, hands-on, spray stuff in the room -- five, six, seven different ways to reach them.

In her fourth year of teaching, building on an earlier stint as a docent and data base organizer for her university's marine advisory program, Kit became a student at a marine biology laboratory for the summer. She followed this up five years later with a week-long course developing marine curriculum aboard a clipper ship. Both experiences added considerably to her knowledge of oceanography and inspired her to take students on field trips to observe sealife.

Five years into her teaching, two events took place which radically increased the pace of Kit's PCK development. First was a shift in her perception of the nature of science, prompting her to let go of trying to "cover" content.

> In the beginning I felt very pressured by what we covered and how we covered it. About five years ago, I went through a paradigm shift when I read about the changes in sub-atomic physics and realized we weren't dealing with certainty. Now I look at science as ever evolving, not a set of concrete facts. I see how much more interrelated the sciences are -- that the plate tectonics model can help us understand why planets in our solar

> system differ; atomic structure can help us to understand astronomy. Now I think of science as a process -- a way of looking at life through a series of logistical steps. I think the kids view it as basically concrete facts until they realize that things change -- 'Oh my God, you mean that Pluto might be two planets?' I have to be able to give the kids something somewhat concrete -- a structure -- a way of looking, of categorizing, of contrasting and comparing. This is what will allow them to advance into the next century. Now I teach for students to be able to cope with their ever changing world and to find a piece of themselves to be true to. I am freed to teach the critical thinking skills I did not have as a child. The world is changing SO FAST! How do you get information? How do you process it? How do you synthesize it? How do you use it? How do you apply it? And where do you go when you you need answers? To me that's what my job is all about.

A second key event occuring in Kit's sixth year was becoming the cooperating teacher of a brilliant student teacher named Nora, a pairing which turned into a job-share partnership when Kit's second daughter was born the following year. This sustained collaboration had a major impact on both women's growth. As part of her practicum, operating out of the "report mentality" of many college students, Nora put many of Kit's ideas in print.

> All these years I taught in bits and pieces. I could talk about my dreams to Nora. She had the time to work on the dreams and put them into writing, which was a great gift. I didn't have the time or the energy and I needed that crystalization. What she gave, she took, and what she took, she gave. I don't think she's aware of all the gifts she gave to me. Before this, I had tremendous frustration about what I wanted to do and didn't have time to think about.
>
> At first, I felt my teaching was boring. Not alot of creativity -- the hands-on and humor just weren't there. I think there came a point when I was stagnant in what I taught, and now it's not possible because knowledge is so available and moving so fast. I recognized the need adolescents have for creativity and staying open to new knowledge -- my own need for that, but finding the tools that allowed me to stress these things have only come in the last three to four years, since Nora started picking up on my ideas and expanding them. She did it over and over. It was wonderful to speak my dreams and see them realized.

Nora's push to document various units and her encouragement of Kit to do likewise had a profound influence on Kit's PCK development. It left Kit with materials which reflected exactly what what she wanted to emphasize, offered a concrete basis for revision, allowed students for the first time to see the scope of a whole piece of curriculum, and empowered them to stay organized.

In an example of how novices equipped with new research-based teaching strategies can expand the knowledge of veterans, Nora also shared what she'd read and experienced with cooperative learning in her teacher education classes. Kit was very receptive to these strategies, but had little exposure or experience with them.

> Nora had a lot more knowledge about structured group work, which helped me shift into teaching in a way I enjoyed much more: Less teacher-centered, students taking more responsibility, all of us socializing a little more.

During her maternity leave the following fall (her seventh year of teaching), Kit and Nora split a job, giving Kit the freedom to take several workshops on cooperative learning and adolescents' developmental needs.

> When I had the job-share with Nora three years ago I really found myself expanding. I had the collegial support and brain power to work with, and I was working part time. I could attend more workshops and have time to read the paper or a science fiction book.

These opportunities, she feels, prompted her to make several significant changes in her practice. First, experimenting with cooperative learning helped Kit see the value of social responsibility as a motivator for learning:

> Students think, 'I'm going to be responsible for learning this because I have to teach it.' The other kids will ask them questions. So students have to be clear with each other. They have another another purpose for learning it.

Equipped with greater knowledge about students' affective and cognitive needs, Kit began to include more variety in the way each class was structured, which, in turned, helped her feel more aligned with her deep purposes.

> I realized it was okay to teach social skills and that this would make me feel more comfortable in the classroom. I saw that students need to chat, not sit down and be quiet for 45 minutes. Before this I found myself snapping all the time, "You're not paying attention!" I came to realize they were trying their absolute best, but it was more than I should expect. They needed a structure where, for fifteen minutes they would sit silently, look and me and listen, then they would have their time to be working, possibly with a hands-on activity during which they could talk. The workshop gave me license to allow them to be adolescents. I began to break down classtime into fifteen minute blocks: My time, your time, clean-up /summary time. Not that it always is that, but that's what I aimed for.

This division of classtime was evident in my second classroom visit when "students' time" was devoted to identifying particular minerals. As Kit was handing out the packets with the minerology keys, a student started to chat with a neighbor. Kit responded, "This is my time. You will have your time to talk in a few minutes," conveying a sense of equality and turn-taking rather the idea of "power over."

Freeing up classroom talk during "students' time" helped Kit to build rapport by allowing students to share important personal information. The varied format and cooperative strategies also gave her a way to teach social skills and manage noise in the classroom in a pedagogically responsible way.

> I created time to go over to Johnny and say, 'You did a good job on your paper. I was reading it last night.' Or Monica could come up and tell me that her mom was incarcerated and her dad's on the road with a truck and she can't get this permission slip signed. She knows she needs it signed for tomorrow and she's really upset about it. It allowed more bonding, and allowed students to work on the social skills: eye contact, how do you communicate effectively, who had difficulties, how to assign roles and tasks, and how to follow through on them. It gave me a structured way to do this when I was afraid to have too much noise because people would look in.

Kit further increased the level of responsiveness in her classroom by encouraging students to use journals to communicate both cognitive and affective concerns about class to her, telling them:

> 'You can change something that isn't working. You have the ability to express your concerns in your logs; I will listen and address your concerns.' I wanted them to learn to communicate effectively to find solutions.

The content of these entries offered on-going information about about how to modify her PCK in order to accommodate students' needs. For example, the idea to break down assignments into doable bits originally came from students who gave her suggestions on timelines.

Nora, it seems, empowered Kit to teach the way she intuitively knew was effective while Kit feels Nora drew from her an understanding of the components of powerful learning experiences. Kit is now able to offer students materials she feels perfectly reflect her values and approaches, unlike at the start, when she was struggling to piece together units which could actually take hold:

> At first it was just overwhelming finding materials. Now I have confidence that most of the pre-packaged materials will give you the major concepts, but not the activities. I had to go to lots of places and lots of different people to figure out how best to get information over to the kids. And then I would just have to try it. I would pattern new units after others that were very successful: Little increments, activities, trips, speakers. Now I try to see where a unit can be integrated with other places. It takes me a long time to plan.

The following year (Kit's eighth), Nora's work in a nearby district allowed their collaboration to continue.

> For eight years I have wanted my students to have a science guide book. When Nora went to Hillsborough, she decided to do a Science Handbook and brought it to me: Expectations, how do things, information about equipment and so on. It was me talking, but Nora put it all into written form.

Working half-time for the last three years has forced Kit to create ways to help students stay organized which, interestingly, has been another source of PCK development. To compensate for her reduced availability, she has instituted a "Student Log" in which all classwork, homework, and handouts of the day are recorded and stored. It has given her a precise picture of what she has accomplished each day, creating a detailed record for planning the next time round. Turning what could have been a liability into an asset, Kit feels that keeping a student log has strengthened the sense of community and student ownership of the learning within the classroom.

> Kids are responsible for the log book. Different kids in each class note who is absent. Everthing they need is in there. Absentees can come in and see what they missed and know to ask for the sheet on lightyears or the expectations for the travel brochure.
>
> I can't do everything. I need students to take care of the log, just as during presentations, I need them to run the overhead projector, so I can check around.

Truly needing students' to help run the class, Kit feels, has allowed her to function on a higher level, using her energies for diagnosis and intervention, rather than on clerical or managerial tasks. Turning part of the management of the class over to students, Kit feels, has allowed them to become more conscious of its objectives and overall direction.

Another change taking place in the last two years is that Kit now has her own room, which has freed her to use more variety in her instructional arrangements.

> My space has never really been my own. This and last year are the first time I moved the furniture into groups, because it was adamantly upsetting to another teacher if I moved heavy lab benches out of rows. Now I share the room with my job-share partner and she is in cahoots with me. But I have a lot of habits left over from having to accommodate the other people who used to share my room: how I organize things, what's out, what's not out, what's up on the walls. Nothing could be left out because another teacher would need the counters to do something totally different. I would have to adjust myself realizing that my way of teaching created situations other teachers could not manage.

With a file cabinet of her own, materials are finally situated in one place. This has helped Kit pull together curriculum and refine her ideas more easily.

This past summer, Kit attended a week-long institute on "Education by Design" (EBD) which integrates cooperative learning and critical thinking skills into a problem-based outcome-driven format. She has been experimenting with "jury panels" of professionals inside and outside the building who share their expertise in particular problem areas and critique students' group problem-solving processes. Using EBD's constructivist methods, Kit feels, has constituted a "quantum leap" in her way of operating in the classroom, by placing students far more center-stage and recasting her role as much more of a facilitator. This has taught her what a powerful motivator social pressure can be; students are now even more responsible for acquiring and teaching each other content. She has also found, however, that students need the modeling of effective PCK in action in order for students to be stronger teachers of each other; balancing student-centered EBD approaches with more teacher-centered ways of delivering content is what she would like to experiment with next.

Keeping abreast of technology, last summer Kit also attended a course at a state college titled "Technology in the Classroom" where she located sites on the Internet for use in the middle school classroom. She is beginning to use them as sources of ideas and materials as well as a way to break down some of the isolation she feels as a classroom teacher.

Perceptions of Herself as a Teacher

Kit is committed to excellence. At the end of every term to acknowledge superior work in each of her classes, Kit awards "Vos Savant" and "Einstein" certificates to a girl and boy who have excelled in the content, processes, and attitudes she emphasizes. Many students rise to the challenge because she meets them more than half-way. She tells the story of a particularly challenging student who was pregnant and not succeeding in school. Kit came in early and brought her a 7:00 AM breakfast in a picnic basket so that she could finish her assignment. The girl wrote her a card saying, "Thank you for believing in me." Efforts like these, however, often create a conflict between Kit's notion of the good teacher as one who is highly prepared, gives and listens; and the demands on her by her own young children who leave her with limited time.

Kit sees her strengths as being

> open-minded, always changing what I'm doing, soliciting feedback from the students. I'm really interested in trying new things and finding out what the kids are interested in. I try to reach for those teachable moments when a question comes up and I drop everything to see where we can go with it. I try to relate science to their everyday lives.

Teaching gives Kit an opportunity to express the full range of her own capabilities:

> I teach because it gives me a place to do a lot of things I like to do. I can be creative, active, helpful, and funny. I can draw and act. I'm in control and am respected.

Her classes are a place where she can feel comfortable.

> You need to make a safe environment -- have certain kinds of structures at at the same time, some way to pique curiosity. Sometimes I can be extremely structured, but I have a rapport with the kids fostered by respect. I think some of my activities are an expression of MY needs. I need structure. I need projects broken down so that they are not overwhelming. I'm driven to produce a classroom in which I can be successful: a certain amount of predictability balanced by a certain amount of freedom.

This balance is evident in the orderly yet varied environment one feels in Kit's classroom. During my first visit, students had their homework out and sitting on top of their notebooks, waiting for Kit to check completion. Students whose work was already out by the time class started were awarded a treat. As Kit circulated, students' attention was directed to the board where she had posted the agenda for the day . She was quick to respond to a student talking out of turn; the next moment making a joke about flying fish. Students would be joining one of three groups and rotating through three activities: observing moon phases in the supply closet using hand-held Styrofoam lollipops;[1] reading about the ocean in Johanna Cole's, *The Magic Schoolbus on the Ocean Floor* while looking at photos of a class trip to an island containing a nature preserve; or completing a trivia contest containing obscure biographical information about the teachers in the school. Students wrote the evening's homework on their assignment sheets before shifting into groups.

The period was quickly paced and tightly packed. Despite it's being the last week of the school year, students were largely on task -- helped in part by Kit's request that I supervise one of the groups and her special needs aide the another while she conducted a lab. It seemed to me that the balance between academic and non-academic content allowed the class to remain productive at a time when serious work can be abandoned in favor of housekeeping and pure entertainment.

> Kids say on their written feedback, 'There's always something creative we can do in here; I always like coming in.'

Kit wants her classroom to be a interesting to students. Colorful displays of student work decorate her classroom and in the halls directly outside it. An entire inside wall is covered from waist height to the ceiling with a forest mural; maps of the world, students' constellation posters and oceanography collages, photographs of "Arts Day," a canoe trip, a team tee-shirt, and flowers drawn in colorful chalks on the blackboard cover other parts of the room. Opportunities exist for students to become trained handlers of the live animals (guinea pigs, parakeets, rabbits, tarantulas, anoles, iguanas, fish, frogs, snakes, snails, and mudpuppies) living in the room.[2]

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[1] This activity is described fully in the section on "Instructional Representations" for the Astronomy unit.

[2] In fact, Kit co-wrote an Eisenhower grant in 1989 to fund the purchase of these animals and the materials to train students in their proper handling and care. Called "The Pet Express," she has found it to be a valuable way to help students who aren't used to thinking of themselves as "good" in science to develop self-esteem as they show other children in grades K-8 through this multi-disciplinary traveling zoo what they've learned about the animal kingdom. In this way, she invites potentially

Kit sees herself as committed to the whole child. One feels how important the extracurricular activities are that she and her academic team organize for nurturing unity and knowledge in students. She showed me a rap song which students had created about the facts they had learned about a local river while on a recent canoe trip. She spends much time preparing and debriefing students about such activities.

Kit sees a strong moral dimension to her teaching. She recounts a cheating incident that she was able to process without pointing fingers by having students privately self-evaluate in their journals in response to the question, "If a friend asked me for answers, what would or should I do?" Following this internal review, she offered a perspective on caring through a role-play in which she modeled taking time to confirm a friend's answer without giving it or showing it in the text, then having the friend say it and write it. Pre-empting a day of science instruction, she analyzed, strategized, and then implemented a plan with students faced with a challenge of this sort. Not stopping there, she asked students to transfer their understanding to other parts of their life -- "Where else are people taking advantage of you or vice versa?" -- a question many students didn't want to face. She relates that she felt frustrated that she had to interrupt the "regular" content to deal with cheating, yet what, she felt, could be more important than developing students' self-knowledge and moral character? She reframed the nature of her task as a teacher, feeling that she was responding to a universal need far more important than her previous agenda for the day.

Kit feels that her teaching objectives have often been embedded in interesting activities and have not been that conscious:

> I'm really in the throes of teaching, emotionally. I don't always pull out and conceptualize why I am doing what I do. Usually clarity about my objectives comes after the fact. I know what they are subconsciously when an activity catches me and fits into that unconscious goal. But I don't think I have, until talking to you, really distilled why I teach what I teach. I don't think I've ever talked about it. I know I want them to have what I didn't as a child: Confidence to rely on myself, to know how to frame

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disaffected students to indentify with her agenda, rather than reject or bargain with it as Lee & Anderson (1993) found students to do.

the questions, where to go for answers and then make an informed decision.

Pushed further, Kit articulates that fostering concepts, creativity, and empowerment are her deepest goals:

> When kids leave, I want them to be open-minded to science and to their world ... to feel comfortable, curious and confident enough to take a risk. It's okay to make mistakes; you do not need to be perfect -- it's a process. If they can believe in themselves, they can master anything. Ultimately, I think their lives will be happy if they are continually evolving, as opposed to living out a series of right and wrong answers or dead ends.

In keeping with her process emphasis, Kit gives very few tests. Those she does give are shifting toward a story format.

> Last year in eighth grade I had six tests or quizzes. A lot of my tests are moving into, well my minerology test is titled, "An Afternoon with Dave Diamond and Amy Thyst." It is just five essay questions, but it's set in a Harlequin romance novel format [see Appendix R]. It's really hilarious. One of the teachers said, "You've really missed your calling!"

Kit's assessments regularly include students' perceptions of their performance and each other's work using scoring rubrics the class designs (see Appendix S). She feels these give her direct insight into their needs while empowering them through metacognition.

> My assessment is heavily based on skills: being able to get information, present information, and meet deadlines. Students have to do self-evaluation, set self-goals; they have to give feedback to me about what they need and don't need to succeed. They do that on a regular basis for different activities, including field trips.

Yet, acquiring specific content is also very important to Kit as seen in her careful reinforcement of material so that all students succeed.[3] Her recent PCK development, for example, has expanded to include an understanding of the value of shifting between part and whole for learning certain concepts and how visual mapping can help this process:

> I was teaching rocks and the kids were really confused. They couldn't remember which were igneous, sedimentary, and metamorphic. So I did this visual mapping. We'd go into each little igneous rock, and then I'd have to pull them back out to give them the overview, even though I'd done an overview characteristics lab, and review the big picture again. Overview, go in depth and overview again with a visual mapping. That still didn't work for some kids though. They needed to have the information in an outline, so I offered that as well.

[3] Details about this reinforcement are found in the section, "History of the Astronomy Unit."

At the same time that Kit takes teaching very seriously, she delights in creating playful and memorable learning experiences.

> In the last three years I have really realized that the kids just love it when I include theatre, humor, and anything magnificent, shocking, and entertaining. They LOVE the geological swear word, "Holy shist" or the "FU seaweed," fucus. It's silly, but you know these names will never leave their brains.

Kit enjoys modeling that she is learning along with the kids and doesn't have all the answers, which she feels empowers them to feel okay about making errors. She reports that student evaluations always highlight that

> I love what I am doing. I think that is what has inspired my students more than what they've learned is watching me be thrilled to share with them something I've just learned. They teach me as much as I teach them.

Sometimes her students teach Kit things they don't realize, such as renewing her faith in herself as a teacher. Sharing this on the next to last day of school during an observation for this study, she affirmed a mutual respect by recognizing what each brings to the other.

In thinking about her development, Kit sees a gap largely between what she can do and what she wants to do, rather than between what she knows and what she doesn't. She sees the largest constraint on her development as a teacher to be one of resources:

> Lack of materials, and money for them, lack of my own knowledge of what's out there and lack of time (45 minute periods) to reach the number of students I have. I have to teach myself, find a way for the kids to learn, reinforce it with some kind of creative activity. It takes time.

She has no benefits and is being paid $15,000 in order to be allowed to teach 67 students and leave by noon. She has two science classes, a homeroom, and a study hall and is expected to participate in all afterschool faculty meetings and extracurricular team activities.[4]

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[4] Actually attending faculty meetings has not been possible; Kit now relies on meetings with the principal and others during her early morning duty to stay abreast of school matters. This year because of logistics, she was offered only a full-time position which she has declined in order to remain available to her own children.

Reflections on Professional Development

Several themes emerge in reviewing Kit's professional history. A major one is the shift in the way she views science, away from a stable framework of facts toward an ever-changing collection of more integrated information which can be negotiated through "logistical steps." This constituted a shift in her view of knowledge away from it as "Absolute" in Perry's scheme and "Simple" in King & Kitchner's toward it as being "tentative, evolving, ...[and] interrelated" in Schommer's scheme (as cited in Hofer & Pintrich, 1997; see Appendix A). Since science is changing so fast, she says she sees content as irrelevant, yet she is careful to offer multiple opportunities for reinforcement using varied modes through which to help students master content.

A second theme is that in the early stages of use activities seem to have been a concrete way for Kit to discover her goals, which appear largely internal and intuitive. To this extent her materials have been a significant influence on her PCK of purposes for instruction. Kit has worked hard to cobble together successful units guided by this inner set of standards, but the gift of Nora codifying Kit's ideas freed her to become more intentional in her teaching and more able to refine her PCK. As Anderson & Roth (1989) discovered in assessing the impact of concept-oriented teaching interventions on science teachers, the presence or absence of appropriate materials can make or break a teacher's commitment to constructivism and concept-oriented teaching methods. In the absence of well-designed materials, Kit was burdened to create them, which limited time made challenging.

> I work harder now than ever, but with a half-time position I am freed up by having fewer kids to spend my time differently: I get to do more of what I love, which is to develop and modify my units.

Third, as a result of working largely in isolation, Kit's need for validation of her instincts comes through strongly. Proponents of cooperative learning gave her this, allowing her to become even more natural with students than her first practicum had encouraged, and helped her legitimize social skills and student empowerment as a valid part of her objectives.

> Cooperative learning is important for teachers. It isn't going to go away. It's something we have to work more towards.

Kit's participation in the week-long seminar called "Education By Design" (EBD), which integrates critical skills with cooperative learning in a problem-based context, has further validated her belief in the power of group learning strategies. EBD strategies have made their way into all of her subsequent work. She sees it as a huge step forward in the effectiveness of her teaching because of its impact on students' independent thinking and their increased motivation to learn -- outcomes associated with the methods stressed in teaching for conceptual understanding (Brophy, 1991; Brooks & Brooks, 1993).[5]

History of the Astronomy Unit

First Version: 1987 -1988

In the spring of her first year of teaching at the middle school level, Kit began using an eighth-grade astronomy unit developed by a colleague in her building. It consisted of 17 questions based on a 13-page textbook chapter on astronomy ,[6] a crossword puzzle reinforcing vocabulary and facts, a video called "Solar Seas," and a list of eminent astronomers students could choose from on which to write a biographical report. She planned for students to spend four or five days working on the packet of questions and the crossword puzzle, several days in the library completing the report and had them finish with a summary quiz based on their knowledge of the planets.

[5] Some examples of the way Kit worked EBD into the astronomy can be found in the discussion of the "lollipop'"representation in the section titled "Evolution of Kit's PCK of Instructional Representations."
[6] Earth Science (1986). Holt Rinehart & Winston.

Kit's primary goal for the unit was to have students practice taking notes for a research project and learn about the planets. However, she found that having students compile biographies of famous astronomers was problematic as it involved unfamiliar and technically difficult concepts like "triangulation" embedded in articles from encyclopedias written for adults. In mid-unit, she abandoned the astronomers list and opened the projects to whatever space-related topics and presentation formats students found interesting. She gave them a list of 30-40 possibilities from a variety of sources including her own brainstorming.

> They could pick anything they wanted and could present in any way they liked. They had to have references, notes, sketches or lay-outs, and work on opening and closing statements if they were doing a report. They also could do models, rocket ships, posters, anything, stories of how the universe was created, moon phases, even an explanation of how you go to the bathroom in space, which a lot of kids wondered about. Three kids collaborated on a puppet theater showing the three basic physics laws that govern the universe. It was over my head, but when I looked it up, those kids were on the mark. I took all the projects I thought were really remarkable and had the classes rotate through tables where they were displayed.

Influences on Development

Kit found that expanding the scope of the projects allowed her to tap the talents of all her students, even those who didn't see themselves initially as interested in science, transforming the classroom into a swirl of information and color. This produced a powerful learning opportunity; as McGee & Carlson, (1994) point out,

> the project approach allows integration of content into creative syntheses and permits students to benefit from each other's unique qualities. (p.5)

The range of projects appealed to her own love of creative expression and taught her a variety of information about astronomy, which she valued highly as she considered herself very much a student in this area.

Kit was looking for accessible materials to supplement the unit as she knew from her experiences as a student that reliance on the text as the primary knowledge source would not adequately stimulate students' interest in the mysteries of astronomy.

> I was looking for hands-on activities, things that were not paper and pencil, not worksheets, not text-related, things that the kids could relate to every day.

On the recommendation of a science teacher at another middle school, Kit took the initiative to visit a NASA resource center at a liberal arts college about two hours from her town, spending a "personal" day browsing through activity packets, videos, slides, and other visual aids. She came away with a guidebook of activities called "Toys In Space," which involved students playing with gyroscopes, yo-yos, jacks and balls, and other toys, then predicting how they might behave in space (see Appendix T for sample activities). She also brought back two videos, one which would confirm or refute students' predictions by showing how the toys actually performed in zero gravity, and another called *Astro Smiles* containing more information about the toys as well as humorous incidents related to life in orbit during a space mission. In a playful way, Kit figured these would allow students to strengthen their hypothesizing based on prior knowledge as well as increase their stake in discovering the actual performance of these objects in space.

<u>Second Version: 1988-1990</u>

For the next version, Kit made several changes. She added the "Toys in Space" activities and the two videos and expressed great joy at being able to accomplish two goals at once: having students internalize a sense of gravity's effect on our lives and the problems it poses for life in space, while introducing students to the pleasures of toys from simpler times. At this point, students were not tested on their knowledge of gravity or the laws of physics embedded in these activities. The final test continued to stress knowledge about the planets.

Kit also decided to booklet the papers associated with the astronomy unit, rather than give out individual assignment sheets which students often lost. She found two space-related Gary Larson cartoons which she put on the cover. Feeling that the video *Solar Seas* was boring for students because it was difficult and moved slowly, she substituted another called *Probing the Planets* which reinforced her focus on planetary knowledge.

She continued to stress information-finding and built in checkpoints by which students were expected to have located resources, taken notes, then written or created main ideas for their space projects.

Influences on Development

Kit found that the hypothesizing and the videos seemed to help students come into a fuller appreciation for the way gravity affects every day life on Earth, because they engaged multiple learning modes (auditory, kinesthetic, visual) and students found them fun.

Students' boredom with the movie *Solar Seas* as well as her desire to reinforce content about the planets guided Kit's next choice. She wanted to increase accountability for homework completion, so decided to staple assignments together so that students could keep papers in one place and look forward to what the unit entailed in its entirety.

Third Version: 1990-1991

For this version of the unit, Kit retained everything from the preceeding two years, but added a science fiction book report, hoping to broaden the approaches to interesting space-related questions by bringing in literature and thereby hook students who loved to read novels. To reinforce the sequence of the planets, Kit also added a ten-minute video called *My Very Educated Mother Just Served Us Nine Pizza Pies* -- the title being a mnemonic for remembering the sequence of the planets -- and a worksheet depicting their order for students to color in.

Influences on Development

At this point, Kit was still in the throes of balancing the demands of a full time job with those of raising a young child and consequently had put her inventive energies "on hold." As a result, the unit changed only moderately in this year. However, she was beginning to see the value in making certain all students had contact with core knowledge about astronomy, which the open-ended nature of students' projects did not ensure.

Fourth Version: 1991-1992

In this year, coinciding with Kit's mentoring of Nora, the unit doubled in size.[7] Despite this, Kit felt that she was covering less material because her PCK of instructional strategies was expanding to include more multimodal approaches to content based on students' real questions and this required moving more slowly.

> The unit really mushroomed when Nora came. She could help me get students' questions down. She had read *Circles of Learning* and understood cooperative methods in much more depth.

Kit's attendance at the National Council of Teachers of Science convention in the spring before she taught the unit produced more subject matter knowledge of astronomy and new materials. These prompted her to omit the science fiction book report because she felt too much class time had been taken up with reading, and the reports, which she had made available to all students, did not capture the attention she had hoped.

[7] As I was Nora's student teaching supervisor, I had the opportunity to observe this collaboration first-hand.

Using slides from the Voyager space mission included with one of the convention workshops, and space music from a radio program called *Music from the Hearts of Space*, Kit created a dramatic presentation of the planets to supplement students' textbook readings and replace the video *Probing the Planets*. Still shots of Voyager's photographs, she felt, would linger longer in students' minds. She wanted students to practice comparing and contrasting aspects of the planets with those of Earth. To increase reinforcement and student involvement in her lectures, Kit appointed someone to take notes on the overhead projector while she flipped slides of the planets. At the end of class, she had students focus on the overhead notes for a review.

> They could watch the slides, be engaged and taking notes, but know that if they missed anything, they could look front and in the last five minutes the overhead would come up with all the answers on it and I'd go over it.

Omitting her list of 30-40 project ideas, Kit substituted a project from the same workshop which asked students to create a brochure for one of the nine planets, selling it as an exciting travel spot, a place for camp, or offered either a weather report or the type of alien best adapted to the planet's characteristics (see Appendix U). To ensure that all students succeeded, she created checkpoints by which they needed to complete various parts of the project: References, opening and closing statements, main ideas, and so on. Her intention was to model for students how one takes a large task and breaks it into smaller steps in order to accomplish it on time and with good results. She found that students' confidence levels rose within this structure because they had clear guidelines and time to meet her high standards.

> Right after the star lecture, I assigned them the brochure on a planet. They chose their planets, but I needed all nine planets represented, and no more than four students per planet. Their pink unit booklets had the assignment sheet and a worksheet for this activity. They had to take copious notes about their planet on their own. They had five days to work on it in addition to other assignments.

Intentionally building on prior knowledge, Kit asked students to apply their learning from a previous unit on physical geography when they hypothesized about whether a given planet was "living" or not:

> Does it have an ever-changing surface? Oxygen and water, which are major factors in weathering and erosion? Is it a static or nonstatic environment?

Kit wanted students to know that they come to astronomy with a great deal of knowledge, some of which they have absorbed simply by living. In her words, "These vessels are far from empty."

Other changes included adding a lecture on the structure of the universe using pictures of the spiral galaxy obtained from reference books, and acquiring a computer program on astronomical facts from the NASA resource center involving planet information, moon phases, and a flight simulation and some space trivia cards. The latter were later dropped as they proved too challenging for eighth graders.

Influences on Development

The unit grew significantly in this year, Kit feels, primarily because her knowledge had expanded through the workshops and materials she encountered at the National Council of Teachers of Science convention the preceeding spring and because Nora, her student teacher, had begun to document ideas Kit had lacked the time to put on paper, such as a timeline for the unit.

During the preceding year, Kit recognized students needed to think more about what they were learning, so expanded the amount of time they spent on various parts of the unit. She found that students needed more knowledge about the planets so that they could compare and contrast them with one another; her growing PCK of these needs prompted her to narrow the range of projects to the planet brochure, weather report, or alien portrait to guarantee contact with a core body of planetary information, even if this meant giving up the breadth of creativity of the earlier assigment.

> The planet projects were much more structured, but this tended to get more excellence across the board. Before, I would get a bunch of mediocre and then a few stellar pieces; now I was getting a few stellar

> pieces, but basically all the projects were up here [gesturing]. The kids were really invested.

Fifth Version: 1992-1993

In this year, Kit shared her job with her former student teacher, Nora, who was now certified to teach.[8] This extended collaboration allowed Kit more time to pull together materials for this and other units and to attend workshops on cooperative learning and adolescent development. Both the extra time and the workshops affected the unit's content and form. Her growing sense of the interrelatedness of science topics and summer curriculum work funded by an Eisenhower grant significantly expanded her PCK of purposes and strategies for instruction. She created a much more interdisciplinary experience for students and became more intentional about focusing on core ideas: These ideas fell into two groups, one scientific, the other social. The first included concepts related to the structure of the universe; the second to the theme of cooperation, both within the space program and within her own classroom.

Addressing the scientific focus, a month before the unit began, Kit asked all students to observe and record the movements of the moon based on an idea she picked up from a regional teachers' convention.

> I added the moon because I had very little knowledge myself, having never studied it formally. Over time I added to what I knew by attending several workshops at a regional science teachers' convention and meeting this wonderful person who gave me the moon phase activity.

Inspired by a student's project two years earlier to bring his classmates to a local observatory, she also encouraged any interested student before the unit began to join her in an evening field trip to observe the stars.

Boosting her PCK of students' prior knowledge and misconceptions, Kit officially began the unit by asking students to write a journal entry on what they were most curious

[8] Nora continued her services as a sounding board and organizer of Kit's ideas, quickly becoming a powerful curriculum developer in her own right.

about within the field of astonomy so that she could catch their interest, find out what they already knew, and to discover misinformation.

> From their journals I have designed notesheets based on their questions to be filled in during my lectures.

Students' wonderings helped her see the need to clarify the size and structure of the universe. She continued with her multi-media presentations of the spiral galaxy and the procession of the planets, adding two more presentations on the stars and the concept of the light year to help students answer their own questions.

> With the stars lecture, I teach concept of the light year. I tell them that light travels 17 times around the Equator every time I snap my finger. That's the lead-off for the star lecture. I do this because one of the big questions is, 'Is there life somewhere else?'
>
> 'Alpha Centauri is the closest star to us and it's 4.7 light years away. How far is that?'
>
> They have to figure out how many miles and kilometers away it is. That's when they learn that when they see its light they are looking back in time. They begin to realize that they can't even get to Pluto for the next couple of centuries because of its elliptical orbit. It blows their mind. You'd have to go through generations in space to get to the nearest star and technology hasn't yet gotten us to that point. So they come to see that no one today can know for sure if there is life on other planets. It's been statistically proven and disproven; so they make their own predictions.

To provide a more coherent framework for students' questions, Kit sequenced her lectures to shift from larger structural relationships within the universe dealing with the spiral galaxy, light years, and stars to those at the planetary level within our solar system, finally focusing specifically on Earth -- the logic behind moon phases, the differences between gravity's effects on Earth and in space, and the ways in which life on Earth might be brought into space.

> I go from far out to closer in, then back out when we do space travel and space colonization.

Understanding the power of children's books to illustrate the relationships of heavenly bodies both simply and colorfully, Kit also included for the first time Robin and Sally Hirsts' *My Place in Space*[9] to reinforce key points from her presentations.

> This book helps creates in kids' minds an organization of the universe. It says, 'Where do you live? You live on Earth. Our star is the sun. You

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[9] New York: Orchard Books.

> live in solar system, which is part of the Milky Way galaxy, which is part of the Super Virgo star cluster,' and groups it a few more times in the universe. I use it to help them understand why the constellations move through the sky and how are we orbiting. It clarifies relationships and order of sizes. I have them all sit around me and I hold the book up.

She also read excerpts from Joanna Cole's, *The Magic School Bus: Lost in the Solar System* (1990).[10] Adding these children's books, she felt, contextualized the Earth in a powerful way for students because they invited receptive "younger selves" to interact with simple, yet interesting material.

To represent the core ideas of rotation and revolution within the structure of the universe focus, Kit thought up the idea of having a student volunteer pirouette around another student in each class to simulate the earth's path around the sun. Unlike students in previous years, she found that those who observed this simulation had no trouble distinguishing and remembering the difference between the two concepts. Using another 3-D representation, Kit illustrated the dynamics behind the different phases of the moon by having groups of students crowd into her supply closet and examine the shadows on hand-held Styrofoam lollipops in front of a light she held.[11]

Continuing within the framework of the structure of the universe, to illustrate the concept of gravity and its role in our lives, Kit shared with students recently released information from studies of Soviet cosmonauts on the effects of lack of gravity on the human body. She found students were fascinated to learn that man lengthens and blood flows differently in space, that degeneration of bones occurs due to effects of microgravity on circulation, and that pregnant women were not allowed in space because cells wouldn't orient properly. Kit feels such knowledge helped students more deeply internalize just how much gravity has defined the basic nature of our body's structure.

Turning to her second unit focus, as a result of learning more about the adolescent need to belong to a group and the way this need can be effectively built upon using

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[10] New York: Scholastic, Inc.
[11] Both simulations are discussed more fully in the section "Evolution of Kit's PCK of Instructional Representations."

cooperative learning structures within the classroom, the theme of cooperation became increasingly important to Kit.

> One of the points I'm making is that the only way we got to space was by working together using a communal knowledge base. Students come to realize one person could never get to space. Being able to speak, to know what you're feeling, to be able to communicate, to work with others, to share space with others, to negotiate -- in space and on earth, that's what life is about.

To reinforce the power and importance of cooperation, Kit included for the first time Spencer Kagan's cooperative learning activity, "Lost on the Moon," (1989) during which students discovered that even the Boy Scouts and Civil Air Patrol cadets among them could score much higher working in groups than alone (see Appendix V). Kit's PCK of instructional strategies prompted her to include several modes to increase the realness of this exercise.

> First students read in pairs a segment from the text about the moon. Then I showed a nine minute video about Apollo on the moon which shows the astronauts bounding. I felt they needed a visual picture for the "Lost" activity. Then we do the activity itself.

Kit reinforced the importance of cooperation and possible pitfalls to it in several other ways. One involved a communication activity requiring students to explain how to build a space station to a partner without being able to see how the partner was interpreting their words, visually underscoring the effect of assumptions about shared meaning.

> Working with pictures of components with names like "habitation module," "solar power array," "logistics module," and "trust boom," they have to design a space station and attempt to communicate this information to a partner who attempts to build another one exactly like it. (I'd like doing it in a 2D vs. 3D format with tinker toys, but I can't afford them.) After they do this, I show them a space station designed with these pieces which never look anything like anybody else's. When partners compare, they learn things like how "on top of" can be interpreted in different ways and that things are easily reversed, like looking in a mirror. I ask, 'What kind of impact is that going to have when you are sending satellite signals? What are you going to have to say?' Eventually the kids are very good at getting the exact, but sometimes reversed, model.

Strengthening the interdisciplinary nature of the unit and building on prior school knowledge, Kit added space-related activities with math and social studies components.

> The communication activity was language arts-related. I also used a math-related activity in which they assemble a model of a space station using tooth picks and marshmallows inside an oatmeal container. A great

social studies activity asks students to consider how one would celebrate holidays in space if you were working with people from Japan, Germany, Russia... . It basically asks students to summarize knowledge from four or five years of elementary school.

In this unit version, for the first time, Kit also had students use their journals to reflect on what would have happened to the space program if its many constituents had not cooperated. Then she had students connect these reflections to specific issues they might be having with peers in their cooperative groups.

> I have been using journals more and more in the last three years. In this unit I use them for reflective kinds of things, not content-related: Goals, what students feel, want, don't want. When they do group work, if they have a problem I ask them to write it down and give it to me.

Further reinforcement of the theme of cooperation took place when Kit expected pairs of students to take responsibility for the set-up and maintainance of particular "stations" associated with the "Toys in Space" activities; and to complete two self-evaluation forms regarding their level of cooperation with their partners as they explored the "Toys in Space" exercises (see Appendix W) at the middle and end of the unit. Again, Kit directed students to reflect not just on the success or failure of their own actions, but also on the actions of their partners, and how both sets of insights could be built on for future collaborative efforts.

Kit's developing PCK of instructional strategies is visible in the way she encouraged students to use each other as resources for various parts of the unit like the planet brochures, and in the process, subtly reinforced their knowledge of planetary facts:

> I might ask, 'Okay, we're going to brainstorm catchy phrases today. Who needs help? Tell us about your planet.' And the kids will be able come up with creative thoughts for each other. I'll ask, 'Who has content to share? If you have a ton of astronomy, give some away! It's not cheating! You don't need it; they do! Ask them if they have some geology, because you're short on it.' I teach appropriate ways to share knowledge.

We also see it in action in the way she encourages understanding by having students simplify content into their own words and having students to help each other through humorous word play.

> Sometimes I ask, 'How could you get this across to your younger brother? Why would you want them to visit Mars? Visit the Mars bar factory?'

> I start joking. 'Can you get a pun on words?' and it triggers something else. Another kid might get them to go another step further. I have kids who are good with puns to help others; it builds self-esteem.

In an ironic twist, lack of resources during this year strengthened the learning community Kit was trying to build. Because she did not have enough science texts for every student to have his or her own, she instituted reading pairs, where students would share the text and read assignments together. By making what is usually a solitary activity into a social one, she found that students with less motivation and/or reading skill stayed more involved with written content and thus increased their comprehension. In this way, she inadvertently addressed the need for science teachers to work directly with students' reading processes to help them gain the most from texts (Rivard and Yore, 1992).

Wanting students to weave their new learning in science with their everyday lives in order to make the unit "more applicable to their needs and desires,"[12] Kit greatly expanded the scope of the unit by asking students to apply their science and social learning to the creation of their own space city. Ranging far afield of traditional textbook science, students had to think about such subjects as what to do about a currency system, how to make the judicial system fair, which toys they would want to bring because of the influence of microgravity and so on. To set the stage for this, at the suggestion of a student, Kit first showed the movie, *Star Trek: The Lost Generation,* to give students a visual picture of the problems associated with living in microgravity to help them anchor their ideas.

> Even the kids who hade seen Star Trek VI are really interested in it, because it now applies to what they are learning in class, which are technological considerations for building a space city. I will highlight when those things come up in the film, or when something is totally unreal. I also give them an article on Klingon speech which they have to summarize.[13] Some kids actually order the Klingon dictionary.

Students worked in groups to explore the "Human Considerations" and "Technological Considerations" for establishing a city in space. Asked to use both

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[12] This emphasis on the usefulness of knowledge echoes findings in research on effective teaching strategies for developing conceptual understanding (Eichinger & Ross, 1991).
[13] Gorman, J. (1993, April 5). Klingon: The final frontier. Time, p. 57. Adding to the interdisciplinary nature of the unit, the article details the linguistics of Klingon speech and how the language has been propagated by Trekkies on five continents.

imagination and social science knowledge, they grappled with how citizens would be selected, how the city would run, what the impact of microgravity would be on health care, and how inhabitants would entertain themselves. Pulling for application of scientific knowledge, questions also asked students to address issues of transportation, manufacturing, layout, food production, waste management and energy needs. Afterwards, students worked together to collate the entire class's responses to all the considerations, a task Kit felt they enjoyed because they were allowed to read each other's work and tally responses for each area. The practical skills of tallying and summarizing, she found, offered a potent exercise in synthesizing the group's ideas. In this respect, Kit offered students an opportunity to hear each other's thinking like that offered by "The Classroom Profile" Shapiro (1989) devised for helping students to become aware of the different ways their classmates conceptualized light.

Influences on Development

Experience with earlier unit versions had taught Kit that both she and students were fascinated by the vastness of space. She feels that she was now comfortable enough with her own level of knowledge to open the unit with students' questions and let them dictate to a much greater extent the unit's content and direction, echoing Shapiro's belief (1989) that with support, students' personal questions about content would take them further than any pre-designated activities in a teacher's guide. At the same time that she was becoming more responsive to students' interests, she feels that she was also becoming more intentional in the selection of core ideas to highlight. Her PCK of students' learning needs in the astronomy unit prompted her to see that in order to retain what they were learning, students needed an integrated sense of the universal context into which a logical progression of celestial facts could fit.

Kit also knew that she wanted to be more effective in helping students to develop the social skills needed to be successful and confident science students. As a result, instead of the whole class/individual format of the first four unit versions, students spent much more time in cooperative pairs and small groups, and consequently, more time discussing content among themselves. Her decision allowed her to capitalize on the power of social interaction Ball and Wilson discuss (1996) as a significant motivator for some students' learning. Using the cooperative format also created much more space for students' ideas to enter Kit's classroom:

> They help run the class. I am listening to hear what they have to say. I get worthwhile ideas and varied examples from them and file them away for the following year. I cover less material, but what I cover they understand much better.

Cooperative groups have also helped her stress the idea of revision in students' work habits:

> I stress that the best product is not the first product. I've really tried to support them on the evolution of their work. through constant correction, group brainstorms, focusing on a process. Most things are not a done deed, but yet my expectations are very clear.

Kit had encountered the "Young Astronaut" materials during the preceding summer when she developed a curriculum project under an Eisenhower grant awarded to colleagues from the local elementary school who wanted to design an interdisciplinary approach to the study of space during the "International Year of Space" and needed a middle school participant to qualify. The middle school teachers at Kit's school weren't interested in adopting the curriculum she devised, so she decided to integrate parts of it into her astronomy unit, strengthening its already multi-disciplinary flavor.

Data from the cosmonaut studies were part of a flood of information about space newly available in the West because of Peristroika. The Soviets had been able to gather knowledge about the effects of lack of gravity because Soviet cosmonauts were allowed to stay in space for much longer periods than their American counterparts.

Kit's decision to include the "Space City" activities was a way to help students integrate and apply their learning -- something she was increasingly seeing the value of. In this respect, the direction of her unit development mirrored the recommendations of science education authors Trowbridge & Bybee (1986), that science education should be a balance of study between a body of knowledge, scientific processes, and human enterprise so that students will develop an integrated view of scientific enterprise.

Sixth Version: 1993-1994

In this version, Kit began to use journals more extensively to permit a "tighter flow of information" between teacher and students and to continue to help her develop the unit around students' interests. Asked again at the time of the unit what students would most like to study about space, Kit began to see patterns in their responses: stars, black holes, and whether there were life on other planets -- topics not generally covered in pre-college science classes.

> What catches adolescents is feeling that astronomy is about them. Otherwise, why would they be concerned about a black hole or the death of the sun?

Kit also adopted an idea from Nora, now working full time in a neighboring school district and experimenting with her own version of the astronomy unit. Nora's idea was to have students create a poster about one of the major constellations. Kit thought this would help clarify students' understanding of interstellar relationships and bring the stars down to a human scale.

> They picked out of a hat which constellation to illustrate including seven associated with zodiac signs. The guy at the observatory gets furious when I let the kids do the zodiac constellations. I say it's mythology. These stories are of importance in the history of civilization. Students begin to find that out. Some stories are so funny -- the stuff of soap operas.[14]

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[14] Kit also had students read a news article debunking astrology, Andrew Fraknoi's, "Why astology believers should feel embarrassed" in the *San Jose Mercury News*, Sunday morning, May 8, 1988.

Pulling in language arts, she had her students sketch their constellations on large pieces of poster board, detail the associated mythologies, and tell how to find their constellation in the night sky.

> I bring in stick-on stickers of the stars that they can put in their constellations. Think they are the cat's meow. They bring in their own glow-in-the-dark stars, too.

As with the planet brochure, Kit established checkpoints by which students needed to have parts of the project done: references; the arrangement of the stars; a final drawing; notes on the mythology, and so on.

In this year, adding an art historical dimension, Kit had students read a newpaper article a paraprofessional brought in chronicling what the arrangement of the stars might have been to result in Van Gogh's depiction in his "Starry Night."[15] Her hope was to help students see that the night sky has been a source of fascination and inspiration from time immemorial and to see themselves within that context.

> Van Gogh was really a scientist. I have a large poster of "Starry Night" in the room. Students read how the night sky looked 106 years ago: This is Venus; this is the moon; and this is the way it was in the country Van Gogh painted in, which was at the same lattitude as our town. He synthesized the north view and the south view. Venus and the moon were part of the east view. We talk about it and students say, 'Oh my God, this [studying the night sky] has been going on for how many years?' I ask them to write a 5-7 sentence summary of what they learned from the article. It's also on tape for kids who can't read; they then dictate their answers to someone else.

Offering yet another interdisciplinary tie-in, to recognize exceptional creativity in students' planet brochures, Kit gave out "Arthur Dent" and "Ford Prefect" Awards in each class[16] based on characters in Douglas Adams's *Hitchhiker's Guide to the Galaxy*, and hoped that this would inspire more to pick up the book.

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[15] Article by John G. Radzilowicz in his column "Skybound," 1994, in the local paper.
[16] Ford did what the kids are doing -- offering a guide to various parts of the universe.

Influences on Development

The unit became more complex, yet easier for students, Kit feels, because it was increasingly tailored to their questions. Since she also saw herself in a process of discovery, she felt the unit had more vitality and less predictability than her other units which precluded her from falling into the trap of forgetting through repetition how hard some of the concepts could be:

> It changes all the time, even on the day of class. I know what I'm doing, but if they ask me a question I often say, 'Okay, we'll talk about this.'

Kit was beginning to realize a deeper core goal within the unit: Developing in students a sense of perspective on life within a universal context -- something the Van Gogh painting and the mythology on the constellation posters helped make clearer. She hoped this perspective would help them realize a common connection to generations of people before them:

> It's fascinating for students to look up at those stars and think that someone else looked up at the stars two thousand years ago and wondered like they do.

Seventh Version: 1994-1996

During this version, Kit primed students' questions about science in general and space in particular by stressing current events for the first two quarters of the year.

> You had to pass in a written report and give a thirty second presentation to the class...four kids per Friday. It opened their eyes so much. 'Oh, did you see this? I saw that and my mom said this.' It didn't have to be about stars.

These Friday discussions opened students to the myriad ways science enters our lives and increased conversation between themselves and parents. This history of shared conversation, she found, lay a solid foundation for the unit's success at a point in the school year (late spring) when many students disengage.[17]

[17] Kit points out that the timing of the unit is significant in terms of her approach. At the start of the year her units are typically more teacher-dominated than at the end when students have internalized

In this version, Kit added two more videos: One depicted the first moon walk; another, interesting pictures, animation, subtitling, and space music, along with up-to-the minute shots of the planets.[18] These photos helped students decide which planets they wanted to pick for their brochures. She also added several worksheets and a lecture on the asteroids which had been receiving more press. A student brought in an article on meteors, asteroids, and craters which pointed out that professional asteroid and comet-watchers are paid up to $50,000 to watch the sky. It mentioned how asteroids are named which helped Kit realize that studying the asteroids could be another way to make space more personal.

> I wanted them to see that they could name an asteroid after you and you don't have to be anybody brilliant. You could see these things, too.

Coincidentally, she had just been listening to an NPR broadcast about one of these of these people and learned that only within a couple of years an asteroid had passed between the moon and the Earth in a very close encounter. Through sharing material like this she felt she was able to reinforce the unfolding drama of science.

At this point in the unit's development, the text is used only as a resource:

> We don't have a text, except as a reference: Holt, Rinehart's *Earth Science*. I don't have enough books. Next year we will be adding one called *Exploring the Universe,* which is a little trade book. I think kids will be more apt to use it than their texts.
>
> Students were not pleased with the way Kit had designed the final test. There were some disgruntled feelings that students didn't do as well because they didn't get to show all they knew, or the test didn't ask things students felt were important. It's interesting that kids would come up with those feelings. Most of the grades were A or B.

Students' reactions suggest a position of authority over the material that made it seem like the test was taking them, rather than the other way around. Kit projected the grades on the overhead and had students process their overall performance as a class, which she felt many found both interesting and useful.

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the expectations, social skills, and the general *modus operandi* of her science class. At the latter end of the year students and teacher are more relaxed and flexible because of a shared history of accomplishment and pleasure.

[18] A student brought this in and Kit used it on a day when she was out. Commenting in this regard, she says, "A lot of stuff comes from students and I just capitalize on that."

Influences on Development

After showing the Moonwalk video, Kit realized that most students didn't realize how small the Apollo capsule was and that they had little understanding of the progress made to create the space shuttle, given the humble nature of the first manned space flights. For the next version, Kit decided to spend $100 on a book of pictures from the Voyager II mission and expand students' sense of the history of the space program, so that they could truly appreciate the technological accomplishment the shuttle represented.

> At the start of the unit some students don't have enough of a foundation even to say what they want to know. The kid that has the questions already knows about the planets. He follows the satellites, knows the Apollo mission to the moon, has seen those pictures. Most didn't know that it was a tiny capsule. I took it as a given. They needed to see why the space shuttle is so incredible -- what more technology actually gives you: A 59 ton payload, able to take up more people, stay up longer, communicate with Earth, get around the moon, not land in the ocean. Students don't have a context for appreciating that piece.

Offering not just a celestial context, but also an historical one seems to be a deep goal Kit has uncovered through her years of teaching the unit. Ironically, what started out to be a look at the present and future has also become an opportunity to examine the legacies of the past.

> One of the things I think kids don't have is a historical perspective. This unit gives them a better understanding of people not their own age, which has been lost because we don't have extended families in our own homes any more. You used to learn perspective automatically through respecting the knowledge of your grandparents. Even ten years ago there was more of this than I see now. Acknowledgement of the past helps students see the rainbow instead of the color red. They come to view their parents differently and understand why there are different attitudes about things, like why you don't care if you leave the faucet running, but grandmother does because she used to bring in water by the bucket load from the well.

Eighth Version: 1996-1997

In her most recent version, Kit updated her slides of the planets by using recent satellite pictures set to classical music. She substituted the movie *Apollo 13* for *Star Trek*

VI, finding that it gave students a much clearer context and appreciation for space exploration. Kit established a list of criteria that the planet brochures had to meet (see Appendix X) and expanded the range of project options to include such things as store catalogues ("Charon's" -- where you can buy such items as "'Craters, Inc. Nailpolish' inspired by the reflective yellow methane ice found on Pluto") and cookbooks ("Our chefs have traveled over 4.67 billion miles from Earth to Pluto to discover a taste that is out of this world!") She is finding that students synthesized more content into their projects this year because of her PCK of how to ask for it.

Perhaps the greatest change in the unit, however, is that Kit has done away with the space city exercise in order to create the time to accommodate the problem-based, cooperative format of "Education by Design." Instead of lecturing, she broke questions she would have addressed into clusters and gave them to groups of students to teach each other. She also had students design, correct, and grade homework for their peers, based on what they had been responsible for teaching. This change produced the following humorous exchange between Kit and one student, exasperated because her peers hadn't gotten their work done:

> *Girl:* *Six kids didn't do my homework. Is it my fault?*
>
> Kit: Did you give them a clear deadline, support them, and remind them?
>
> *Girl:* *Yes, all of it! (Pause) Is this why teachers are so crabby?*
>
> Kit: Yes, they think it's their fault when students don't do their homework. They feel responsible. If you have done everything you can, you will just have to give them zeroes. They will have to learn, in this case, by not succeeding.

Learning by not succeeding, within limits, is what prompted Kit to observe at the start of this case that teaching is partly about having students "take their falls." She sees that asking for excellence involves some risk. She has learned that her students have to be allowed to experience a certain level of frustration and confusion before they reap the pleasure of figuring something out for themselves. Developing the PCK of how to leave room for the right amount of stumbling has been challenging and extraordinarily valuable, she feels, for ensuring the kind of engagement with content and processes she seeks.

Reflections on the History of the Unit

Over the course of nine years, the unit has grown from two to six weeks, from emphasizing physics and astronomy to including mythology, social studies, art, history, and technology. Reflecting a general trend in her teaching, Kit sees the unit as becoming increasingly centered on psychological and interpersonal issues and those content questions of most interest to adolescents. Her approach has become increasingly student-centered and constructivist. She has evolved from wanting students to learn a little about space to having both cognitive and affective outcomes: cognitively, how to compare and contrast information, how to find, synthesize and use information; affectively, how to interact and solve interpersonal problems and to understand that the whole is greater than the sum of its parts. Her goals have come into sharper focus over time.

> My core objectives are in my heart, I am beginning to realize. I've never really put them into words, although they are becoming very visible to me as I talk with you. Though I do want students to increase their knowledge about astronomy, content has never really been a major thing for me. Science is the vehicle to do what I need to do. I am giving students a reality base to help them determine how people weave fact and fiction; to teach them to rely on their own intuition and knowledge to make appropriate decisions; to foster creativity, love of learning, wonder about their world and empowerment -- things I didn't have as a child. These are the motivating factors of my whole teaching career.

Kit replaced the original biographical sketches with creative projects because it was hard to find meaningful information. Her experiences with these projects, new content, and curricular knowledge prompted the development of her PCK of instructional strategies: She decided to limit the initial scope of projects and create more structure to provide guaranteed engagement with core knowledge and uniformly higher quality products. Four lectures lay the groundwork for the projects -- her PCK of students' needs in the astronomy unit prompting her to sequence them in such a way that students had a coherent and integrated context in which to learn about the planets and the physics of the "Toys in Space." This past year, instead of lecturing, she had students teach each other the content, but now sees the need to model effective teaching so students can become more effective instructors in their own right.

Kit's growing PCK of instructional strategies and students' needs have prompted her to integrate and reinforce the components of the unit in multiple ways.[19] For example, students learn about the teamwork needed to put people in space at the same time that they practice teamwork in their activity groups. Connections are made between issues arising within these work groups and the eventual need for students to work with people in real job settings.

Kit's PCK of instructional strategies has expanded to accommodate hetergeneous performance levels in a variety of ways. Readings for technology and human considerations for space colonization, for example, are offered at different levels of difficulty.

> They have different readings pulled from all over the place written at various reading levels; they may or may not have to do with the exact issues, but are related to space, UFOs, solar energy, the colonization of space, the design of space cities. One of the big things they wrestle with is whether kids should be allowed in space.

Kit has introduced children's books which invite visualization in students of all levels; she encourages confidence in all students through stressing humor. Small-group work encourages question-asking among students and students becoming resources for each other. Over the last four or five years she has given more time to those who needed it, while supplementing with additional activities (e.g., the astronomy-related computer programs) for those who move faster.

Kit's PCK of accommodating students of different performance levels also shows up in becoming more deliberate and more repetitive, weaving earlier learning into different parts of the unit, e.g., comparing the size of volcanoes on Mars to those on earth and

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[19] See Table 4, "Representations of Core Ideas in the Astonomy Unit."

having students compare their planets to what they had learned about the Earth in earlier units on earth science. Bringing relevant books from the library into her room has made acquiring factual knowledge easier for all students. Having kids help each other over "the hard spots" as been a boon to slower students. Finally, she has raised the level of performance for all students from factual recall on planets and the "Toys in Space" quizzes to include creative syntheses of facts related to planets; and questions in story form for an application to live in a Space City which require students to personalize the information and pull from all parts of the unit.

Over time, the moral dimension of the astronomy unit has become increasingly pronounced. Self-knowledge as a prerequisite for being a responsible member of a community is one thread of this theme -- something Kit has reinforced by putting much of the assessment of learning in students' hands and having them compare themselves against themselves. An increasing emphasis on empathy has also characterized recent unit versions.[20]

Kit's PCK of her goals for instruction, her PCK of teaching strategies for the unit, and her PCK of students' needs have been positively affected by the cooperative learning format she has adopted in recent years. Greater access to a much wider range of student ideas afforded by this format has expanded her repertoire of instructional representations. She has become more flexible in what she emphasizes and more multi-modal the more she has listened to students' interests and suggestions. Students' questions and needs prompted her to seek out other teachers, workshops, conventions, grant opportunities, current events and curricular materials. She saw in students the need for humor, creativity, self-expression, and freedom, recognizing that she had those same needs both as a student and as a teacher. Though she realized the need for these much earlier, the time, materials and

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[20] For example, she included an activity called "Parting Gifts" asking students to consider what they would give to an international colleague with whom they had cohabitated in space for six months; videos subtitled for the deaf; asking students what they would miss most about life on earth if they went to live in space; and the communication activity on building a space station which students kept at until they successfully communicated with their partners.

organizational support of her student teacher only allowed her to bring these qualities into the unit in the last three to four years, bringing home the humbling truth that often we imagine better than we can teach.

The longer she teaches, the more flexible Kit is becoming relative to the direction of the unit. The stages in the evolution of her PCK relative to purposes for instruction and instructional strategies might be mapped as follows:

1) Text-dominated objectives using mainly reading and some experimentation for acquiring information; projects and short-answer formats for reporting what's been learned.

2) Text- and activity-dominated objectives using multi-media lectures in addition to reading, videos, and experimentation.

3) Developing more affective goals and more clearly articulated cognitive goals geared around students' needs and interests; increasing opportunities to integrate learning around goals using multiple modes (visual, auditory, kinesthetic).

4) Developing small, concrete steps needed to support creative processes in students while reaching toward the goals just listed.

5) Turning over increasing amounts of the delivery of content to to students to teach each other in carefully structured cooperative groups in order to enhance motivation and retention.

6) Finding a balance between student-led and teacher-led teaching so that students can observe her modeling effective teaching for them to emulate with their peers.

The Evolution of Kit's PCK of Instructional Representations

Table 4 (next page) shows the core concepts in the astronomy unit and the various ways Kit has represented them over the years. Because the unit is six weeks long, Kit has evolved many goals and ways of reaching them. Three of the most concrete representations are discussed subsquently.

Table 4: Representations of Core Concepts in the Astronomy Unit

Key: A = Analogy (Teacher, student, or text-made); D = Demonstration (By teacher or student); E = Example (By teacher or student); I = Illustration (Teacher, student or text); M = Modeling (By teacher or student); S = Simulation (by students under teacher guidance)

CONCEPT	REPRESENTATION	WHEN USED	SOURCE
Structure of the Universe	(I) Solar Seas -- Video	1988-1989	School Library. Dropped after one year because it was too dull
	(I) Probing the Planets -- Video	1989-1990	School Library.
	(I) Pictures of spiral galaxy	1991-now	Reference books
	(I) NASA lecture: History of space; slides, music	1991-now	Kit created. Slides were free as part of NSTA Boston Conference.
	(I) MY PLACE IN SPACE (children's book)	1992-now	Came across it when looking for books for her own children
	(D) Snaps fingers: light circles Earth 17 times; nearest star is 4.7 LY	1992-now	Kit's idea based on various texts she found to answer students' questions
	(E) Constellation poster	1993-now	Nora, former student teacher and job-share partner, now teaching at a local middle school
	(I) "My Very Educated Mother" (video)	1990-now	NASA Center at Champlain College
	(?) Asteroids	1994-now	Zinn, *Guide to the Stars*

Table 4, Continued

CONCEPT	REPRESENTATON	WHEN USED	SOURCE
Rotation & Revolution	(D) Month-long moon observation, complete chart	1991-now	Regional science convention
	(E) Planet brochure	1991-now	NCTS convention
	(I) Ms. Frizzle's chart on length of a year for planets in the solar system	1993-now	Cole & Degnan (1990), *The magic school bus: Lost in the solar system* - - Kit's idea
	(S) Simulation using sun, earth, & constellation posters	1993-now	Kit's idea
	(S) Styrofoam balls lab	1993-now	Regional science convention
Gravity	(D) "Toys in Space" activities and video	1988-now	College resource center
	(D) Designing a space station/colony	1992-now	Young Astronaut Program materials
	(I) Asimov short stories	1993-now	NCST convention
	(I) Ms. Frizzle's chart on wt./mass on planets in the solar system	1993-now	Cole & Degnan (1990), *The magic school bus: Lost in the solar system*
	(I) Moonwalk video	1994-now	School library
	(I) Asimov video	1994-now	Student brought it in
Science as Evolving	(I) Worksheet: Remembering History	1993	(NASA) Young Astronaut Council materials, 1990
	(I) Current events	1994	Kit's awareness of the nature of the discipline as not fixed and certain, but growing and tentative
	(I) Video on Apollo	1994	
	(E) Space as another frontier -- e.g., Pluto might be two planets	1994	

Table 4, Continued

CONCEPT	REPRESENTATION	WHEN USED	SOURCE
Cooperation	(D) Lost on the Moon Exercise: Getting to space via communal knowledge	1993	From Steve Kagan's (1989), *Resources for Teachers*
	(D) Space station communication exercise (NASA, 1989)	1993	Eisenhower grant materials furnished by a colleague
	(I) Learning from each other: Students review each other's projects; Use each other as references	1988-on	Own idea
	(D) Read aloud in pairs	1993-1995	Necessity -- not enough textbooks
	(I) Constructing a Space City worksheet, (YAC, 1992)	1993-on	Eisenhower grant materials (Young Astronaut Program) furnished by a colleague
	(D) Communication exercise; log entries on interpersonal concerns	1993- on	" " "
	(I) Cooperating in Space worksheet (YAC, 1989)	1993- on	" " "
	(I) Worksheet on Parting Gifts, emphasizing mutual respect	1992-on	" " . "
	(I) Subtitled videos for the deaf	1992-now	School library (My Very Educated Mother... and Asimov)
	(D) Communication activity: Students are both receivers and givers of information; keep doing it until they succeed.	1992-on	Regional science convention
	(D) Responsible for maintaining Toys station for other students' use	1988 - on	Kit's idea
	(D) Students generate behavioral expectations and consequences	1993	Kit's idea
	(I) Self- evaluation sheets as part of the Toys Activity	1992-on	Inspired by a cooperative learning workshop
	(D) Students take notes on overhead for the class; frees teacher to circulate	1992-now	Kit's idea
	(D) Students keep the class log book for absentees	1992-	Nora's idea? Needed to help stay organized in her half time job.

Table 4, Continued

CONCEPT	REPRESENTATION	WHEN USED	SOURCE
Confidence	(M) Models that Kit's doesn't know all the answers.	1988-now	Inspired by her first cooperating teacher
	(M) To dispel anxiety invites humor in the planet brochures, *Astro Smiles* video, and in the headdresses of the Earth and Sun in the rotation simulation	1988-now	Kit's ideas
Perspective	(D) On self: Increase awareness of possibilities and expansion of self via creative presentations of content (stories, puppets, music, models, etc.)	1988-1991	Kit's idea
	(D) On Earth: Planet brochure; Space city activity	1991-now	NSTA Convention
	(D) On teacher: Fair classroom, yet teacher admits to getting angry and making mistakes sometimes	1993-1994	Kit's idea (using journals as one medium to resolve conflicts and inform Kit about them.)
	(I) On self in the universe: Article on Van Gogh's Starry Night reminds students that others before them have pondered the night sky; and that they can "interpret" Van Gogh's painting w/ their new knowledge	1993-present	Paraprofessional or spouse
	(?) On self (decentering): Comfort of knowing that students' problems are small in the scheme of the universe	1993-present	Kit's idea
	(I) On Society's Needs: Star Trek VI; addressing human and technological concerns in designing their space city	1993	Student introduced idea of watching the movie.

Earth Dance: Rotation and Revolution

Kit used this representation for the first time during the fifth unit version. She decided that she needed a more vivid way to show the difference between rotation and revolution because students didn't know it and/or couldn't remember it. She literally dreamed up the idea of having them simulate the relationship between earth and sun.

> The way I solicit kids is hysterical, because I ask, 'Who wants to be the center of the Universe? Who has a bright shiny personality?' Six, seven, eight hands would go up. They stand up there and essentially do nothing. It's a scream. And for Earth: 'Who's a really down to earth person? Warm and trusting and welcoming? Who do we have here?' Usually a girl who takes dance class volunteers because she has to pirouette. I highlight Earth with a globe and we talk about the characteristics of the planet -- 'It has white clouds, therefore water vapor... .' It's kind of a review of their lecture. Earth spins on her axis, and I say, 'This is rotation. Now let's talk about revolution. No, I'm not talking about war!' and lights go on! No kid gets rotation and revolution wrong if they are in there, walking it, seeing it and laughing about it. Whereas, if they miss that class, they never get it!

Taking the representation further, the second year Kit made several changes. First she realized that she could integrate students' constellation posters in the simulation to reinforce interstellar relationships and the way the Earth's orientation at different points in the year would produce different views of the heavens. She had fourteen other students hold up their posters around the perimeter of the room as a back drop to pirouetting "Earth" revolving around "Sun."

> One of the things the kids want to know is why we see different stars in the sky. I set up the zodiacal constellations around the sun and ask why they can see the Milky Way in the summer but not in the winter. I compare our galaxy to a pin wheel and show them a picture: 'This is where you are. You are looking out in this direction.' We talk about how we are in a spiral galaxy, and in the winter we are looking out toward the little third of the arm that we're on into interstellar space. Then, in summer, when we are on the other side of our sun, we are looking inward toward the center of the Milky Way at the rest of our galaxy. 'That's where you see all those stars, and those are stars you are going to see in the next four weeks.' This lays the basis for why we have meteor showers at certain times of year, because we are looking at what's in a different part of the sky.
>
> It was just magical to see them understand why the Milky Way is visible in the summer and not in the winter. It was the first time I really understood it, what the constellations stand for, and how the ancients dictated their seasons by the zodiacal signs. Awe-inspiring.

Students could easily see which constellations they could expect to spot in the summer and whether *theirs* was among them. In this way Kit's PCK of how to use this representation helped her bridge between the concepts of rotation and revolution and students' personal projects.

Second, Kit further reinforced the difference between rotation and revolution with a mnemonic hook:

> I give them two notes at the end of that class defining rotation and revolution and giving the length of time of each for Earth. I also told them, 'Rotation has an "a" in it for day; revolution has an "e" for year.' You'll hear them quoting it to you.

She then built on the representation by asking students' to connect it with their new knowledge about the planets they had selected for their next astronomy project.

> Homework the night after the simulation is to get the rotation, revolution and weight for their planet from Ms. Frizzle's chart [from *The Magic School Bus: Lost in the Solar System*. They come in the next day and we discuss it. (We assume that weight and mass are the same for now.) Just before I start the slides of the planets, I show the five minute video, *My Very Educated Mother Just Served Us Nine Pizza Pies*. They fill out a worksheet as they watch the video, which we watch twice. They can color their worksheet at home for extra credit. I have them write the jingle down next to the planets. The next day I give them a mini-quiz with five questions: Write the jingle, give the names of the second and seventh planets, what's rotation, and what length of time is associated with it? Generally they all ace it.

Finally, Kit created headdresses for the sun and earth: A golden fan for the sun with a space for the face to peek out and a rainbow with clouds to represent the unique presence of water vapor in Earth's atmosphere. Kit feels that these props help students more easily distinguish the celestial bodies and remember their relationships to each other.

For the third version, Kit has added Earth's moon and has a student revolve around Earth always showing her face, while Earth revolves around Sun. Moon also sports a headdress to help illustrate this additional structural complexity and lay a foundation for a later representation of lunar phases.

Toys in Space

Kit used the these representations the second year of the astronomy unit and has included them ever since. She established six student-maintained stations, each featuring a toy for students to observe: A paper airplane; a gyroscope; a yo-yo; paddleballs; magnetic marbles; and a slinky.[21] She asked them to hypothesize about the toys' behavior under the conditions of microgravity based on what the toys did on earth. Each student was given a set of questions for each toy.

> I wanted to expose the kids to that set of lost arts: playing with non-technological toys like jacks, yo-yos, airplanes, and tops. It's amazing how many of these kids have never played with these things, never made a paper airplane, and they are in 8th grade! It's very hands on, very interactive. It fits the kids because they can get up, move, and socialize while they extrapolate. They come to learn some physical laws and how important gravity is in their own world.

Having students make predictions and justify them, before learning what the toys actually did in space and why, allowed Kit to lead them through a process intentionally built on their prior knowledge and beliefs, a process recommended as necessary for creating conceptual change (e.g., Kinnear, 1994; Ross, in Saul & Jagusch, 1991).

Students worked in pairs, rotating through the eight stations, until all had experimented and hypothesized.

> I showed them the videos *Astrosmiles* and *Toys in Space* where they could actually see the toys working in space and if what they had predicted was accurate.

Kit then gave students a written answer key detailing several principles of physics underlying the toys' behavior on Earth (see Appendix Y) as well as what would happen to all the toys if played with in space (see Appendix Z for a sampling). Since the video didn't cover all the toys and covered some students hadn't experimented with, Kit made sure students also had the written key, which contained material the video excluded.

> After we watch the videos I ask, 'What did you think the toys would do? What did they actually do?' Students correct answers by looking, reading, and listening. The answer key they can take and read on their own. They go through and add anything they can to their answers. I review everything as we look at the videos. They usually ace the "quest"[quiz/test].

The original answer sheets Kit gave students asked them to respond to four or five questions related to the activities for two different toys per page, but she found that students

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[21] To accommodate the whole class in small groups, Kit created two more stations, one featuring a NASA computer program with space hangman, a flight simulation of travel through the night sky, later replaced by SimEarth,which reviewed the entire year of geology, astronomy, meteorology, oceanography, in addition to new materials associated with astronomy, and another featuring trivia "space cards."

needed more room to write their observations, so for the next use, Kit retyped the questions giving more space. The second time around, Kit found that students were still unclear that they would be contrasting the behavior of toys on Earth with behavior in space, so she retyped the questions, featuring one toy per page and made room for students to write in both sets of observations, hypotheses, and facts.

In later years, Kit's PCK of concept-oriented teaching has taught her how to use the representation more intentionally as a basis for reinforcing other cognitive and affective aspects of the unit, reflecting the recommendation of researchers that concept-oriented teachers link concepts to achieve deeper understanding and greater retention (Brooks & Brooks, 1993; Eichinger & Roth, 1991; Prawat,1989, 1993):

> I've added a little bit more to the physical science part by introducing the concepts of centripedal and centrifugal force. I use these activities to increase students' awareness of the difficulties of being in space, as they go to plan a space city. We talk about the problems associated with microgravity. The videos lay more of a basis, a visual picture. They react to them a lot. These exercises also help them when they do their planet brochures because they are now more cognizant of the downward pull, and how it varies from planet to planet. It helps them really use their learning: 'What do you know, and how can you *apply it* to the problem or situation?' They come to see that they are very intimate with gravity. Thinking about it really forces them to decenter. They take the air they breathe, the water they drink, and gravity for granted; they expand outward and begin to ask 'What if?'

Kit's PCK of how to build on students' responses has grown as a result of observing that they weren't used to using what they already knew in the context of a classroom activity such as this one. She finds that it takes a while for them to overcome their socialization as passive receivers and begin to recognize and apply existing knowledge in making predictions. This brings to mind an observation by Hofer and Pintrich (1997) that

> instructional elements... including the nature of tasks...classroom structure, the physical arrangement of the classroom, reward systems, and textbook organization and language carry epistemological impact. (p. 124)

Students socialized in other classes to expect learning encounters to be close-ended and one-way must shift their expectations to become active agents. As they are supported to do this, Kit feels that they are quicker to replace their misconceptions.

Moon Phases Using Styrofoam Lollipops

Kit lay a foundation for this representation by having students observe the moon's location and phases a month before starting the fifth version of the unit. Toward the end of that version, she had students crowd into the supply closet where she gave them styrofoam lollipops to represent the moon and had them rotate as a group, so that they could observe the way a shadow cast from a lamp she was holding would hit the lollipops. With each rotation, they observed the shadow and would call out the particular phase the "moon" was in.

Kit didn't use the representation during the next version as it was timed for late in the unit and the year ended before she could fit it in. For the seventh unit version, based on sensing from the earlier try that the content was too difficult and not working for the majority, Kit laid more extensive groundwork for the representation. In addition to observing the moon and answering questions about its location one month before the start of the unit, she had them read in pairs about the moon's phases in their text, draw and name the phases, then orally rehearse what the text said in groups of eight or nine at the front of the room while the rest of the class was involved in two other activities. Only then did she move students into the back room for the lab itself, which she found took much less time because of her set-up activities. Since this lab coincided with a classroom visit, I was to observe students' delight at being easily able to name the correct phases and even identify solar and lunar eclipses.

> It was the first time they had defined gibbous, waxing, waning, etc., and then drew the phases of crescent, first quarter, full, last quarter, before we did the lab. It was slick as can be. The lab only took ten minutes. In the past, it took a lot longer. I couldn't believe how it facilitated what we did in that back room. It's the first time in my life that this stuff began to make sense to me. Really exciting!

What was particularly remarkable was that the lab took place during the last week of school. Kit commented:

> I heard students saying, 'It was a full moon last night. What's it going to do tomorrow? The next night? What's it going to be in a

> couple of days? A waning gibbous!' That's right! And this is a group that is highly social and disengaged from other courses weeks ago.

Students' enthusiastically skilled response to the moon phase lab lends support for the notion that developing and using technical vocabulary seems a likely indicator that they have begun to understand the relationships depicted.

It is also likely that the success of this representation came in part from its timing late in the unit, after students had already experienced the "Earth dance" simulation in which the concepts of rotation and revolution had been illustrated. In this respect, Kit produced the three conditions Eichinger and Roth (1991) found to be associated with conceptual development: "connectedness among concepts, connectedness to prior knowledge, and usefulness."

In its most recent incarnation, inspired by her EBD workshop, Kit has added some additional steps to enhance the simulation's effectiveness. She now has students both draw the shape and name the location of the moon during the month before the unit begins. Just before she introduces the lollipop simulation she gives groups of students a 6 inch by 6 inch sheet with all the moon phases out of order. Also included are the various phase names which are in order. Students cut out each phase and paste it in sequence on poster board, with the correct label beneath. To do this, they "scramble" for their notes and the text as resources to guide them. Then they present their posters to the rest of the class who critique it. Only after the class has listened to 4-7 of these quick presentations does Kit conduct the lab, and now it is done with the whole class in her darkened room. To help students remember the difference between waxing and waning she offers several mnemonic hooks:

> 'Light right on waxing night,' and 'The left is lit on the last quarter.'

She is finding that this sequence produces high involvement and high retention.

Reflections on the Nature and Use of Kit's PCK of Instructional Representations

All of Kit's instructional representations allow students to get up out of their seats and appeal to a sense of play -- qualities Kit has found intuitively attractive.

> The activities I am excited about all have the same elements. They are hands-on, social, interactive, make students take a bit of a risk, and have surprises at the end. I realize it's always the same things that catch me. It's all sub-conscious. I'll go: 'That's IT! I want it!'

The styrofoam balls and the toys both came from sources other than herself; the Earth dance was her own idea. As her experiences with the representations have accumulated, so has her subject matter knowledge of the concepts they portray. Over time this understanding has allowed her to contextualize each representation more fully through preliminary activities like creating the constellation posters first, then using them in the Earthdance simulation or having students read, draw, and sequence the moon's phases before engaging in the lab. She has also become more skillful in integrating the concepts embedded in each representation into other areas of the unit, as for example weaving students' observations about the effects on microgravity on the toys into their considerations for designing a city in space.

Summary of Influences on Kit's PCK Development

From Herself

Her Upbringing

Kit's interest in psychology stemming from challenges in her family of origin prompted her to see the importance of developing students' social skills and confidence in decision-making -- which her later exposure to cooperative learning validated. From her mother she gained a love of the arts which makes its way into the dramatic, multi-modal representations she is drawn to and the project opportunities she provides students. Her father's high standards carry through in Kit's classroom expectations and careful structuring of student experiences with representations and other unit elements.

Her Experiences as a Student

As a student, Kit reported learning the most enjoyably and hence completely from the few opportunities in which she could use humor and creativity in independent projects. Offering students early on the chance to express themselves similarly, while they learned about astronomy, significantly enhanced her PCK by allowing her to observe what they were cabable of, what their interests were, and where she needed to provide structure to raise the level of performance across the board. Her PCK of students' affective and cognitive needs expanded significantly when she began to be less center-stage (something she was never comfortable with, but which was the model she saw in school) and divided class time into her time, students' time, and closing activities. Through this format and the use of journals in later years she has been able to learn a great deal more about her students' needs and interests. These insights have worked their way into her PCK of instructional strategies, prompting her, for example, to gain excellence through supporting all students to meet her high standards by breaking projects down into detailed smaller steps.

Her Subject Matter Knowledge

Much of Kit's subject matter knowledge has been gained on the job, as her major, zoology, is only a small part of her middle school curriculum, which features earth science for eighth graders and life science for seventh. In this respect, her experience appears to echo the findings of Smith and Neale (1991) that less than adequate subject matter knowledge of science was the norm in the primary teachers they studied. Unlike the teachers in Smith and Neale's study, however, both the nature and depth of Kit's subject matter knowledge have continued to grow the longer she has taught and the more she has integrated new materials and pursued further education. Her recent successes with "Education By Design" bring to mind the findings of researchers who noticed that more knowledgeable elementary science teachers responded better to training in constructivist methods than those with less knowledge, providing they agreed with the notion that "less is more" which Kit clearly does (Smith & Neale, 1991; Anderson & Roth, 1989; Hollon, Roth & Anderson, 1991).

Kit chose to major in science because of her perception of it as a stable and well-organized body of knowledge. About six years ago, two insights precipitated a paradigm shift in Kit's perception of the discipline: first, she became familiar with the uncertainties at the heart of sub-atomic physics through her reading and conversations with another science teacher. These altered her sense of science as a set of fixed truths. Second, the accelerating growth in scientific knowledge in the areas of technology and immunology/cancer forced her to see the impossibility of "covering" anything fully, prompting a greater emphasis on students' skills and attitudes about themselves as managers of information. For these reasons, she has come to resemble the high knowledge teacher in Brickhouse's study (1990) who regarded scientific theories as "tools to think with," rather than as rigid truth and those who perceive science as a relatively burgeoning "conceptual context" (Stodolsky & Grossman, 1995).

These changes have influenced Kit's PCK of purposes for instruction. She has become more intentional in stressing both scientific and self knowledge, critical and creative thinking. By placing space in context -- both structurally, in clarifying how our earth relates to other celestial bodies, and mythologically, as a source of inspiration for people throughout time -- Kit has made astronomy increasingly accessible to students.

Changes in Kit's view of her subject matter have also influenced her PCK of instructional strategies. Because the content of the astronomy unit has been relatively unfamiliar, she has had the experience of learning along with her students, mirroring the on-going discoveries of scientists and imbuing the unit with a certain drama and excitement. She now seeks a balance between structure and spontaneity, taking time as needed from her planned agenda to address unanticipated questions and needs. In this respect, she seems to resemble the high knowledge physics and biology teachers Hashweh (1987) studied who were better able to connect material across topics and concepts, assess and respond more effectively to students' preconceptions, and make the most of teachable moments.

Her Teacher Education

Kit has increasingly synthesized the legacies of her master teachers: balancing letting go of control so that there is room for the unexpected, to be responsive to these moments, make changes, and be emotionally honest, while at the same time creating a safe and structured environment in which all students could succeed. She has become comfortable with viewing teaching as a form of learning, where revisions of her PCK are healthy and appropriate and often come from observing and responding to students' reactions to her plans. In her words, "I am constantly reeducating myself."

Her Philosophy of Education

Kit's practice and associated PCK appear to draw from three philosophical traditions: Idealism, Pragmatism, and Existentialism. She conceives of her role as a facilitator, coach, and encourager (Pragmatic) who helps students pursue what interests them in the service of becoming authentic (Existential), while empathizing with their experiences and helping them develop their character (Idealistic):

> I'm stressing the emotional well-being, communication, empathy, because without that your knowledge is not going to be helpful. It's

> working on E.Q. -- emotional intelligence. When their E.Q. is at a certain competence level, kids can take in all kinds of stuff, develop the skills to be able to do whatever they need to do.

She sees her purposes as helping students' develop self-knowledge (Idealistic) in order to have a dynamic relationship between themselves and the world. Emphasizing growth and meaning is important to her in order to bring about positive social change (Pragmatic), and awakening in students the responsibility for directing their moral lives (Existential). Her PCK of instructional strategies draws from the Idealistic tradition in stressing mnemonics and whole-part-whole relationships, and the Pragmatic in emphasizing learning by doing, multiple modes, connecting learning to life, and flexible grouping for instruction. Her curriculum has aspects of the Pragmatic tradition in its emphasis on current events and interdisciplinary connections; and aspects of the Existential, in providing students with opportunities to take risks and self-evaluate.

Kit's attitude toward assessment seems opposed to a Realistic approach with its value for objective standards, though she communicates clear standards to students and has recently had students generate assessment rubrics by which to evaluate themselves and each other (Pragmatic). She also seems opposed to the Classical emphasis on rigorous tests favoring careful recall of facts, even though her tests ask for this. She sees herself as more aligned with essay exams stressing students' own ideas (Idealistic) and the wide-ranging criteria associated with Pragmatism.

Kit's approach to planning emphasizes student input (Pragmatic) and building on teachable moments (Existential). Her room has the feel and look of a place emphasizing Pragmatic ideals in that it features desks which can be flexibly arranged, focus areas, displays of students' work, plants, and her desk off to the side.

Of the three representations discussed above (lollipops, toys, and the Earthdance), Kit's PCK around them seems most closely linked with the Pragmatic tradition, with its emphasis on learning by doing, though elements of the Existential come through in the self-evaluations associated with the toys activities and journal entries.

Her Inner Representations of Core Ideas

Kit sees content as less and less what teaching is about, viewing her role as more about fostering creativity and a safe and interesting environment in which to try things out. She feels that as a result of having to teach science she understands content better now than she used to, and consequently has become more systematic in her approach and more detail-oriented in order to help others understand it. My sense of the way she perceives the science content of the astronomy unit is as a figure eight, spiraling down from the outer reaches of the universe and converging on Earth, before spiraling out again to look at the behavior of the moon and the implications for colonizing space. Her inner view of the social aspects of her curriculum seems more like a series of feedback loops between students and the work; students and each other; students and her; students and their lives beyond the classroom. My sense of her view of her teaching as a whole is as an ever-widening spiral, where she expects more and more of students each year and during the course of a given year builds on ever widening layers of understanding.

Her Epistemological Commitment

Kit's student teaching helped her see that the teacher doesn't need to know everything which gave her permission to shift away from dualistic approaches to knowledge and more toward a view of science (and teaching) as a series of "logistical steps" where "nothing is ever wrong, just different." This has elements of Perry's *Relativism* and Belenky et. al.'s, *Separated Procedural Knowing* (see Appendix A). The latter position is also evident in Kit's emphasis on modeling, comparing, connecting, and breaking down large assignments into manageable pieces.

> Initially I felt myself as being a giver of information. How I see myself now is someone who empowers others to find information...more of the mentor, the coach, who doesn't need to have all the answers, who can have her own questions.

Since the paradigm shift she experienced six years ago around the nature of science as less certain and more dynamic than she had believed, she has come to characterize content as less important than processes -- seeing the core goals of the unit to involve decentering of self by opening to the world and others; helping students see their lives as evolving, not a series of right/wrong answers; and being able to cope with change. These goals come across as more of a commitment to knowledge as "tentative and evolving" in Schommer's scheme (see Appendix A) and to an *Autonomous* orientation to ego in Loevinger's model, with its concern for decision-making, mutual interdependence, fairness, and self-fulfillment (see Appendix A).

Despite stating that process is more important than content, Kit has continued to develop her PCK of ways to increase opportunites for reinforcement in the astronomy unit, so strengthening the likelihood that students will master the factual and conceptual aspects of the material. In fact, Kit frequently comments on her fascination with science content; and her enthusiasm for her subject is regularly commented upon by her students in their evaluations -- suggesting that content is not at all irrelevant, as she once put it. She appears to hold it inside a larger context of process and affective goals -- reminiscent of Perry's Stage 6 knowers who learn to rely on their own best sense of things, understanding that context and theory can shape interpretation (see Appendix A).

In this last year, Kit's use of the constructivist/problem-centered approaches of EBD have consolidated her epistemological commitment toward informed self-reliance: Recognizing that students are not "empty vessels," she has raised their level of involvement by having them convey material to each other that they have defined as worth knowing. In this respect, she appears to be replacing herself or the text as the sole authority, with students as the authority, though the knowledge they convey still appears to be treated as absolute.[22]

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[22] Perhaps a more accurate way to think of it is as a form of "temporary dogmatism" since Kit clearly conveys to students the evolving nature of the discipline. Norris (1984) makes a case for this in challenging the notion put forth by science educator Richard W. Moore who believes that open-mindedness rather than dogmatism should be the appropriate attitude to take toward scientific

Becoming a Parent

Becoming a parent has had varied effects on Kit's PCK development. It has put her in contact with a rich array of children's books.

> I've used a lot more children's picture books in the last two years. That's a major teaching tool that's entered into my life.

Reducing her position to part-time has allowed her to be more available to her children while creating more space to plan refinements to her units, locate new materials, and read. The fact that she is a mother, however, has placed a strain on her ability to teach to the standard she demands of herself -- the standard she feels her students need and deserve. When she does, she often feels she "owes a debt" to her own children, by taking time away that should belong to them, though in this most recent year, she feels she has been able to strike more of a balance.[23]

__From the Context__

School

Kit taught in the same school as Dar and Ben, the last two participants in this study.[24] The school appears to have had both positive and negative influences on Kit's PCK development. On the negative side, for many years, it lacked adequate resources to provide Kit with her own room. Sharing a room precluded leaving materials out for later use which necessitated taking valuable class time for repeated set-up and break down

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knowledge in the classroom. Norris illustrates how dismissal of words like "prove" can lead to "pathological doubt" in students, which can develop into cynicism or relativism -- neither of which he sees as a healthier or more useful stance than dogmatism. Within limits, he believes temporary dogmatism offers clear vision, permitting one to explore the fullness of a theory's potential, hence is the appropriate attitude to take toward knowledge in the science classroom.

[23] Unfortunately, her half-time position will no longer be an option, and Kit has decided to resign rather than go back to full time teaching.

[24] See Table 6 on page 303 for an overview of how her district differs from one in a neighboring town.

activities. Since the file cabinet was shared and inadequate, Kit was forced to store materials in several different locations which made coherent unit development hard.

On the positive side, the school's lack of resources has been an ironic source of Kit's recent PCK growth in the area of instructional strategies. She has not had enough texts for each student, prompting her to discover the pedagogic power of establishing "reading buddies." Her PCK development has also been supported by her current principal's commitment to cover fewer topics in greater depth, allowing Kit to concentate her PCK development on particular concepts, processes, and attitudes.[25]

> The building is moving toward an integrated curriculum and the idea that less is more. That really fits with my style. If I said I wanted to throw out anything, my principal would say, 'Do what you want. I don't care what the high school thinks about it.' I also think she really supports ME and my choices. It's a winning situation.

Partly due to the community's ethnic and social homogeneity (White middle- and lower middle class), Kit's PCK reflects little connection to multicultural and social class realities. She does tell the story of a student from Ghana once who included violence in one of his projects. She set limits on it, wanting to present an alternate picture in her classroom, knowing this was where she could exert influence.

Students

Kit's PCK seems to have been greatly influenced by the information she has learned about students' needs and interests over the years, particularly through journaling and cooperative learning. Specifically in regard to her PCK of instructional representations, she talks about the many fleeting examples and metaphors which come to her in the course of giving an explanation:

> I see a face and something comes into my head. I couldn't recall it now unless I saw that same kid's face and expression. Another student would ask me a question, prompting another analogy, and then it's gone. It's not predictable.

[25] This principal began her leadership in Kit's school during Kit's fifth year of teaching.

Novice Teachers

Kit's first student teacher, Nora, was an extraordinary synthesizer and organizer, who had a tremendous impact on the development of Kit's PCK of instructional strategies because of the service she performed in codifying Kit's ideas into logical sequences and locating resources to expand them. This allowed Kit to refine her own ideas more easily and helped students keep better abreast of the direction of their studies. Having to articulate the reasons behind her instructional decisions for Nora gave Kit a rich opportunity to become more conscious of her PCK of instructional purposes and how better to meet them.

Collegial Collaboration

Kit spoke very little of collaboration with other teachers in her building, although she has been involved in a number of interdisciplinary projects such as a unit on endangered species with Dar, the English teacher on her academic team, and has generated academic activities to go along with team field trips. Though there has been a lot of trading back and forth of materials, it appears that Kit has not been able to learn as much as she would have liked from her science colleagues in the building because they have been less inclined to experiment in ways Kit would have enjoyed learning from.

For Kit, salient positive collegial influences have come from her self-initiated observations of teachers in other buildings and districts who helped expand her PCK of students' prior knowledge and, particularly, from teachers at the elementary school who included her in their grants. These opportuntities allowed her to develop interdisciplinary curriculum about space which added significantly to the growth of the astronomy unit. Fruitful new ideas have often sprung from discussions with elementary teachers in her district and in the district where her children are schooled.

New Resources

In common with other science teachers (Stodolsky & Grossman, 1995), Kit has had concerns about material resources and equipment for instruction. Her involvement at conventions has been a significant source for expanding her PCK of curriculum materials and how to use them, most recently giving her an extended series of questions and answers for the software program SimEarth. Kit has also been exploring resources on the Internet which has facilitated information sharing between her and colleagues in other parts of the country.

Synthesis

The primary influence on Kit's PCK of instructional representations seems to have been her own driving curiosity about her students, her content, and ways to expand her teaching repertoire. Journaling and a more student-centered instructional approach have given her access to students' ways of thinking and feeling -- providing valuable fodder for her PCK development. Along with the elementary teachers with whom Kit co-authored eight Eisenhower grants over the years, bringing in new materials and ideas each time, another major impact on Kit's PCK development has been mentoring a brilliant student teacher who freed Kit to be able to see what her ideas were and systematically build on them. That this collaboration was sustained over a three-year period -- first during Nora's practicum, then as a job-share partnership, and finally as colleagues in neighboring districts -- allowed both women to continue to support and nurture each other's growth in ways rarely found in most school systems. Nora has gone on to graduate school and Kit still misses her. Even with the advent of the Internet, the contribution of time and space to develop intelligent partnerships in this lonely profession cannot be underestimated.

Case Three: "Dar" (English)

"I think the more often that one can do visceral simulation, the more likely it is that one is going to get internalization. That's something I've learned. Drama, improvisation, and theater activities are the most powerful learning tools that I know of.." -- Dar

Professional Development

Introduction

Dar, 34, is the second of two children, the parent of a four year-old daughter, and a former intern teacher of mine. At the start of this study, she had been teaching seventh and eighth grade English for eight years in the same district as the other three participants. In her ninth year, she moved to a neighboring school district to teach English to sixth graders. A vegetarian with a keen interest in environmental and other political issues affecting quality of life, Dar was raised by a philosophy professor and an artist (weaver, photographer and state arts coordinator).

Childhood

Dar feels that a significant childhood influence on her was the courage her parents modeled in doing what they thought was right, even if it differed from what others thought.

> My mother sent us to school with recycled brown paper bags and old wax paper bags for our sandwiches instead of plastic; and peanut butter from Walnut Acres that separated and all the oil squeezed out ... and my father, as a philosophy professor, was politically active in the ethics of decisions his university made. He was somebody a lot of people looked up to, but he was also a threat to the university administration, because he was saying, 'You need to be held accountable for the actions you're taking.' I admired that about my dad -- his ability to stand up for what he believed in, in a very quiet way.

Dar was exposed to issues of race, class, and gender as a regular part of her family life and her interest in and awareness of these concerns made their way into her contributions to school discussions.

> Race, social class, those issues have always been family issues. At college my father was considered a maverick because he had a Black roommate. Just in the music that we listened to and the issues that we talked about around the dinner table -- intellectual, engaging, stimulating arguments. It wasn't something I learned in college or high school. It's something that sometimes I brought into classes that teachers weren't expecting.
>
> And gender, the same thing -- because my mom was a raving feminist ever since I could remember. Feminist issues became very interesting to me at college with the women professors, because of the use of the deconstructionist method of reading a text. It allowed me to see literature in a different way and to understand language, which fit right in because my father's specialty in philosophy had to do with parsing the language -- analytical philosophy, where you have to identify your terms and make sure there's not confusion about what you mean by "the good'." So at home, whatever it was that you wanted to talk about, you had to define it first.

Dar cites several key events which further broadened her horizons. She spent her fifth grade year in England, allowing her access to several other European countries which she feels gave her a more global perspective. Three years later, after twelve years of living in a university town, Dar and her family moved to a very rural environment, which she feels had a significant impact on her sense of self. In the former setting she was with the children of professors, and school was quite competitive. In the latter, school was not a priority for her peers, so the move gave her a chance to develop her individuality:

> I found that I didn't want to have to hide that I liked to learn, so it gave me an opportunity to become an individual, probably more quickly than I might have otherwise because I didn't like the social pressure of having to act stupid.

Another key influence Dar cites for developing her sensitivity to diversity and appreciation for compassion was that her brother had a serious mental illness. Having an alcoholic parent was also key, she feels, as it has allowed her to see patterns in her students. As a result, she has felt better able to support these students by being a deeper listener.

Dar sees a strong link between these influences and the way she sets up her classroom today. Alive with color, words, and images, the classroom provides choices which allow students to explore on their own -- books and magazines in the library area, a reference area, computers for composing, corners for conferring about writing. Reflecting Dar's love of the visual arts, the walls are festooned from waist height to the ceiling with multi-colored calendar art, quotes from published writers, faces of people of all races, student work, information about homonyms, note-taking symbols, classroom guidelines, and labels to identify various areas of the room. The teacher's desk, painted red and black, is situated to the side front, with students' tables arranged in arcs facing the blackboard on which agendas are written in a variety of brightly colored chalks. Desk arrangements vary, depending on the format for the day (paired work, small group, whole group discussion and so on). A small bulletin board bordered with colorful paper contains the daily announcements, the monthly luncheon menu, and the daily schedule. Sections of three book shelves are arranged at the rear to create the conference centers, house students' reading journals, writing folders, and bins for handing in work. The floor is covered with a deep blue carpet. Clearly organized, the room is full of art and information. In the words of one of Dar's intern teachers,

> You can feel the sweetness of this room...fluff and fantasy...colors, flowers, real concreteness. This room speaks to you. You're immersed in language here...in love! This room exudes love!

<u>Subject Matter Preparation</u>

Dar majored in English at a selective New England liberal arts college, her father's *alma mater*. Art would have been her first choice, but courses in her area of interest (metal sculpture) were not available. Further,

> In a funny way I loved art too much to make it a major. I love reading, I love books. They made me think and see the world differently, but weren't something that I had such a close personal connection with that I could ruin by having to study them. This is why I have trouble teaching poetry. Even though I want to expose kids to it, it is just that much closer to my heart so it makes it hard to break it apart.

She felt that her training in English was hit or miss by virtue of having had a completely elective high school and college English experience. She found that most of her male professors in college tended to have a pre-set notion of what they wanted students to see which she found limiting. In her final paper for the required course in literary criticism, she commented on the feel of an agenda-laden discussion and how this contrasted with the more constructivist approach of the two female professors she'd had:

> I likened the men's classes to the Dance of the Seven Veils in reverse. You started out with a piece which was totally naked to you and in the course of all of our discussions, people covered it up with what they wanted to. By the time we got finished, to me it always seemed harder to see the piece for what it was. The couple of women professors that I had brought the text to us as something to explore together, and in leading a discussion, they were much more interested in watching us make connections. There could've been an agenda by any of those women professors. I was thinking about Professor W., in particular. She could've had an agenda but she did not stick to it. If we weren't going in the direction that she wanted us to go in, but we were still understanding what was going on or making our own sense of it, that was fine with her. And we got a lot out of our discussions, whereas some of the other classes that I took were more directed. We needed to get to point X.

The sense Dar made of her college literature study points up the considerable pedagogical influence college professors can have (for better or worse) on prospective teachers:

> One of the techniques that I use in my classroom with getting kids to think about their writing and in any kind of discussion about what we're reading is to start with what I think would be interesting, but honor that the kids are going to bring to that discussion what they need to find out and that's what's most important. It doesn't matter what I need to find -- that can only add to the discussion,-- but really it's for the kids to make sense of the issues, the themes, the conflicts, or the decisions. It's their opportunity. It doesn't have to be my agenda.

Despite being flexible with her agenda, from classroom observations and the focus of the Intolerance unit, it's clear that Dar creates an intentional framework within which students' ideas are free to roam, and this framework has both substantive and syntactic dimensions.[1]

Dar doesn't see herself as an "English teacher" because she doesn't use literary critical approaches to reading, emphasizing instead helping students to understand themselves better using the stories they read and write. To this extent, she feels that her

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[1] Detailed in the section "History of the Intolerance Unit" is the way Dar provides a carefully selected content focus and emphasizes the skills needed to think and write critically and responsibly about several different views of it.

formal subject matter preparation had little to do with the way she teaches English. The exception to this were experiences with her female English professors who seem to have primed the pump for Dar's introduction to "shared inquiry," discussed further in the section on "Professional Influences on Teaching."

<u>Entry into the Profession</u>

For several years before becoming a teacher, Dar made jewelry and handled public relations for a mail order business. What precipitated her decision to teach were two things. First was that her employers in the jewelry business had begun asking her to train other people. This process ignited her interest in working with others in this role. Second, experiencing the beauty of Toni Morrison's language in *Song of Solomon* which she read during that time reminded her of how much she loved to read and how powerful a writer can be. This helped her see that what she really wanted to do was "to help young people discover ... what you could find in a book and what you could do with words."

Dar's teacher preparation program was the same one through which Ted and Kit were certified. Situated locally, it took people with college degrees and put them into classrooms with experienced teachers. Dar had program-sponsored seminars in educational theory and practice once a week and spent the remainder of the week in two semester-long placements, one at the high school and one at the middle school level. Workshops she attended dealt with topics like Teacher Effectiveness Training and learning styles. Dar emphasized what she felt to be the critical importance of placing impressionable interns with teachers who intentionally helped them develop their teaching knowledge and modeled truly worthwhile practices. Her first placement, for example, was with two teacher-centered teachers who let her watch them, then do what she liked. She found this unhelpful in answering PCK-related questions like:

> 'How do you decide what you're going to teach in a book? How do you put it into a big picture, and how much history do you put in? How do you break it down, and what are your threads that lead you to the end?' I never got that. The person who was working with me assumed that I knew, but I had no idea how to break teaching down. I don't remember specific modeling; I remember one of the teachers had a very laid-back approach. He was using lessons he had always used, and they worked for him. He had the kids focus on something in every chapter. To me, it never seemed to be leading anywhere. I would do my planning and bring it in and say, "What do you think of this?" and they would say, 'Fine, go ahead and do it' instead of spending a lot of time with me and asking, 'Well, how would it work day by day? Does this homework make sense? Is this plan too much for a student to accomplish in this period? Do you know the key points you want to hit on when you present information?'

So, in essence, her PCK development was left up to her.

In her second placement Dar worked with me.

> My placement in seventh and eighth grade was very different. It gave me a sense of the classroom as this very alive organism that needed to get up and stretch and walk around and sit back down. You know, 'We're going to do pair work today, and we can go back to individual work, then build up to groups.' Everything seemed more deliberate and purposeful. We spent a lot of time talking about, 'Well, is this the best way, or what could we try that is a little different?' I would give my ideas and you would bring me back to center and say, 'These are the things you should be aware of that could get in your way. If you can puzzle through and come up with alternatives, then let's try them.'
>
> So that was really different. It gave me a much clearer sense of what kids' needs are and how to focus the material so that it made sense to them. They were the center of everything. The other thing was your interest in multiple intelligences and always giving me other ways of seeing how to teach. In fact, my growth as a teacher might not have come the way it's come, if I hadn't had that experience. If I had another experience like the first one, I think I would have spent two or three years longer trying to sort out some of those things on my own.

Changing not just schools, but age levels had an impact on Dar's growth, as she found middle schoolers to "have a different kind of intellectual curiosity" and a sense of learning as fun, exciting, and energizing -- which matched her own feelings about her purpose, prompting her to seek work at this level.

Professional Influences on Teaching

Dar credits the "Great Books" workshop she took in her second year of teaching with solidifying her commitment to critical thinking.[2]

> Five or six years into my teaching, I had this student who asked me, 'Ms. 'K., how come you're the only teacher in here who's making us think?' It's just that constant, 'OK, I'm not going to let you back down on this; I want to know. This is not a yes or no question.'
>
> I think one of the big influences supporting my commitment to critical thinking was the Great Books course. That was really shared inquiry, which to me made the most sense of any of those kinds of courses that I've taken. It stressed the questions you don't know the answers to. So when I ask questions it's always with the idea that, 'I still can't quite figure out this moment in this book or film. This question is fair game. What's really going on here? Let's decide what you think is important. Maybe we can make some value judgments down the road, but let's get all these ideas out first. I want to know what you think because it might help me figure it out, too.' So shared inquiry affects how we read -- what the goals are -- and the choice of reading. I look for stories that create a lot of questions.

Even at this early point in her development, Dar tried to model an egalitarian constructivist approach to content, honoring students' prior knowledge and the potential for it to teach her, not just for her to use it to teach them.

Her experiences with shared inquiry, Dar feels, set her up to resonate with the constructivism of Nancie Atwell's writing workshop (1987) which she learned about and instituted in her third year with the encouragement of her department chair. Because of Atwell's reinforcement, she feels the development of her PCK of instructional strategies has been integrally tied to her perception of students' needs and experiences.

> I connected with Atwell very deeply. She taught me to interview kids and write down their answers. Over time, listening to what was coming out of them has allowed me to transform what I needed to transform; see what I wanted to emphasize; the directions I wanted to go; and the kinds of things that I thought were important. She had a major impact on how I teach.

Dar's first efforts with the writing workshop carefully mirrored Atwell's format. She encountered several problems. Initially, she felt that she failed to establish clear enough expectations in the form of concrete organizational reminders, so some students

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[2] For more about this see Criscuola, M.M. (1994). Read, discuss, reread: Insights from the Junior Great Books program. Educational Leadership, 51(5), 58-68.

were "clueless" for a while about how to spend their time; and because she didn't set interim deadlines for the required five pieces of writing per term, she was swamped with paperwork at the end. These experiences plowed the field for subsequent PCK development around the need to structure the environment with these issues in mind.

Another valuable piece of PCK development took place that first year when Dar saw the effects of sacrificing time to confer with students in order to complete the daily "Status of the Class" record-keeping Atwell recommended. Because of limited time for conferring with students early in their composition process due to this record-keeping, Dar's feedback took place later on, during the editing phase. At this point, she realized that her feedback occurred too late to stimulate better student writing, so she began to shift away from daily record keeping toward more intensive discussions with individual students and lengthy written feedback on early drafts.

A huge breakthrough in Dar's understanding of the pedagogical power of the writing workshop format came at the end of spring term that year, in the midst of conducting the second round of evaluation conferences. It occurred to her to ask for the most valuable thing her students had learned about writing that term. She was stunned when her first conferee replied "vocabulary," because this had never been formally taught. The boy said,

> 'I conferred a lot with Kevin and you know him, he always uses the weirdest words, but his stories are so cool; you can really see what's going on. So I guess I must have learned it from him and maybe a couple of other kids in the class who use pretty good words, too.' [3]

Thinking he would reply with something related to the content of her mini-lessons, she jumped up and excitedly asked the whole class, "What have you learned about writing this term that I didn't teach?" She found this evidence of the power of students to learn from each other a deeply validating experience, coming as it did at a time in her young career when she had made the bold decision to break away from the curriculum used by other members of the English department and strike out on her own.

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[3] Excerpted from Dar's Master's thesis.

With repeated practice, Dar gained a greater sense of what students needed from her in order to be successful writers. Better prepared the following year, she still had more to learn when she encountered students whose personalities were less independent, which prompted her PCK of instructional strategies to expand to include more pre-writing activites to stimulate their prior knowledge. She continued to mine students for insights into their problems as writers and had them set personal goals each term.

Dar regularly read journal articles on reading and writing during her first years of teaching, which put her in touch with Linda Rief, with whom she later took a course at the Institute for Reading, Writing and Learning at UNH, where Donald Graves, Nancie Atwell and others had worked. In an ironic twist, the course was taught in the same room where Dar herself had studied English as a sixth grader, offering her a vivid opportunity in which to contrast old and new pedagogy. Dar feels that a major turning point in the development of her PCK of teaching for conceptual understanding came after implementing Linda Rief's recommendation that students read writing samples written by other students as a way to help them develop the concepts around what constituted well conceived and poorly conceived pieces of writing.[4] She found that this process positioned them to construct a set of values which had heretofore only resided with her, so freeing them to write toward a standard they now owned and understood.

Dar feels that her work at the Institute helped her to see herself as a member of a scholarly community and as a professional keenly interested in how her students learned. She came to see discussions about writing less about writing and more about the "complex and idiosyncratic" processes of thinking and learning. From the rich data of her end-of-term questionnaires, Dar was able to confront the great diversity of learning needs and interests in her students which deepened her PCK of ways to accommodate them.[5]

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[4] I was able to observe this particular lesson in action during the second classroom visit.

[5] Questionnaires from 45 8th graders that term, for example, uncovered 25 different writing problems, 39 different things students learned about themselves as writers, including appreciation for the process and personal growth, and 34 changes in their development as writers over the preceding two years.

As part of her Masters in Education program, which she began in her sixth year of teaching, Dar took courses focused on questioning techniques to help students find meaning and value in what they were reading and writing. She wrote her thesis on her own development as a teacher of writing. That and the fact that she continues to read young adult fiction, she feels, have helped develop her PCK of ways to bridge between students' current realities and content aimed at helping them to structure their perceptions with care.

> D- When I first started teaching, the *Sweet Valley High* books were in vogue for teenage girls. Now it's these "stalker" books by R.L. Stine and Christopher Pike, which are horrible. They are in all the book fairs because they sell like hot cakes. I've learned a lot more about social control, how we're enculturated, and issues connected to sex roles and stereotyping through the work I do with kids, reading the books with them, and the interaction that we have. Having a dialogue about what they're picking up on and what they're seeing on TV helps me in my content area because I feel that I can use the questioning techniques to help kids to walk themselves through their logic, rethink how they get where they get and help them shift how they're making sense of the world.
>
> *R-Toward what or away from what?*
>
> D-Often away from sweeping generalizations or jumping to conclusions about other people. Creating a bigger world view. Seeing the connections between adults and younger people and why kids and grownups have so many conflicts in families. So toward more compassionate thinking and away from this knee-jerk reaction or even "political correctness." For example, when we do the endangered species unit kids will say, 'Well, we've got to stop those people in South America from cutting down the rain forest trees, and they're awful people down there.' I use this as an opportunity to say, 'OK, well let's simulate. You're a person who lives in the Amazon. You have no money, 6 or 7 children, and no food. A thirteen year-old from America says to stop cutting down this forest because they don't want you to kill all these nice, fluffy, soft animals.' It becomes an opportunity to help kids make sense of and reorganize their thinking, so that it's not just knee-jerk reactions or going with trends that may have faulty assumptions.[6]

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[6] Dar's concern reminds me of the useful distinction Richard Paul (1987), head of Sonoma State's Center for Critical Thinking and Moral Critique, makes between people's primary and secondary natures. The former, he posits, is "spontaneous, egocentric, and strongly prone to irrational belief formation...the basis for our instinctual thought." (p. 130). The latter, our capacity to be rational, requires careful training in recognizing that "we do not deal with the world-in-itself but with the world-as-we-define-it in relation to our interests, perspective, and point of view." We shape [these] in light of what significant others think, and, as a result live in a world that is exceedingly narrow, static, and closed. For purposes of self-protection, we assume our view to be moral and objective. For the most part, our viewpoints are in fact amoral and subjective. ... The training needed to transcend our natural subjectivity is seldom intentionally encouraged in the lives of young Americans, who, more often than not, are surrounded by parents, teachers, and peers, whose technical and nontechnical knowledge is transmitted from a single perspective, which youngsters then apply uncritically and definitively to complex social and personal concerns." (p.131) It seems to me that Dar intentionally works to

In summary, although Dar continues to make subtle changes in the reading and writing workshop from year to year, the major shifts in her PCK of instructional strategies have included creating a more structured workshop format, increasing the time spent on finding topics, emphasizing conferencing, expecting fewer final drafts, revamping the way work is evaluated to include self-assessment, student construction of what each letter grade "means" in terms of effective and ineffective writing, and writing along with her students.

Perceptions of Herself as a Teacher

Dar feels that she is much more intentional today about creating a classroom community at the start of the year. Her PCK of instructional strategies to this end has expanded to emphasize theater games, exposing students to lots of writing, having "Ten Minute Writes" about one of the quotes from famous writers posted on the room's walls or on a topic she throws out.

> I think being able to create an environment where students feel comfortable physically and educationally, giving them lots of choice, clear expectations, an opportunity to take part in a lot of different ways, forming the classroom constitution and the material we work with, reading to each other, giving time to explore themselves by talking to each other, reading each other's pieces -- just that kind of collegial environment is a strength of mine. I think kids appreciate me being well organized, having the tangible information that they need, making clear when things are due: 'These are the steps you need to get there; this is the process we're going to do.' using a lot of different methods of giving information, getting information, sharing information -- visual, oral, movement, trying to combine learning styles, multiple intelligences... .

Dar sees herself as committed to developing a democratic classroom.

> It's the idea of "Who constructs the knowledge here?" It's really the kids; that's what it comes down to. I will never forget the guy running the Great Books workshop saying, 'Think about it. Why bother asking the question that you know the answer to?' That was a real eye opener for me. It really reinforced for me why I teach writing the way I do. And, in a bigger sense, to always be pushing myself and the kids to ask those questions and not being seen as the giver of knowledge. I have information and experiences that I can share that can help us

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augment this single perspective by having students consider a range of viewpoints in the Intolerance unit.

> understand the world, but there's also a lot that the kids know. It makes the classroom more democratic, I think.

The commitment to democracy is implicit in both the methods Dar uses in her approach to reading and writing and kinds of concepts she has students discuss[7]. Classroom observations reveal an atmosphere of warmth and mutual respect. This starts at the beginning of the year when Dar and the students devise the classroom guidelines and shows up again in such areas as class discussion, where students have been trained to be careful listeners, responsible to themselves and to the group.

Dar likes to create a business-like environment. She alternates between focus behaviors ("Eyes up here. Everyone understand what to do next? Ask questions now;" "Let's get tuned in;" "We can already see some striking patterns."[8]) and going with students' energies. For example, there were fifteen student-initiated questions during the first visit[9]; many students offered personal experiences evoked by student writing with titles like "Face Plant" and "How to Tame Your Younger Brother" during the second.

Dar sees humor as an important bridge-builder and leveler. Laughter punctuated the first observation at least ten times, which seemed to narrow the power gap between teacher and student, conveying a "we're in this together" quality. Strenghthening this, Dar was consistent with her self-portrayal as a "co-creator" of classroom knowledge, open to and about her own learning process. For example, she asked a herpetologist whom one of her students was interviewing in front of the class, "How can crocodiles and alligators be studied in the wild if they are dangerous to be around?" and when she introduced me to the class, she drew attention to the fact that she was once my intern teacher and now she had an intern teacher and so had become part of a lineage of mentoring.

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[7] See the "History of the Intolerance Unit."

[8] Dar was in the process of recording students' votes on a matrix on the overhead during this observation (#2). As a way to extract the characteristics of effective non-fiction writing, the task called for students to rank order the best crafted of ten pieces of writing by anonymous students from earlier years.

[9] This class (Observation #1) featured a student interviewing a herpetologist on the differences between crocodiles and alligators.

Believing that kids, given proper support, both know and can learn more than many think, Dar continually empowers students to learn from each other. One student and his guest, for example, were the primary focus of an entire class period in the first observation; student writing from previous years was the focus of the second. In fact, students' concerns often drive the direction of discussion. Highlighting this one year with a particularly verbal cohort, Dar instituted Friday chat groups for eighth graders to explore topics of consuming interest to them -- whether related to the local, national, or global scene -- as a way to blend her commitment to critical thinking with their burgeoning thoughts about life.

Reflections on Professional Development

Dar's views of her subject appear to have been rarely explicitly addressed as an undergraduate, which would have entailed calling attention to the frames surrounding each of her English courses and the assumptions undergirding them; although, in a striking example of stepping outside the frame, she raised the topic herself in likening her experiences with New Criticism to "the Dance of the Seven Veils in reverse." Until she encountered the Great Books Program's approach to shared inquiry, Dar appeared to be largely self-taught in her approach to teaching literature to her students. Literary critical approaches used in college played a small role in her emphasis (with good reason, some would say, given the age of her students), although her feminist literature professors seem to have primed the pump for her later introduction to the methods of shared inquiry.[10]

When Dar began her intern teaching, the curriculum and methods of her first placement at the high school seemed to lack intellectual coherence. The focus seemed to be on pieces of unrelated content: *The Odyssey*, teaching Hawthorne, varying sentence

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[10] In regard to the method of shared inquiry, my auditor prompts me to give credit to an important male -- Socrates!

beginnings. With her middle school placement, activities were organized around students' emotional and cognitive needs, which made sense to her. Two features of this placement helped her feel that she had "come home:" Dar found the emphasis on "the why" behind certain teaching decisions to be intellectually stimulating and a source of guidance; and the emphasis on accommodating diverse student needs within a learning community resonated with her family's value for "people as individuals, as precious, who were connected to each other in important ways."

The role of writing to discover what one thinks rather than as simply a place to display knowledge seems originally to have sprung from Dar's interest in women's literature and her subsequent acquaintance with the work of Linda Rief and Nancie Atwell, which she encountered through her professional reading. The ideas of these writing teachers clicked with her, in part, because she was already primed from the Great Books Workshop to see her role as a co-explorer, "not ... as a giver of knowledge."

As a result of her subsequent graduate work, which fostered reflection about her experiences with the writing workshop's emphasis on the student's voice, Dar was able to develop her understanding of students not as what Belenky et. al. (1986) would call *Received Knowers* (see Appendix A), but more as "constructors of knowledge evolving along a cognitive developmental path," like the pedagogically advanced student teachers Ammon and Hutchins describe (1989) in Berkeley's developmental teacher education program. Thus students' ways of thinking have been central to the direction of her PCK development.

History of the Intolerance Unit

First Version: 1990

The goal of the unit in year one, Dar's fourth year of teaching, was for students to reflect on an experience of intolerance they had had so that they could better understand it and, consequently,

> "think twice or help others think twice to practice more kindness. I wanted them to see that cruelty can have a debilitating impact on a person emotionally."

Dar began the unit in the format of the writing workshop. She and her intern teacher asked students to write for the first three days of each week about the concept of "intolerance" using the genre of their choice, including a profile, narrative, short story, or opinion, with the eventual intent of publishing their writing in a newspaper. Students were to produce five pages of writing a week, four to six final drafts for the term. The idea was to tell the social studies teacher on her team about her focus and hope there would be carry-over from each other's classes when he taught students about WWII.

Thursdays during this nine week unit in the second term of students' seventh grade year (their first of two years with Dar), students read books of their choice related in some way to the topic of intolerance. Books were selected from a bibliography which included fiction and non-fiction featuring African Americans, WW II victims, Native Americans, the elderly, and homosexuals. The bibliography came from the school librarian, to which Dar added additional titles based on reviews she had read in middle school journals, the *New York TImes Book Review*, a local periodical reviewing books in the children's section of a nearby bookstore, as well as some she had chosen to read on her own at other times in her life. She categorized the titles, then indicated where in the building they could be found: her room, the library, or the reading specialist's room.

At points during the first three days of each week, Dar and her student teacher would give mini-lessons about writing in a journalistic style or about issues of intolerance. One of the assignments invited students to interview each other on their experiences with prejudice. This produced a memorable opportunity for an overweight boy to sensitize his classmates about his feelings and thereby make the point that truth has many facets.

> He was delighted to be interviewed because it gave him an opportunity to talk about how much it hurt him to have people call him "fatso" and "blubberbelt" or whatever. My intern and I discussed the issues that were coming out of that. We shared a lot of similar ideas; but the other thing is that it showed kids that the teacher's opinion isn't in a vacuum. It comes out of experience with the world and experience with other adults and that we're not the only right person in the world. What we have to say is valuable not just because we're the teacher, but because we're human beings. And that's one of the reasons that I like working with interns. I think it's really healthy for kids to see that.

She honored students and her student intern as teachers of each other and of her, as well as making the sophisticated epistemological point that knowledge is constructed out of experience.

> Working with my intern was not only important in developing the issues that we were going to cover and the approaches, but it also made it more fun in the classroom because there was more dialogue between the class and the teachers. We could learn more and the students had the opportunity to see adults disagreeing about issues like how one perceives. It was much more dynamic.

Dar felt that the unit went over pretty well, but since all the work came in at the end of the quarter and her student teacher moved on to her next placement, Dar was not able to pull the newspapers together. She choose, instead, to post students' work on the bulletin boards.

Influences on Development

Dar intentionally used students as shaping agents at this stage in the unit's development. She gave as wide a range as possible to the reading requirements to capture the attention of as many students as possible in the content.

> I wasn't ready at that time to narrow for the kids what they were going to read. I wanted to give them tons of room because I didn't know what they would find. I made a conscious decision and talked this through with my intern. I said, 'I want them to find or make a connection with this important topic in any way that they can.'

The broad range of reading and writing requirements that first year taught her a great deal about what students could do, giving a baseline for developing her PCK of concept-oriented teaching. This awareness was accelerated by a particularly gifted group:

> The diversity of kinds of writing was probably the biggest that I've ever had come out of one concept -- the concept of tolerance. Somebody designed an advertisement for a product. We had poetry. The students loved to write. They were phenomenal, one of the best groups I've ever worked with. Sometimes I look back and think, 'Well that's because I was young and fresh and now I'm old and tired; that's why I don't get writing that's that strong.' [laughs] But I don't think that's the case. I think this group of kids was really extraordinary.

Bill, the social studies teacher on her team, was very interested in what Dar was doing, but he and Dar didn't actually work together during that first year because a lot of her planning time was spent with her student intern -- whose involvement in the unit's development was considerable -- and because she felt she was running a "big experiment."

The following year Dar had a particularly challenging group of students. Difficulties were compounded by her maternity leave during the first quarter of the year, during which students developed a strong relationship with a temporary teacher.

> So in 1991 I just let the unit go because the very first time I did it, I had a very high level of trust in the classroom, incredible. Probably I could've left the classroom for an entire period and the kids would've worked. They would share anything in front of anybody. The next year I couldn't engender trust. It took a long, long time, into the middle of eighth grade, before the kids trusted me.

This intervening year gave Dar time to read many WWII novels which had been "lying around the school" and to let ideas about the unit come into sharper focus.

> It took a whole year for me to come around and say, 'I'm going to use these books.' The ideas just percolated and the longer they sat in the pot, the more they intensified. I decided the best way to begin was to directly approach Bill and say, 'I want to do this.'

Second Version: 1992

In the first version, Dar had focused on students exploring their personal experiences with intolerance and writing about them "almost as a catharsis or observation."

For this next try, now pared down from a full term to six weeks, she concentrated on the issue of individual responsibility with the Holocaust as a focal point. In this way, Dar added a powerful historical context for students' personal experiences of intolerance.

> Individual responsibility seemed somewhat insignificant to kids on a daily basis because, 'So what if I call somebody a name? I mean, they'll get over it.' Whereas when you take a look at what was going on in Germany, the Germans were either terrified into inaction or would look the other way because they bought into Hitler's rhetoric. The end result, the death of the six million Jews, homosexuals, Gypsies and what went on in the death camps is so terrifying to kids and so mind boggling, so incomprehensible, that they really have to stop and look at individual responsibility.

In an effort to shift from a parallel design to a truly multi-disciplinary one (Jacobs, 1989) where a formal unit would unite students' efforts in both language arts and social studies, Dar sat down with Bill and asked him to read the books she would be offering students. She had narrowed these to four titles, feeling that they would meet a range of students' needs and interests, yet still provide a shared focus: *Friedrich* by Hans Peter Richter, *The Diary of Anne Frank, The Devil's Arithmetic* by Jane Yolen, *and Number of the Stars* by Lois Lowry. The following year she would add Wiesel's, *Night*.

> We have a bias and certain needs that we have to assuage and reading can do that for you. But let's not assume that one book is going to make this material important and vital to every reader. That's why I offer 5 books in the Intolerance unit. I don't think, for example, every kid should be reading Eli Wiesel's *Night.*

Dar began the unit with reading and watching a video of Ray Bradbury's, "All Summer in a Day." Students also watched *The Wave* in their social studies classes.[11] These set up themes which would be further explored in the novels: the notion that the human drama could be divided into victims, victimizers and watchers; the relationship between Fascism and peer pressure; and national responsibility as an outgrowth of personal responsibility and courage.

> Kids begin to see where Fascism rises or comes out of the notion of peer pressure; this helps them understand Fascism and why people fall prey to Fascist ideas. We talked about why it's hard to stand true to

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[11] This deals with a school experiment in which students simulate life under a Fascist regime.

your ideas and also want to be part of a group. The kids really latched onto the material. They loved the stories that Bill told in social studies.

To increase student investment in the readings, Dar let students pick one of the four novels, had them complete nightly log assignments to help them relate to and reflect on daily readings, then had them complete two quizzes. Books were selected for their range of reading levels, the gender of the protagonist, and because several were prize winners.[12] Even though students were not reading the same books, Dar's PCK of instructional strategies allowed her to unite whole-class discussion through shared concepts.

> The questions that I asked were not specific to the story. Instead they were the concepts associated with the issues and something could come out of each book. I made students share that. What would really be the focus of our discussion wouldn't be necessarily the specifics of the book but examples of individual responsibility or examples of Fascist behavior.

In this way, Dar avoided the trap of losing the big picture through an overemphasis on minutiae; yet students were still able to flesh out concepts through the particulars of each book. This effort to identify and link core themes in the literature signaled the pivot point of the unit turning it into a constructivist concept-oriented experience (Prawat, 1989; 1993; Brooks & Brooks, 1993).

At the end of the project, further strengthening the classroom as a community, students had to present their novels to the rest of the class.

> It had occurred to me midway, 'How are people going to share the information they're getting out of their books? I decided on an oral presentation and everyone [in each novel group] had to have a role. They had to cover the basic elements of a plot line, character, setting, and have a visual aid. Some of the book groups were huge, so I broke them into two parts; one had to present the first half of the book, the other, the second. The audience would have to take notes and write summaries as a log entry -- which is something I learned from my master teacher, that when people give oral presentations, the kids who are listening need to be responsible for the material.
>
> They went very, very well. I said, 'Oh this is a great thing. Next year I'll have some nice handouts.'

To manage four sets of assignments that year, Dar gave students all four book assignments on a daily reading sheet. Part way through the unit, over one weekend, she

[12] Students could read as many novels as they wanted, but were only held responsible for completing all the work for one.

created a master log assignment sheet of all the preceding assignments so students could review what they had and hadn't completed. This allowed them to stay organized and gave them more control over their progress.

The unit culminated with an essay selected from eight possibilities she and Bill had developed, reflecting Dar's PCK of how to accommodate heterogeneous performance levels (see Appendix AA). Using a variety of content and calling on differing levels of abstraction, essay topics asked students to apply their insights into key concepts gained from reading and discussion. Some application choices were classroom-based, others ranged further afield, such as whether the US should help to stop the genocide occurring in Bosnia. About 15% of Dar's students took the opportunity to transfer their learning to world situations. Most of the remainder were caught up in dealing with the concentration camps.

> For kids with severe learning disabilities or for kids who were so cognitively concrete to expect them to connect to something beyond themselves was at times unfair. They really needed to deal with what was in front of them, what they could read in black and white text, or watch in a movie and write about directly, because they weren't operating on a very flexible or facile cognitive level.

When the time came to compose the culminating essays for the unit, Dar created the idea of a house as a way to represent the structure of an essay.[13] In students' self-evaluations of their final drafts (Appendix CC), they were directed to reflect on their process and content, a metacognitive activity Dar hoped would lead to greater transfer of learning into other essay writing situations.

Students' grades for the unit were based on a final project in social studies which could take a variety of forms, including video productions and other artistic opportunities; and in English, on the final essays, log assignments, oral presentations, and self-assessment (Appendix DD). In evaluating the log assignments, Dar gave points from 1-5

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[13] The development of this representation is described fully in the section on "Instructional Representations." See Appendix BB for the most recent handout associated with it, used in the fourth unit version.

depending on how deeply students appeared to connect with the question raised. Dar added to her PCK of instructional strategies when a student's excellent response to one log assignment prompted her to present the class with a model of a top-flight log entry to guide their efforts (Appendix EE):

> I have an example of a log entry from a girl who is learning disabled in response to *Fredrich*. I gave her more than five points for it because I was so struck by it. I thought she connected. She was a really tough customer for me. She hadn't shown me that she was really tuning in before this.

In this way, Dar intentionally supported students' genuine engagement with the material, an outcome prized by teachers committed to teaching for conceptual understanding.

Influences on Development

A significant influence on the development of the second version of the unit appeared to be taking a year off after the first go round:

> That one year I needed to take off so I could really let these ideas percolate and they just POOM! -- they really came. It was powerful. The following year the kids just had their minds blown and they loved it. It was their favorite thing we did all year, which is very odd.

Another influence on unit development seemed to be a closer collaboration with her social studies colleague, Bill:

> Bill and I spent a lot of time talking about the unit. He shared with me a bunch of his stuff and we created the essay questions. We worked very closely on those that year. Students had time in social studies and they had time in language arts to write their essays. So after they had finished reading the books and we discussed the questions, we did a lot of brainstorming on the overheads in our separate classes on different topics. Kids brought in related newspaper articles -- there were a lot. The Holocaust Museum opened that year; there were articles about brainwashing and white collar cults and how people get sucked into behaving in ways they might not ordinarily do and why that happens.

Once the essays were written, both she and Bill read them, giving students the unusual opportunity to receive feedback from two distinct vantage points:

> As a colleague, Bill is much calmer than I am. I get really swept up in the passion of the injustice, and he's really fascinated by the complexity of Hitler's perversity and also his brilliance and what was going on in Germany. I bring the passion and he brings the steady, 'Let's take a

logical look at things,' and raising the "what-if" questions. So the kids get a nice balance there. He always has something to counter-balance me, and I always have something to counter-balance him-- to spark it up where it starts to slow down.

Other influences on the second version of the unit and Dar's PCK in particular were tied to the requirements of her graduate work which involved extensive journal writing, which made her PCK more visible to her.

> I didn't have an intern and I was in graduate school doing a lot of reflective work. By having to keep a journal, I was able to focus on the continual questions I ask myself: 'Why am I doing this? Is *how* I am doing this going to allow kids to make that elusive paradigm shift -- help them use writing to understand content and use content to learn to write what they are thinking? Or am I, in the end, full of shit?' That kind of thing: self-doubt and a need for perfection simultaneously.

One of her graduate classes on moral development asked her to videotape her classes' reactions to the movie of Sheila Gordon's story about apartheid called "Waiting for the Rain." This allowed her to observe the range of moral developmental levels of her students which was seminal in shaping the way she addressed students' moral reasoning in the unit on WWII.

Third Version: 1993

The next year, to broaden the range of hooks into the unit's core ideas, Dar added a video called *The Swing Kids* [14] and a fifth novel, Eli Wiesel's *Night*. Managing five novels was not as challenging as she thought it would be because students were put into smaller groups. Using larger print, she created individual assignment pages for each novel rather than lumping them all together with a tiny font size on one page as before. This also allowed her more flexibility to tailor log assignments accordingly.

> One book described life in the concentration camps and how people survive it; another story was about a friendship between a Jewish boy and a non-Jewish boy in a city. I could focus in on friendship and

[14] This is described more fully in the section on "Instructional Representations."

> stress decision- making in that regard. That was the next version. I think that this version is really the best that I've got so far.[15]

However, creating assignments a week in advance for five novels was daunting, and about half-way through, Dar began to simplify the assignments for *Anne Frank*, because her PCK had sensitized her to the kind of student who would be attracted to it. For this novel, she simply asked in each assignment for students to focus on any diary entry that had captured their attention.

> And I felt I could do that in *Anne Frank* because I know the type of kid who will pick it. Always a young girl who is more introspective than her peers and will very quickly connect with Anne Frank. It doesn't take a lot for me to get them to start talking about what's in the diary.

Dar felt mixed about the appropriateness of particular novels: Lowry's book was one many students had already read and was written at an elementary reading level; *Night*, on the other hand, was very tough, both intellectually and emotionally -- not a book for every twelve year-old. Yet Dar discovered, on the whole, that seventh graders found the unit "riveting" and were changed by it -- perceptions which helped her evolve her PCK of developmental patterns in students' experiences as they moved through the unit.

> They learn history through literature. Literature is the story of people's lives, and people's lives are so much more interesting to them than history as they would see it in a textbook. The other thing is that the Holocaust is so horrible that it appeals to the seventh grade mind. They are shocked by it; they have a gruesome fascination with how the Nazi's could have done what they did. Then it all settles in and hits them. They are struck by the fact that human beings did this, and it isn't a movie. Realizing that humanity has the potential to do something like this again is pretty powerful.

Dar's reading assignments continued to allow students to move from the particular to the general and helped to focus the comprehension of learning disabled students, who struggled to connect what they were reading to class discussions:

> Each book has some really powerful events and characters who make decisions that are surprising. Having the kids focus on those particular things allows them to come to a generalized discussion and have a better handle on it. We did quite a bit of talking about victimizers dehumanizing their victims and how that dehumanization affects each. And if we have the question: 'What moves some individuals to stand up

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[15] Dar continues to think of the unit as evolving, even as she expresses satisfaction with its current structure.

for others even at personal risk to themselves?' the kids will be able to say, " 'Well in my story the character Gitl, the aunt, does such and such and she risks being thrown into the gas chamber.' So students have a concrete example and then we can extrapolate from that, or bring it close to home and say, 'Have you ever been in a situation?' to try to make those bridges.

Students' were asked to include in their reading logs, interpretive questions they had about their stories -- questions they were trained to raise (see Appendix FF) based on the Great Books approach to shared inquiry.[16] One of the final log assignments for the unit, for example, asked students to create a five question quiz that had three interpretive questions to which another student had to respond.

Essays topics for this year were amended to reflect current events, the addition of the movie *Swing Kids*, the book, *Night*, and to encourage students to write about topics other than the death camps, as Dar found reading large numbers of essays on this topic the year before to be overwhelming. The unit had a life changing effect on one of Dar's students, the daughter of an elderly man and his epileptic wife. Considered a "social outcast" as a seventh grader, she went beyond simply writing an essay and wrote a book:

> She read *Anne Frank* and was totally taken by Anne Frank as a human being -- her courage, her inner beauty, her personal strength, her goals. Her goal setting for herself I think was something that really struck this girl Patricia. Actually, she was Patty back then. She started reading everything she could get her hands on about Anne Frank. She said, "I want to know everything there is and I want to convert to Judaism." Wow, wait a minute! I started putting her in contact with people I thought could really help her, a Rabbi, getting her to read more, talk to her parents who were completely baffled by her. Her mother had a severely difficult time in school, a really caring woman about her daughter, but not a very good communicator. Her father was a 71 year old man who had a child very late in life: He came to a conference and just kind of sat there with his eyes closed. I thought he was sleeping, but that's just the way he is.
>
> Patty spent the summer studying, came back in eighth grade and for her I-Search project wanted to make a text for seventh graders so that they could have something else, written by somebody their own age, that could help them understand. She wrote a book*: Shoah: A Memory Book of the Holocaust*. She wrote to an in-state Holocaust Museum and got permission to Xerox the photographs to put into her book. She typed the whole thing, with "Suggested Books to Read," an Appendix about Anne Frank, with a picture that she drew of Anne Frank, and a timeline of key events that she felt were important. She then ended up teaching my seventh graders. When she's 18, out of the house and off to college, she

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[16] Because she had her students for two years, Dar felt their abstract thinking could be pushed further in their eighth grade year, as they had a basis for this development in their experiences with interpretive questions in 7th grade.

wants to convert to Judaism.

> The students just think she's incredible! She's garnered a lot of respect from her peers. Part of it's because she has done something none of them would have even considered. She wrote a book, published it, made ten copies, one of which is in the school library. As a result of this whole experience, Patty went from being a peculiar young girl who didn't fit in anywhere and always wore the same jeans and the same outdated rock T-shirt, to an eighth grader, caring about her looks, caring about the world, wanting to have an impact on people, and wanting other people to think about prejudice and intolerance.

Continuing to share ways the unit had transferred into students' lives, Dar talked about the comments of her students who had moved on to the high school and the comments of students just finishing the unit:

> Sometimes, after school, students will come back and visit. During the World War II project when I've got kids after school working on their essays, the older kids will say, 'What are you working on?' It's best when boys do it because it has this eye-blinking, jaw-dropping effect on the kid who's staying after for me: 'Oh, that! That was the best thing I ever did. Oh I loved that!' And other kids highlight it, when they do their year-end evaluations at the end of seventh grade. They highlight it at the end of eighth grade as well because they've learned so much about themselves. They remember vividly their experience with the characters in the books and the movies and I think this makes them think twice about behaviors.
>
> A lot of students tell me that the most important thing they ever learned. The eighth grade presentation is often one of bravado, but I see kids coming back really retaining that sense of how this can happen so easily that I should be careful. Even with the hardest cases, it touches a point of compassion inside of them. They think, 'Even as much as I hate my parents, the world, and my life, I can't believe that somebody would actually torture a group of people the way these people are tortured heartlessly.' It makes them feel human. Sometimes they're very up front -- I'm thinking about letters kids have written me. It's stunning that it can have such an impact.

Influences on Development

Dar feels that a major influence on the direction of the unit and her development as an interdisciplinary teacher began in this year through a collegial relationship she started with another energetic, well educated young woman who taught social studies in a nearby town. The two had met when Barbara interned in the room next to Dar's. They had begun collaborating the spring before Dar's third run-through of the unit in preparation for a conference presentation.

> Barbara lassoed me and basically said, 'Do this thing with me, you'll love it.' This "thing" was to give a presentation at the Middle School Institute on integrating curriculum. So we sat down and we started sharing our ideas about how we go about working with somebody else, or how we go about integrating the learning experiences the kids have. I focused on the World War II project and she focused on her project with high school kids on the Vietnam War. We started knocking around a lot of ideas: 'Oh yeah, you should read this. Oh why don't you try this. Have you ever read the Bertold Brecht play? Another good movie you could try... . Have you seen the text *Facing History And Ourselves*?' So she was sharing a lot of stuff with me and I was sharing a lot of stuff with her.

Another influence on the third version, Dar feels, was the fact that 21% of her students were coded learning disabled or ADHD, and she had to work very hard on basic reading, writing, speaking, and social skills, as well as organizing students to complete homework. In response to poor presentations from her special needs students, for example, Dar revised the oral presentation assignment and evaluation forms (Appendix DD). Working with these students prompted her not to lower her standards, but rather, to develop her PCK of instructional strategies by breaking down directions and expectations into smaller, clearer steps, so that students of all performance levels could meet them.

Dar felt the high number of special needs students had an impact on the very capable kids, whose experience was undercut by the nature of a significant portion of the class:

> One of my seventh grade classes was very big, 27 kids; but just the sheer diversity and an increased number of kids with Attention Deficit Disorder made focusing on the brutality really a double edged sword, because typically this population is very immature. That kind of stuff is seen as funny, 'Oh cool, let's throw some more in the gas chamber.' Then you have these really sophisticated kids who are reading at a senior year of high school or college level who are wondering, 'What's going on here?'

Having no control over this, Dar felt that she could at least accommodate her accelerated students by offering them *Night* as a reading alternative.

In her revision process throughout the unit, Dar used post-it notes to remind herself of changes she wanted to make the next time through. These allowed her to re-use a handout without editing marks, if she didn't have time to revise, yet reminded her of what she'd learned and would ideally like to do the next time through.[17]

Fourth Version: 1994

In this year, Bill was suddenly taken ill, so Dar had more to manage. Once again, having a student intern made a difference:

> In both the previous year and this one I was working with interns. The first intern was mezzo-mezzo, but the second got very involved in the material and helped a lot with the essays -- getting them right out and giving feedback because Bill wasn't there.

Dar added two simulations, one based on Dr. Seuss's, *The Star-Bellied Sneetches* to focus students' prior knowledge on the conflict between peer pressure and social responsibility, and another called "Bear in the Woods" to help them feel the fear the German citizenry would have felt in defying the Nazis.[18] Dar also distilled five "essential" questions for the unit and focused discussion and literature log questions around them. Prior to this, Dar and Bill had approached the core ideas in discussion but had never actually codified them (see Appendix GG).

Influences on Development

With the arrival of a long-term visiting teacher to replace Bill, changes had to be made.

> Because Bill was ill, I was working with a substitute teacher who was very graciously willing to do the World War II project, but it meant a lot more was on my shoulders.

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[17] This is a "trick of the trade" that both she and Ted use to expedite revision. Would that researchers could collect these to track teachers' insights!

[18] Both simulations are described more fully in the section titled, "Evolution of Dar's PCK of Instructional Representations".

She made portions of the unit optional, like watching the video *The Wave*; and struggled with the lack of the richness Bill's substitute brought to students' experiences of the WWII unit:

> I don't know how Bill does it, because we never had time to look at each other's lesson plans and objectives. He doesn't just focus on the Holocaust. He really gets at the complexity of the political situations, the economic situations, the decision making on the parts of the Allies in terms of getting involved; he goes into depth and interweaves what's happening to the Jews in Germany with what is happening in the present. The substitute just focused on the Holocaust and what happened to the Jews. I don't think the kids got the rich experience that they could have because she was so narrowly focused. It's gripping material so it accomplishes a lot at once, but the essays just didn't have the same depth.

In addition to pointing up the difficulties of sustaining the quality of a project based on coordination between teachers, these comments clearly contrast the effects of someone with rich subject matter knowledge and someone without it.

A major influence on the unit's development was that Dar and Barbara had continued to meet throughout the year in preparation for a second collaborative presentation.

> We did our presentation again only we did it at the New England League of Middle Schools conference. We only had an hour to talk about integrating curriculum, so we both chose to do something on the Holocaust. We spent a lot of time together working on our various approaches. We decided to take our handout that we had made the year before and talk about our starting points -- to come up with this notion that Ted Sizer talks about with the Essential Schools movement which is, "What are your essential questions?"
>
> We called our project "A Puddle to Play In" because we decided that really what you do for kids is you give them the mud and water, and you say, 'OK, it's time to play.' You let them get in and get dirty and then they move the borders; they move the shape of the puddle and they define, as a group, the knowledge that they're going to take away.

Both her constructivism and her commitment to core ideas so valued by concept-oriented teachers come through in how she and Barbara collaborated and in the understandings they evolved. Barbara helped Dar develop her PCK of instructional strategies by encouraging her to distill key questions oriented around facts associated with WWII, but tied to issues of peer pressure because she felt "that's what kids could really connect with."[19] It was also

[19] Barbara's had developed an appreciation for the importance of distilling essential questions through her studies with Theodore Sizer at Brown.

Barbara's recommendation that Dar add the two simulations to help her create powerful hooks for linking students' prior experiences of greed and intimidation with subsequent WWII content.

Other factors influencing the course of the unit Dar feels were the nature of the students in this year -- very bright and highly verbal, but not inclined to work hard. As a result, Dar felt *she* had to work harder, yet got less from students than what they were really capable of.

> I'm thinking about one of my brightest kids who could never get an "A" because she always put things off to the last minute. She was passionately involved in the material. but she wanted to go play -- 'Anything but make me sit down and have to put my ideas down on paper!' Even with all the work I did with the writing workshop at the beginning of the year, kids with incredible ability were just not that motivated to work very hard. So, I loved all those kids, but it was really kind of a challenge to get them to produce what they were capable of producing. And that has an incredible impact on how much you can do with a unit.

Dar reflects on the fact that she knows more now, but the challenges are different, which recasts how she thinks about the first time she taught the unit with Bill.

> Maybe some of the things that I did this year if I'd known about them during that very wonderful first experience would have made me think I'd died and gone to heaven -- the teacher of the century. But with these kids, there were so many other factors that came into play that despite the improvements, success was difficult.

So depending on the chemistry of the group, Dar found that students could be both catalysts for and drags on unit and associated PCK development; and that catalysts weren't always the brightest students, and drags weren't necessarily the most needy.

Future Versions

Because Dar moved to another district to teach sixth grade English where WWII is part of the eighth grade social studies curriculum, she has not had a chance to teach the unit again. If she did, based on recent experiences in collaborating with the science teacher on her new team, she would include much more opportunity for performance. The power of teaching others was something she had been thinking about since her days as a goldsmith, when she discovered that having to explain complicated processes forced her to think about the work differently and in the process, improved her own creations. Based on this, she suspected that asking students to explain their work to an audience would help them understand it better.

Dar has learned that the process of having students make their learning visible in multiple ways (from creating dramatic presentations to building web sites) for an audience of parents and peers can have a profound effect on relationships between students and content, among themselves, and between them and their teacher.

> In group dynamics they talk about "the fifth day" when people push through barriers and begin to bond. That happened this year with the Biome project. The students' projects were done before February vacation, but the performance night wasn't until the end of March. I didn't think they would sustain interest over that length of time. I knew the projects were excellent -- very creative, high content, but the two rehearsals were disasterous. I was so stressed; it took so much energy.
>
> Performance night was brilliant. Parents were blown away. The thirty kids who performed are different kids because of this experience. It gave them a chance to have input -- they designed the show. They could be creative, take ownership, and be responsible. I had one kid say he would handle being stage manager. I said, 'You're going to have to do it yourself, because I can't supervise you.' He said, 'No problem' and he did it. And these are sixth graders! Their self-esteem is so high. They are full of gratitude to have had a moment to shine, to be successful in a lot of people's eyes. They trust me more; they listen to me differently. I hear them in a deeper way.

Reflections on the History of the Unit

The core goals for this unit shifted from "exploring a personal experience with intolerance to better understand it and practice more kindness," to exploring the nature of individual responsibility through an explicitly interdisciplinary approach involving the history and literature of WWII.[20] Other goals were tailored to successive students via fresh and current events (school, town, nation and global).

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[20] See Appendix Q for a complete listing of Dar's goals for the unit to date.

> Each year the kids would be bringing to the class different needs. One of my goals is to respond to the needs the kids have at a particular time. Socially in the school, maybe politically in the school, with the principal or rules, or issues about overcrowding, that allow you to spin off in class what's going on and nationally, politically what's going on, such as should we get involved in Bosnia? That was a question two years ago for an essay topic and now we are involved.

A subsequent version of the Bosnia question, for example, would ask, "Should we maintain our presence there?" to keep it current. Like Wade (1994) however, Dar's overarching goal seems to have remained one of developing student understanding of the concepts of human rights and responsibilities, and tying these to the concrete and the immediate (e.g., peer group interactions), reflecting her PCK of patterns of response students have with material based on their social-cognitive developmental stage.

Dar's PCK of instructional strategies came to highlight constructing an understanding of concepts based on making direct emotional links with the material, while also strengthening students' critical thinking by increasing an emphasis on integrating multiple points of view. Initially, she tried to meet these objectives by an openness to such projects as allowing one student to interview another on his feelings about being overweight, and sharing the way her perceptions of intolerance differed from those of her first intern teacher. In later units, after narrowing the focus, she increased students' visceral response to the material by adding a movie featuring teens of the time with whom her students could identify; and using graphic simulations to elicit student empathy.

Dar steadily increased the number of voices all students could hear: those of their classmates, characters in books and movies, earlier selves, current selves, their teachers, Jews, Nazis, German citizens, and people in both local and global current events. She arranged for students to have written feedback from two different teachers on the same piece of writing (some combination of herself, her student teacher, and Bill) and had students integrate these points of view with their own self-evaluations. Through her essay, discussion, and literature log assignments, she increased the ways students could transfer their learning by giving them more opportunities to apply their cognitive and emotional insights to situations beyond the classroom.

Dar's PCK of organizing the unit evolved from a heavy emphasis on free-writing (three days a week) with one day a week for reading to a greater emphasis on reading and reflecting. She maintained choices in reading materials, but limited the types of writing to reflection logs and essays. This decision allowed her to maintain her core value of nurturing the student's voice, while zeroing in on the core skills of one type of writing: expository prose.

As she gained more control of her expectations for the literature logs through mapping out assignments for the different novels in advance, Dar empowered students by helping them monitor their own progress. By doing this, giving students the tools to self-evaluate their essays and literature log entries, choice over which novel to read, and which essay topic to select, offering activities suitable for a range of performance levels, becoming more concrete and explicit in what the components of excellent essays and oral presentations were, Dar's growing PCK of instructional strategies increased the opportunities for all students to succeed.

Dar grew in her understanding of how to work with a different teaching style and knowledge base in her colleague Bill, by learning to weave her emotional depth with his analytic insights, coordinating key ideas, and evolving a rhythm to keep the unit moving. Working closely with Bill increased her self-knowledge, by allowing her a chance to discover their similarities and differences.

Reviewing the history of the unit as a whole, what is striking is how central risk-taking has been to Dar's growth. She began the unit during her first experience as a mentor teacher -- a time when others might have been tempted to model only the most familiar lessons. She intuitively knew that by offering as wide an array of topics and books as she could, students would show her "what they needed to find" in the material and give her a baseline from which to construct her sense of what the unit should ask of them. From the start, her orientation to the unit was one of discovery -- an orientation she maintained even as she increasingly sharpened the focus on several key concepts. Being responsive to the different needs and interests students brought each year allowed her to evolve and refine the unit; but she learned, even with increasing PCK and skill, that the composition of some classes sometimes precluded the success she sought. So she had to place her attention on those pieces over which she had greatest control and surrender to those over which she did not.

In summary, Dar extended her PCK in the Intolerance unit by learning

1. to focus on a few powerful core ideas and pursue them from a wide range of vantage points;

2. to be more concrete and explicit in illustrating concepts, using visual, written, and kinesthetic modes;

3. to evoke students' emotional involvement with the material as well as complex and independent thought;

4. to accommodate a range of performance levels by managing multiple novel assignments and offering specific supports for eliciting excellence in writing, speaking, and listening, including self-evaluations;

5. to increase opportunities for students to transfer their learning beyond the classroom, including making changes in their behavior;

6. making time to talk with colleagues in order to develop a coordinated conceptual focus;

7. to identify patterns in students' responses to the material;[21] and

8. to recognize stages in the young adolescent developmental continuum toward compassion and empathy.

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[21] e.g., the horror of the camps eclipsing, for most students, more abstract thinking about human nature.

The Evolution of Dar's PCK of Instructional Representations

The different representations Dar used in the course of the Intolerance unit's history are outlined in Table 5 (next page). Discussion of those representations with longer histories of use and those with particular salience follow.

Table 5: Representations Of Core Ideas In The Intolerance Unit

Key: A = Analogy (auditory/visual); D = Demonstration (hands on, visual, auditory); E = Example (auditory, writing); I = Illustration (visual); M = Model (hands on, visual); S = Simulation (kinesthetic, visual, auditory)

Core Idea	Representation	When Used	Source
What is intolerance	(E,I) Newspaper : "The Tolerance" Writing 5pp/wk, 4-6 drafts each, about an example of intolerance students had experienced first-hand, to understand it better, and as a result, "either to think twice or help others think twice to practice more kindness towards each other." [And] to see that intolerance has "a terrible and often debilitating effect on the other person emotionally." (2.9) Formats included: Short story, profile, narrative, point of view, poetry, advertisements, interviews...	1990	Idea generated and implemented with D's intern teacher in parallel with social studies content in a teammate's classroom.
Individual responsibility and national responsibility are tied.	(E) Reading WWII novels in which these roles are portrayed and discussing them: Anne Frank, Friedrich, The Devil's Arithmetic, Number of the Stars.	1992-now	Read young adult WWII literature in the fall of 1990 (books "lying around" the school).
	(E) Night	1993-now	On hand at school
	(I) Watching films related to WWII directly or indirectly in which these roles are portrayed: *The Wave*, "All Summer in A Day."	1992-now	On hand at school
	(I) "Swing Kids"	1993-now	On hand at school
Decision-making: Balancing group values w/ personal ones	(E) Each novel has powerful events and characters who make decisions that are surprising.	1992 - now	
Fear affects our choices	(S) "Bear in the Woods" Simulation	1994 -	
Greed and peer pressure reinforce exclusive-ness with terrible conse-quences	(S) "Sneetches" Simulation	1994 -	

Table 5, Continued

CORE IDEA	REPERESENTATION	WHEN USED	SOURCE
Democracy is a valuable form of government	(E) Offers choice in writing assignments, books to read (within specified limits from 1992 on)	1990-now	Writing Workshop based on Nancie Atwell's, In The Middle
	(E) Student-generated reflection topics in learning logs and open-ended interpretive questions for discussion	1988-now	Great Books workshop
	(D) Teacher writing alongside students, sharing her writing publically, and asking students for constructive feedback	1990-now	Graduate summer course with Linda Rief at UNH Graduate summer course with Linda Rief at UNH
	(D) Asking students to share their work publicly and soliciting constructive feedback	1992-now	Great Books workshop
	(D) Students create a 5 question quiz w/ 3 interpretive questions and give it to another student	1993-now	Text-based; current events (school, town, nation, world); class discussion
	(E) Choice of final essay topic, some of which asked students to apply their learning to current events	1992-now	
Essay as house	(I, A, D) Draws a house on a poster and labels the parts: Catchy opener, topic or question and its importance (foundation); transition (doorway); supporting points (different rooms); conclusion - stressing main points, opinion, conclusions, answer original question, make prediction (attic); closing sentence (chimney)	1992- now	Own idea, refined from a verbal analogy to visual, to a day-glo colored handout to be kept "forever."

The Essay as House

Dar's "Essay as House" representation has clear stages of development over its five years of use. The first year, Dar was interested in offering a structure for a particular assignment, but felt frustrated that she had to teach something which had never been adequately taught to her.

> All my teachers always assumed that I knew how to write an essay. I was never given a structure. I know I would remember if they had because I would pay attention. I always felt in college that kids had information that I didn't have. I wanted to know where they got it and never wanted them to know I didn't have it, so I muddled along. What I

was trying to do with my students was to create a metaphor.

So the initial impetus for the representation's development was remembering how she used to feel as a student.

> I didn't want to be too prescriptive. As a young writer, it used to annoy me in high school to be told I needed a topic sentence and other jargon that were never made meaningful to me.

Like many of her solutions to pedagogical problems, the genesis of the house was somewhat mysterious.

> It often happens that just before I fall asleep, the answer to something I am worrying about will pop into my mind and I'll just know that's it. It's not something I am actively working on.

She had been thinking about words as something you built, a carry-over from an etymology unit she and I did together during her internship. From this came the idea of the essay as having

> a structure, a foundation like a house and that it had to be strong like cement. Transition sentences were like doorways.

Dar drew the house on the board, explained the analogy emphasizing the importance of catchy leads, erased the house and asked students to complete their opening paragraph for homework. She had described the whole metaphor because she knew from experience that some students wouldn't stop with their opener and would compose the entire piece.

The next day, Dar engaged the whole class in an interactive process where they read their paragraphs aloud and compared them to the criteria for the first paragraph written inside their house's foundation.

> I wanted them to decide if their catchy leads were really a welcoming doorway to their houses. It wasn't a perfect analogy because you don't usually have your front door in the foundation! We would ask, 'Does your piece have a catchy lead? Do you state the point of your essay clearly in the opening paragraph? Have you organized your essay so that you can follow your ideas?'

When teaching essay-writing the year before, Dar had had students use a different colored pen or a pencil to underline their topic and closing sentences, but the effect was not bold enough. On the spot, in that first class that day, she realized a way to highlight the house's structure was to pull out different colored highlighters and have students use them to signal the location and nature of key sentences.

> We used highlighters for the first sentence of each paragraph which were like doorways into rooms. The stairways were the transition sentences at the end of each paragraph and they were in another color. I would say, 'The first sentence you highlight should set us up for the paragraph. Everything that follows needs to be about that idea. And the very last sentence needs to wrap it up and move onto the next idea.' I shied away from using the term 'topic sentence,' even though I put it down on the written portion. I just called them 'points'.

Then she had students compose and compare their later paragraphs with the established criteria. Reinforcing the structural parts of the process she,

> had the kids count the number of sentences between each doorway and transition sentence to determine if they had enough supporting detail.

In this way students built their "houses" from the ground up. Dar modeled for students and students for each other, components of the composing process, especially how one finds new insights via reflection. As with Scardamalia's students (1984), problems became important reference points for learning.

The second year she taught essay form (third unit version), thinking it would help students own the structure more fully, Dar had students draw the house, but they were caught up with finding rulers, making the lines straight and the house square, so content became eclipsed by process.

> I was hoping that they would draw along with me, but it didn't turn out that well. For kids with severe disability in fine motor coordination, it was very time consuming to do the actual drawing and they lost the point. People would be too caught up in drawing the houses and wouldn't actually write down what belongs in the foundation. Or one day a kid would be absent and miss the whole middle of the house.

That same year, Dar created a poster of the house and kept it up on the wall. Her experiences with it advanced her PCK of students' writing needs:

> I would have these little clouds coming off the sides with things that should be in there. That worked out okay, but then I realized that the information should be written down for all kids, so that when they left the classroom it would be expressed the same way. Using the same language we could reinforce the concepts. Adolescents really need that kind of support.

In the third year of Dar's use of this representation, she provided students with a brightly colored handout. On one side she used a computer to draw an empty house; on the other, outlined information about different parts of the essay, so students had both visual and written approaches to the material (see Appendix BB):

> I made a Xerox on dayglo orange, green, pink, blue, neon colors, three hole punched it and said, 'You can use this right on to high school. This will be one piece of paper I never want you to throw away or recycle.' (Usually I give white paper so it can be recycled.) The decision to have the specifics already written down was directly related to the fact that many of my students are learning disabled. Tutors who work with them are doing everything they can to help these kids, but don't necessarily have the skills themselves. So this wasn't just for my kids, it was for the tutors as well.
>
> This took a lot of stress off of me. One of the presenting issues for kids who're handicapped is that they don't come to school. They'll miss a couple of days of note taking -- key information -- and if I have it written down on paper already, I don't have to hunt all over the place for the overhead and try to xerox it and make sure it's complete.

Ironically, the frustration of having to accommodate diverse student needs seems to have spurred her PCK development. Instead of reacting with resignation, she figured out how to become more efficient and more effective -- helping herself and her students mutually.

Using the overhead, Dar had students brainstorm what they felt each portion of an essay should contain and place their notes in the corresponding parts of the house.

> I asked for what they wanted me to write up here and included my important pieces. And I wouldn't let them turn the pages over.

As before, students would listen to each other's paragraphs, give feedback based on the criteria established, then further revise their pieces.

After filling in the house, in a vivid example of reinforcement and student empowerment, Dar then asked students to read the back side of their day-glo papers. Dar felt that they found it richly satisfying that they had actually generated the same information the teacher had.

> When I first handed out the day-glo sheets, students were so jazzed by the image they ignored the writing on the other side. We filled in the house. I had the image on the overhead and student volunteers would write in for the rest of the class one thing, another thing, the next thing. It took us two days and at the end of the second day I said, 'By the way, in case you can't understand what you've written, turn your papers over.' They were like, 'Whoa! You wrote it down for us!'

> Maybe that's why this kind of format it doesn't feel so hopelessly academic. Students help to define it. Then they also get to chuckle, because when they turn over and see what I've written, they say, 'How did you know we were going to say that?'
>
> I say, 'Because you guys are good! Because you're really good! You know a lot!' and they really feel tickled.

Using this constructivist approach, Dar was truly able to educate -- to lead out of her students the organizational concepts needed to help them think about and present ideas coherently in a way they found interesting and validating. What had started as an essential set of steps for her learning disabled students turned out to be a powerful form of scaffolding for developing the independent essay-writing skills for the general population as well. In this respect, Dar's practice clearly reflected another of the key attributes of teaching for conceptual understanding -- scaffolded instruction (Prawat, 1993; Anderson & Roth, 1989).

As a final opportunity to reinforce their understanding, Dar gave students anonymous copies of student essays from previous years to critique according to the criteria they specified for each portion of the house:

> I blocked out the names and Xeroxed copies of essays from previous years. In groups of two or three they had to sit down, after we had taken notes on the House of Essay and before they even started writing their second draft, and I said, "Does it do what we wanted it to do?" They had to write down answers to the questions that I gave them that were specific just to the lead paragraph. They worked back and forth between essay and criteria. "Just check, first of all, does it have the right length? Does it have enough sentences? Does it have a catchy lead? Does it have a transition sentence?" And boy did it get them to focus and to revise their own essays. They actually wrote overall, the best quality essays this year. Even though they like to talk. I want them to reflect on their experience in a much deeper way.

In her current teaching placement with sixth grade students, in the fourth go-round of this representation, Dar has added an initial step between generating the house analogy and actual essay writing:

> I realized that their brains were so all over the place at eleven or twelve. It's amazing how they can lose a train of thought. In order for me to be sure that they were going to stay focused I really emphasized the notion of topic sentence. One night they had to write up to five topic sentences and then pick two to write a paragraph about. So we did a lot of that work beforehand. If they knew what their topic was, then they could color code it to get those sentences in the right place.

Demonstrating that powerful representations can take on a life of their own, Dar extended the metaphor to help her sixth graders alert readers about the nature and extent of their topics:

> I asked, 'Is this going to be a ranch house or a colonial? Do you want yours to be a three-room bungalow, or would you want it to be a mansion with lots of lavish things? And that really depends on how long you want to make it, how much information, how many subtopics.' Then I asked them to think about themselves being a real estate agent. 'Would you have to call your client up on the phone and say, 'Hi, I have a colonial in downtown Lakeville for sale? It's got twelve rooms and two bath rooms.' -- that's kind of like your opening paragraph. You're highlighting your subtopics in that opening paragraph. You want to get somebody's interest." So it all fits in. The more I use the representation, the more I can play off of each little thing.

The possibilities of the representational format prompted one student to generate his own version which he called the "Essay as Fast Food."

> He said, 'Writing a topic paper is like eating a fast-food meal.' He was thinking that the bag is the whole thing, the hamburger is one of the subtopics, and the Coke provides the transitions between the paragraphs because it washes them all down.

Over the five years she has used the representation, it has become more concrete, more explicit, and more interactive.

> I don't run into people scratching their heads, saying, 'I don't know what I'm doing.' They may need help figuring out what order things go in, but as I start to ask them questions like, 'What happened next?,' they suddenly start to see, 'Oh, what happened next! Oh, chronological!' I'll reinforce this with another reference to the representation, like, 'Often, the kitchen *is* connected to the dining room!'

Dar is engaged in creating independent writers -- students who can reason through a process using what Scardamalia (1984) calls "purposefully constructed effortful abilities" aimed at supporting the language skills they have gained mostly without effort in the course of living. Though wary of jargon, she has now come to appreciate that these "effortful abilities" are greatly strengthened through a shared technical vocabulary.

> What's what's been so exciting about this year is that these key words: "Foundation," "catchy lead," "main topic," '"opic sentence," '"clincher" and "transitions" are part of our classroom vocabulary. The word "topic sentence" isn't a dreaded word in here, whereas I have terrible associations with it. I had to create meaning with the terms, which has helped me guide students toward making their own decisions. That has been this year's revelation.

Echoing an insight of Tchudi and Mitchell (1989) that "questions about [writing] form are best answered in *operational*, not *definitional*, terms" (p.208), that is, by showing rather than telling students about structural issues, terms in Dar's classes become meaningful when the concepts they define prove useful:

> I now understand more about the value of a topic sentence, but only as it relates specifically to essay or non-fiction writing. It's become a very helpful tool, not so much because, 'You've got to have a topic sentence because that's what all paragraphs have to have,' as, 'This is a way for you to organize what you are thinking about, what you want to say.'

In the same way that Dar now waits for students to construct an understanding of the need for topic sentences before naming them as such, she has had to construct for herself, over time, an understanding of the link between grounded technical language and nurturing students' autonomy. In this respect, the essay as house representation has become not just a product of Dar's PCK, but a living mechanism for its growth.

Videos

In the second version of the Intolerance unit, Dar first represented the concept of the human drama as divided into 'victims, victimizers, and bystanders' through Ray Bradbury's, "All Summer in a Day" (see Appendix HH). This story focuses on the cruelty of Venusian children to an Earth child they envy because sunshine was a regular part of her life and she yearns for its return on rainy Venus -- a once in seven year event. Aware of the power of film to reach more students and ignite students' emotions, Dar used both the story and the video as hooks to focus attention on the issues of peer pressure and Fascism, balancing group values with individual ones, and the decision-making process involved therein.

From the key words "victim," "victimizer," and "bystander" eventually came the idea, triggered by her colleague Barbara, for key questions like, "Where would you, as an individual, sift out in terms of these roles, if you had been in Nazi Germany?"[22] By using the example of school children in Bradbury's story and *The Wave* (seen in social studies) to evoke situations more closely related to students' personal experiences, Dar's growing PCK of instructional strategies allowed her to establish a shared context for the core ideas of the unit on WWII. By layering historical, fictional, and personal representational contexts and working back and forth between them, she used students' comparison-making as a basis for constructing their understanding of just how difficult it would be to have acted with integrity in Nazi Germany:

> We talked about the difference between the two situations: With Bradbury's story it's children behaving cruelly without adult supervision, vs. 1938 Nazi Germany, where if you saw a pogrom occurring, there would be no way you would go in and stand up for the Jews when somebody was standing out front with a gun, or stick threatening your personal safety. And as we began to discuss that, they began to see the complexity of it.

In the film "The Swing Kids" added to the last two versions of the unit (Bill's idea), students observed developments in the lives of four boys in Nazi Germany and the different ways they responded to the pressures of Fascism.[23]

> What it does is it gives kids a chance to see what it would be like to have been a teenager living in Nazi Germany and being opposed, but being powerless and having to take a risk by putting your life on the line. For teenagers who can only think of themselves, it helps them understand how hard it is to be brave and how easy it is to turn on your friends in school the way they can.
>
> Students think it's a very powerful movie and the ending...the first year I showed it, three of the girls couldn't leave the room at the last. They just burst into tears. It does raise questions in the kids' minds like, "Where would I fit in?" because the kids are their age and it's pretty convincing. It introduces the element of fear in a big way because you see people's lives being threatened. It makes it much more real than perhaps a book might.

Dar found that by coupling this movie with the following simulation in the unit's next version, she was able to raise the level of students' identification with the material.

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[22] See Appendix L for a list of Dar's key questions for the unit.

[23] Because the movie contained some strong language, Dar wrote a letter to parents explaining the curricular purpose of the movie and gave them the choice not to have their children see it. None exercised this option.

The Sneetches

In the most recent unit version, again at Barbara's suggestion, Dar used Dr. Seuss's story of *The Star-Bellied Sneetches* as a hook for representing the concept that "greed coupled with peer pressure can have terrible consequences."

> Every year I was faced with the same challenge of trying to get the kids to connect with and personalize historical events and with what could happen in the here and now. Part of the developmental phase of junior high kids is that they become very involved in fitting into a peer group. And certain kids get through that more quickly and certain kids get stuck in it for a very long time. In some ways I'm powerless to affect that no matter how much we talk.

Her PCK prompted her to time this representation early in the unit in order to give students an immediate and shared experience of the unit's core ideas before reencountering them in other settings later on. First, Dar had students read Seuss's story, then immediately form two circles, one inside the other based on who had been given a star.

> This activity is brutal. I hand out stars randomly and have an inner circle, an outer circle, and a bag of M&M's. If you don't have a star, the goal is to try to get into the inner circle to become a member of the Star-Bellied Sneetch reading group. If you can break through, you get an M&M; if you can't, then you have to sit down and do written work. The people in the middle are holding hands. I tell them, "If you Star-Bellied Sneetches in the middle keep the others out, I'll give you <u>two</u> M&Ms."

After completing the activity, Dar had students watch the *The Swing Kids*, then using her PCK of how to layer one representational context with another, reintroduced the Sneetch activity and asked students to reflect on their earlier roles in the simulation:

> One of the things that comes out of this simulation is that the kids become extremely aggressive about wanting to get into the group. So we talk about, 'Well it's just a game. It's just a game.' And then I point out by the time we watch *The Swing Kids*, 'The Holocaust is just a game' which puts students in direct conflict with what they say. They come back with, 'Well, you told us to play the game.' I reply, 'Well the Nazis said, 'You have to do this,' too. So how is that different?' It's rare that a kid in the Sneetch group will say, 'No, I'm not going to do this. Maybe one or two.'

Juxtaposing the representations set up a direct contrast which, she felt, aggravated students by forcing them to examining their own inconsistencies.

Based on what she learned from this go-round, if she were to do the unit again, Dar feels that she would have *increased* the intensity of the simulation by changing the reward system. She would give no M&Ms to anyone one in the inner circle, if even one person were allowed through, because this would more closely replicate the self-policing of Hitler's youth groups. Further, she would restrict the initial debrief to be in written form only as the oral debrief only allowed the loudest voices to be heard. She wanted the anger of her quieter students to be audible as well. So her PCK surrounding this representation became more sharply focused on ways both to make it more parallel to the targeted concepts around Fascism and to increase the opportunity for effective learning for all students by having them clearly establish a baseline reaction in print against which they could unequivocably compare responses to similar concepts later in the unit and in their personal lives.

Bear in the Woods

To keep students from distancing themselves from the content, at Barbara's suggestion, Dar represented the concept that "fear can affect our choice of actions" in the most recent unit version with a simulation called "Bear in the Woods." Giving students a visceral experience of immobilizing fear in order to help them to internalize lessons on integrity, she designated two students to be hunters and asked the rest to lie down on their stomachs and be bears. If someone moved, the hunters had the right to shoot them. In this way Dar attempted to give students an experience of the life-threatening circumstances which inhibited so many Germans from taking action against Nazism.

As with the Sneetch simulation, key points from the debriefing were recorded and remained on the wall for reinforcement and future reference.

> Anytime we did major brainstorming like that, I had a kid at the board act as a scribe -- someone writing down students' observations on big pieces of paper. Then we would take those big pieces of paper and leave them up on the wall to constantly refer back to. Or if I wasn't going to do it that way, then I'd write them on another piece of paper and Xerox them and have students put it into their folder.

Students' responses to this simulation and the Sneetches helped develop her PCK of the distinction between what someone might be cognitively capable of understanding, yet emotionally unwilling to entertain:

> We have them as seventh graders and then as eighth graders. In the second year, we reintroduce a similar theme and it just seems like the kids haven't got it. For example, this group that I started with the books in seventh grade, in eighth grade, for about a month and a half, I set aside Fridays, circle time, they could bring articles they wanted to discuss, issues. I remember being struck by some of the intolerant comments kids would make. I'm thinking about this one girl who wrote her essay on Fascism, 'Oh, it's such a terrible thing and this is what I'd do..'. and then, in eighth grade, during a conversation talking about Blacks in the ghetto, she referred to these people as "them," how scared she was and how she didn't like them and I replied, 'You are the same child that last year was championing 'Let's not be Fascists; let's be good to each other?' By the time she'd gotten into eighth grade her social issues had changed. She needed to fit in with peers more now. She had always been a straight-A student and she was facing different peer pressure issues and no matter how smart, no matter how capable she was of making that connection, she just couldn't budge on certain things. It's one of the things we always bang our heads against the wall with. How do you get the kids to transform?

Nonetheless, if Dar were to use the “Bear in the Woods” simulation again, she feels that she would not use it with every student.

> So much is going on for students with an activity like this that complicates the point I am making. It didn't feel right. I'd use it only with students who still weren't getting it. A lot of kids were already moved. I don't think it's the right tool to get carry-over.

Reflections on Dar's Instructional Representations

The evolution of Dar's representation of the concepts associated with essay writing has a longer history and more clear cut stages of development than those associated with other core concepts in the Intolerance unit. It began with drawing a house on the board, having students discuss the various parts, then erasing it. Dar added to her PCK of students' patterns of difficulty by learning that this brief exposure to this important set of ideas was too limited to have a lasting effect on their essay writing abilities. Having students draw their own houses the next time was not the answer either, as it proved too time-consuming and cumbersome, and the focus on key ideas was consequently lost.

Finally, she settled on a image/word approach using brightly colored paper with an image on one side with spaces to write in key phrases and an outline on the other encapsulating the same information. Students still brainstormed, then turned over the paper for validation and reinforcement. She further reinforced their critiquing skills by sharing anonymous student essays from earlier years which students could evaluate by applying their newly generated criteria. Most recently, she extended the metaphor of the house to highlight how involved the essay could be (a three-room bungalow, a twelve room mansion), suggesting that one index of the power of a representation is its flexibility in depicting additional refinements to core ideas.

The inclusion of *The Swing Kids* and the two simulations to augment students' experiences with Bradbury's story, their novels, and their work in social studies reflects Dar's understanding of the critical need to engage students' hearts as well as their minds. She still wonders whether she and Bill could truly evoke the kinds of changes in behavior and perception that they strove for.

> I don't know that it can be gotten at this point in time. It may be one of those things that I don't reap the benefit of. I don't get to see how it blooms into their personality ... .

Thus Dar's PCK development of instructional representations has prompted her to become increasingly concrete and detailed, pulling on students' emotions and calling for a reconciliation between head and heart. Further, Dar has found great pedagogic power in playing different representational contexts off each other, creating the opportunity to develop more subtle and varied views in students. Perhaps most significant is that working with these representations appears to have fed Dar's PCK -- sharpening her focus on the concepts she wants students to learn and how to best help students learn them.

Summary of Influences on Dar's PCK Development

From Herself

Her Upbringing

Why read literature? For Dar, at the middle school level, it seems, foremost, to be a way to examine central questions about human nature and what constitutes "the good," questions stemming from her earliest teachers, her parents. She was drawn to select representations as a bridge toward these goals. Dar's love of art and dance make their way into the visual and kinesthetic aspects of her representations. That she chose to concentrate on developing a representation for essay writing over fiction or poetry writing, suggests her attraction to as a practical real-world place to grapple with and communicate important ideas. So her background appears to have been a basic shaper of her choice of instructional representations aimed at developing usable skills, critical thinking, and moral development.

Her Experiences as a Student

Dar rebelled against her early student experience, thinking it was often random, disconnected from her interests, or too prescribed. Because she was able to take the perspective of her students by identifying with them through her own frustrations as a student, and imagining what her students were experiencing while on the other end of her own lessons, she could tailor her representations to their real needs. Her learning style (independent discovery; visual mode) attracted her to the Writing Workshop format and constructivist methods associated with her "Essay as House" representation. So ability to reflect on her personal experiences as a student appears to have been another significant influence guiding her PCK development.

Her Subject Matter Knowledge

Dar's subject matter preparation appears to have had little direct influence on her use and choice of representations except as a foil against which she works to provide what she felt she didn't learn. Dar's subject matter knowledge as related to teaching middle schoolers appears to have come mainly from insights gained from her personal reading, on-the-job experiences, and workshops attended after becoming a teacher. Her love of her subject has prompted her to expand her content knowledge by reading widely in the area of young adult fiction which has deepened her insights into the realities her students bring to her classroom and how to evolve the PCK needed to bridge between these and the discipline of English.

Dar's subject matter knowledge allows her to help students clarify for themselves what constitutes adequacy within the parts of an essay. The house representation has sharpened these distinctions for her and her students. Dar's knowledge of the various approaches to literary interpretation has shaped her PCK by allowing her to move between linguistic analysis (decoding, summarizing plot, meaning of imagery and symbolism) and reader response, depending on students' needs, interests and the particular moral/philosophical dimensions she wants students to grapple with. Her PCK is constantly evolving as she continues to expand her content knowledge, even to finding links between her discipline and other disciplines like history and science.

Her Teacher Education

In keeping with the direction she found in her teacher preparation program, second practicum and subsequent professional development, Dar tries to find ways to represent content consistent with what students appear to need in order to learn certain skills and/or address key philosophical issues. Hence, she is open to revising her PCK of representations or adding new representations the more she understands both what students need and refinements in what she is trying to teach.

Her Philosophy of Education

The philosophical traditions which seem uppermost in guiding Dar's PCK of instructional representations in the Intolerance unit are Existentialism and Idealism (Hamm, 1981; see Chapter I) because they emphasize personal accountability and the importance of nurturing the good, respectively. She taps into the moral potential of English to explore universal questions about human nature: Is Fascism inevitable? What is our personal responsibility to society? Dar wants students to gain deep insight into themselves and their decision-making, thus she emphasizes personal meaningfulness through her representations and the literature logs, where students are rewarded for the strength of the bridges they build between themselves and their reading/class discussion.

Dar's essay-as-house representation stems from a more Pragmatic tradition. Here she attempts to bring classroom activities in line with the "purposes, audiences and materials of the literate world."

Since Dar wants all her students to leave with usable skills, she turns her PCK toward activating multiple intelligences (a Pragmatic concern) hoping to broaden and deepen her reach: Intrapersonal (self-evaluations of essays; log assignments); interpersonal (discussions, treatment of others); kinesthetic (Sneetches simulation; "Bear in the Woods"); spatial (movies, many colorful displays in room both teacher- and student-made) and linguistic (speaking, reading, writing) (Armstrong, 1994).

All of Dar's representations stress metacognition, a Pragmatic concern, where students think about their thinking to increase consciousness of what's learned and the likelihood that it will be transferred into other life situations in and beyond school.

Her Inner Representations of Core Ideas

Dar's sense of the moral dilemma at the core of the Intolerance unit seems to boil down to the resolution of two potentially opposing needs: The need to stand up for one's beliefs, with the need to belong to a group. Her PCK of how to represent this dilemma was primed by watching the personal courage of her parents and developed later through her exposure to Bradbury's "All Summer in a Day," in which this conflict is crystallized. As this dilemma came into sharper focus for her, she continually sought more and more graphic ways to portray it.

Very early on Dar had the sense of essays as something you built. She recalled a unit on etymology that we did together during her practicum as triggering a sense of language as built from smaller parts. Students' word-building became "word buildings" in her mind; it was a short intuitive leap from this image to inventing the concept of a house to represent essay form.

Her Epistemological Commitment

Dar seems to stress the source of knowledge as the self, open to influence by group and teacher insights about shared material -- an epistemolgical position at the advanced end of the schemes in Appendix A. With students' writing, for example, she is careful not to load discussions about essay writing with unfamiliar "techno talk" belonging to adult writing specialists, preferring instead to use language students have established meanings for, and through such language to work back and forth between the attributes of the house representation and their actual writing.

In discussions of literature, Dar intentionally pushes students away from dualism, toward something Richard Paul (1987) would call "multilogical thinking" -- being able to integrate insights from multiple points of view. We see this in her value for helping students contrast the simplistic treatment of Hitler in students' novels with the portrait Bill draws of him:

> One of the things that Bill was really good at was bringing alive the character of Hitler. As maniacal as he seems to us in hindsight, he was a very convincing orator and there were things about him that made him very appealing to the German public. It wasn't as simple as "that was a bad guy."

By presenting other facets of him, (Hitler's political genius and his charisma), Bill helped students to see how difficult it would have been to resist Hitler had they lived in Germany at the time. Gaps between novelistic and analytic treatments of the issues raised about WWII prompted some of Dar's brightest students to appreciate "that nothing is as simple as it seems at first," lending support to the speculation Hofer and Pintrich make (1997) that while age and epistemological sophistication are related, it is "unlikely that most first-year college students spent their previous years as dualists" (p.122), particularly, I would add, when they have experienced a learning context which intentionally works against dualistic notions about the world.

Developing more complex understandings of WWII would not have happened as fully, however, if Bill hadn't treated students to a more sophisticated understanding of Hitler and human nature. This became clear the year he was ill and students were denied access to his analysis. That year, Dar felt students' essays lacked the richness of earlier years, pointing up the key role a teacher's subject matter knowledge and epistemological commitments play in shaping how core ideas are represented and how students will ultimately remember them.[24] [25]

It appears that because Dar had the full support of her administrator to invent her own curriculum, she didn't feel conflicted in terms of competing epistemological agendas, for example, hers in contrast to one that could have been embedded in prescribed materials.

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[24] Again, this underscores the importance of studying the epistemological impact of various aspects of the instructional environment as Hofer and Pintrich recommend (1997) to understand how these may effect change in students' constructions of the nature of knowledge and themselves as knowers.
[25] This example also points up both the fragility of interdisciplinary collaboration from one year to the next and its power, where two subject matter specialists can significantly enhance the work of each.

In summary, her epistemological commitments appear to be central in guiding her desire to collaborate with Bill and in the development of her PCK of instructional strategies and representations.

<u>From the Context</u>

School

After the fourth year of teaching the unit, Dar moved from one school to another and switched from teaching seventh and eighth grade to sixth grade English. The teaching climate differed in the following ways (see Table 6 next page):

Table 6: A Comparison of Two School Districts

CONTEXT	COMMUNITY #1	COMMUNITY #2
Parents	Mixed support; vocal contingent for "Core Curriculum"; little response to the Intolerance unit due to high numbers of dual working-parent families; lack of interest; and illiteracy.	Pro-school; strong professional base; supports classical academic preparation.
School Board	Back-to-basics?	Consistent support for the professional decisions of teachers; hefty budgets.
Administration	Actively supportive of interdisciplinary projects; disseminated "Best Practice" literature and referred to it in staff evaluations.	Pro-teacher empowerment; high expectation for growth via more money for staff development; easier approval process for gaining access to money; and regularly scheduled staff development opportunities during faculty meetings.
Students Today	Shorter attention span; passive; greater diversity; higher number of special needs students.	Entitled; advantaged; more cultural capital.
Students in the Past	More homogeneous; could go further with the material.	

In the second district, Dar had more supplies and a personal computer on her desk, which allowed her to coordinate curriculum more easily. Initially her state returned federal Goals 2000 money fearing too much federal control over curriculum, but later retrieved it.

In both districts, the overriding contextual influence on Dar's PCK development seems to have been the lack of interference from community and administrators and the nature of her students (see below). Dar felt she had control over the content of the curriculum in both her placements, but felt that she could "go further" conceptually with the students in her second placement, even though they were younger, because of the relative increase in "cultural capital" this group brought with them.

Students

As seen in Table 6, there appear to be generational changes in the experiences and orientations of Dar's students in recent years. Both these and the increase in special needs students have influenced her to become more structured, concrete, and interactive in her goals and instructional representations.

Having analyzed stages of mastery in students' essay writing, Dar now has the PCK to help students pinpoint for *themselves* where they are weak by focusing on specific elements within each part of the house representation. In terms of the stages of understanding for the social studies content, she talks about "hitting the wall" in students' abilities to internalize their own high-flown ideals: on the one hand, they could excoriate Nazi behavior, yet, on the other, remain highly egocentric and reliant on the exclusivity of peer group norms. Her frustrations led her to add to her PCK through the use of more graphic representations, which has allowed her to see the power of kinesthetic and spatial learning:

> The books are great, and they are one way of sparking students, but you have to get deeper. You have to put kids in situations where they experience the emotions. Otherwise they are just too detached.

Dar's PCK allows her to respect students' current ways of understanding, while provoking growth via movies, discussions, and their experiences with the simulations. Her sense is that the movies and simulations have been powerful triggers for starting this process, because they engage students in a first-hand emotional experience. Students often try to distance these feelings from what they do to each other; she sets them up, through these representations, to have to reconcile the gap when they are ready to see it. Rather than being daunted by it, she has used their resistance to seeing as a spur to PCK development by inspiring her to find more powerful representations and more effective ways to interrelate them.

Novice Teachers

Dar's first intern teacher helped her give birth to the first version of the unit. Their discussion laid the foundation for the development of core ideas in later unit versions, such as the need to involve students personally in the material and to offer them several points of view on targeted concepts in addition to their own. In order to facilitate a relationship between her intern teachers and her special needs students and their tutors, Dar had to become more concrete in her expectations for essay writing. Thus her interns (and tutors) appear to have been significant triggers for sharpening the essay as house representation.

Collegial Collaboration

Dar's social studies colleagues Bill and Barbara were powerful catalysts for her PCK development. Barbara helped Dar become explicit about her core ideas and how to represent them in viscerally moving ways. Her discussions with both Bill and Barbara deepened Dar's understanding and interest in the ways English could be made to mesh with the discipline of history.

> ... the collegial relationship that I had with these two unique and special individuals has allowed me to develop this project much more fruitfully and rapidly than I would have been able to do on my own.

In her new teaching assignment, Dar has not yet found a colleague with whom she feels a strong connection which has resulted recently in feeling "leaden" when she leaves school each day.

New Resources

The availability of ClarisWorks computer software eased Dar's design process by creating a polished, visually attractive image of the house and greatly simplifying the refinement process as she developed it further.

Synthesis

Students' needs appear to have been the primary influence on Dar's PCK development; however, her own experiences as a student and her commitment to the writing and reading workshop approach to teaching English have conspired to sensitize her to the importance of attending to them. This latter point brings to mind Lambdin's (1988) question about whether subject area can be a factor in accelerating teachers' professional development. Developments in the field of writing pedagogy in the last fifteen years have helped to bring constructivist approaches to mainstream secondary practice, resulting in a growing awareness among writing teachers of the ways students really think and learn. It seems likely that a case could be made that this content, because of its process focus, does accelerate teachers' PCK of effective instructional strategies. It certainly has for Dar.

The second major influence on Dar's representational choices seems to be the synergy arising from collegial collaboration which, in addition to learning about new resources and WWII content, gave her the opportunity to articulate what she was doing so that she could become more intentional about it.

What would a continuum of PCK development focusing on the use of representations based on Dar's experience look like?

Stage One:	A single representation depicting a core idea to bridge between students' worlds and the target concept.
Stage Two:	To refine it as one understood the need to depict more detail.
Stage Three:	To move toward using other representations to depict additional core ideas or facets of a core idea.
Stage Four:	To move toward having students work back and forth between several representations to construct a more articulated understanding.
Stage Five:	Stage Four plus having students generate their own representations and demonstrate how they illuminate the concept(s).

To elaborate on the above, Dar's core ideas became increasingly articulated over time which affected the nature and choice of representations used to depict them. For example, she moved from asking students to consider the general idea of "Intolerance" which was not focused on a particular representation, to a key question which unpacked the concept further: "Is intolerance as seen in Fascism a part of human nature?" This she eventually represented through two graphic simulations which became focal experiences for wrestling with the unit's concepts.

Working to refine core ideas, it seems, can stimulate teachers to develop more powerful PCK of instructional representations. For example, after building the essay as house -- interestingly, the only representation which began as her personal creation -- Dar began to see more subtleties within the structure, like "essays can vary in size and complexity," which she mirrored in the number of rooms one could add to the house. Because the representation became an arena in which to work out her ideas, Dar's case suggests the potential of representational formats geared toward conceptual understanding to offer opportunities to develop teachers and students mutually.

Dar's teaching is a clear reflection of Ball and Wilson's contention (1996) that "concerns for the intellectual and the moral go hand in hand." (p.157) She is concerned not just with teaching students how to organize their thinking, but also how individual and social responsibility interrelate -- a clear legacy of her family's social conscience and the concerns of those at Loevinger's *Integrated* stage of ego development (see Appendix A) who are focused on, among other things, resolving conflicts, attending both to the inner and outer lives of the individual and democracy. Meeting these goals required taking risks, trusting that students would teach her what she needed to learn in order to teach them better. As Ball and Wilson have pointed out (1996), when teachers give more and more of center stage to students:

> [teachers] become more and more dependent on their students -- on what they contribute to the conversation, in what directions they steer the class explorations, on what [students] are willing (or not willing) to do (p.185).

Dar feels that she has created a discourse-based community -- building the trust students need to be truly self-disclosing and ask genuine questions, a central feature of concept-oriented constructivist classrooms (Lampert, 1989; Brooks & Brooks, 1993). Her PCK has evolved to make cognitive dissonance and coping with ambiguity central to her *modus operandi*. Like Wilson, she is intimately engaged in "thinking about what [her] students know" (p.160) -- a deeply compassionate concern, as well as a fundamental need for structuring learning experiences which actually take hold.

Case Four: "Ben" (Social Studies)

> You're Phi Beta Kappa: you've got material; you've got a class, and it's not enough. There's something else. And that something else is the final inch; it's "Come with me." Students see it in your eyes. -- Ben

Professional Development

Introduction

Ben, 52, has been teaching seventh and eighth grade social studies for 30 years, the last twenty-four at the same school as Kit and Dar. For three years of those years, Ben and I were members of the same academic team. He has a sister who is 4 years younger and two sons, 22 and 18. He was born and raised in the same state in which he teaches. Travel has included many three-day trips to Canada with the 120 students on his academic team, more recent trips with the students to Washington, D.C., and Fort Sill, Oklahoma for basic training during the Vietnam war. He sees himself as "very much a homebody."

Childhood

Ben feels that he had many good teachers as a youngster. Two in particular stand out. One was his kindergarten teacher who seemed like a member of the family:

> She was my mother's best friend. They had grown up together. Auntie El was very special. I had good teachers. I think most of us did in many parts of this country then -- people who saw it as a calling, and the community supported them. They put down roots. My teachers were, most of them, "Old timers."

The other was his seventh grade English teacher who encouraged Ben's love of literature as a way to understand people -- a love his teacher probably didn't even know he had kindled.

> I've always been fascinated by human behavior. I remember ordering books, in English class from book clubs, that had to do with poetry -- not because I liked poetry, but because I liked the idea of seeing into somebody's psyche. I remember kind of hiding those books.

> Others would order adventure stories, and I would order Robert Frost.
> Did Mr. O know how I felt about poetry? No. We don't know, do we?
> He didn't know I cried when he left.

As a college student, Ben began thinking about a career in guidance because of the limited college options he felt he and his friends had had as high school students in rural New England.

> In 1958, '59, 1960, there was no guidance, at least in my hometown. Everybody was pretty much destined for the University, if you went anywhere. That was a five hour ride at that time through the old notches. It was pretty much my family's goal to have the first kid graduate from college. I thought I wanted to be a guidance counselor, for educational choices mainly. And I didn't hit on that until I was a sophomore in college, and it just struck me, "I am so unprepared." I was satisfied with the University because I knew of nothing else. Ivy League schools, of course, were beyond anybody's approachability. Bates and Bowdoin and such places existed on paper but they were in another world. 'Are you going to college?'
> 'Maybe.'
> 'Where?'
> 'State University. State College.'
> Nobody ever had dreams. One of my friends did go to MIT. His father was a veterinarian, probably from further south. But, for that neck of the woods, dreams were pretty much limited. At least I felt they were. I had told everybody that I wanted to be a doctor in high school, and I think I did, but dissecting the cat sophomore year...I decided out of that.

Ben's interest in helping students recognize and expand their options remains a cornerstone of the work he does today. The motto of the academic team he is part of is, "Toward a Brighter Future."

Subject Matter Preparation

Although Ben has been teaching twentieth century history and an introduction to the social sciences for the majority of his career, he is largely self-taught, having never studied twentieth century history himself in high school, college, or graduate school.

> I majored in psychology and minored in history. Looking back, some of my psych courses were extraordinarily rich, but I think my history courses were better because I was more interested in them.

As he describes this experience one sees the glimpses of Ben's notion of teaching as a journey with the teacher as a kind of necromancer/tour guide.

> Some of these courses could take me back. Medieval history was wonderful, though I don't retain much of it. My professor chain-smoked as he talked. His fingers were yellow, like Captain Hook's.

Reflecting on differences in the way he conceives of the discipline of history now versus how he did as a college student, he comments that at that time, he saw history as a body of knowledge, not as about real people.

> The more I understood the role of individuals, key events, and the impact of technology, the more I understood that this was about people's lives, that this was real. I didn't realize history was real in college. It's strange, but I didn't make that connection.

Ben recognizes that part of the teaching excellence to which he has dedicated himself is knowing your subject.

> But I didn't know it. It was amazing walking in here from my last school where I taught language arts and geography. Here I'm going to teach 20th century American history? Someone "handed me"a stack of learning activity packages that reached the ceiling.

His experience echoes findings that novice social studies teachers are often expected to teach subjects in which they have had little preparation (Ball & McDiarmid, 1990; National Center for History in Schools, 1991, as cited in Wineburg & Wilson, 1993). With six years of teaching already under his belt, he didn't succumb to ready-made activity packets as many might have done and got to work teaching himself his subject.

> There was a 20th century history text written at the freshman level for slow learners and that's what my colleague Andy and I had to work with. What we've done makes sense to us. We've provided the kids with a framework we understand.

The values underpinning how the history was written that Ben studied in high school and college didn't become clear to him until the '80's after feminists brought attention to them and debate had entered disciplinary discussions and the national consciousness.

> It took awhile to realize that the white Protestant males dominated what we learned. It was a view of history that left out everybody, not just the obvious, but it left out the Holocaust. How come I wasn't taught it?

Ben decided to teach the Holocaust starting in 1973 because he felt morally compelled to do it. It proved to be controversial.

> Any study of World War II stated that atrocities happened, but "it" wasn't taught. We were afraid of it. There was a time, not so long ago, when parents, three parents, as I recall, came in saying, "Why are you teaching this?" That was before teaching the Holocaust became fashionable.

Multicultural awarenesses missing from his own training are slowly making their way into his curriculum; but his feelings are mixed about the rightness of including them.

> It's difficult because there is a lot I don't know. I'm not a multi-culturalist. I see dangers in multicultural education, yet I am very much leaning in the direction of including everybody. I worry about core culture, the things that bind us together. The fabric of culture is torn not because of multi-culturalism *per se*, but, in part, because Grammy's not home anymore enculturating. The schools aren't sure what we're supposed to do. I know I'm not.

Realizing that the entire thrust of his unit on perception is to help his students develop a basis for appreciating the myriad ways human beings create their realities, Ben sees the paradox in his position.

> It's a shock for me because my goal with opening kids' minds is to allow them to be receptive to other ways of being and doing. But my goal is too textbookish: I realize it's OK for those other ways to exist elsewhere, but when they are all incorporated within one society, there are real problems. Shouldn't American heroes tie together Americans? Shouldn't our kids be given these? Appreciation of everybody's ways is great, but it seems to me that we ought have a common language and we ought to have a common something.

Ben's Existentialist commitment to creating awareness of personal bias competes with his realistic desire to teach a body of core knowledge.

Entry into the Profession

Ben's background of positive experiences with schooling, his perception of it as a well-organized work setting, and its status as a respected vocation all attracted him to teaching. What precipitated the actual decision to teach, however, was the reality that positions in guidance would be hard to find.

> I think the teaching part came as an opportunity and not a great calling. There was one guidance position in my town for K-12, but it became clear that that opportunity was going to be pretty much a dead end. I thought, 'Well, what am I going to do if I don't go into guidance?' What were the alternatives? Teaching was certainly a noble calling for a male at that time. The profession was still highly regarded. My folks saw it and said, 'Hey that's good, Sport. Going to be a teacher, huh? You're going to make $4200.'
> 'Yeah dad! Pretty good, huh? $98 a week.'

Ben had no exposure to kids before teaching. His practice teaching began with a six-credit summer course in which he was told to produce on paper what he thought was a perfect class.

> Opening statements to ending, including small talk that we may include in class, verbatim. Dr. N, a lovely man, who may still be at the University, has since told me he is embarrassed about that assignment. He was new at the time. We did not spend one moment in a classroom with the students. So we presented classes to our peers, and they responded very well! (laughs)

In spite of this artificial beginning, it was here that Ben saw it as his duty to lead wisely as a teacher and the need to connect genuinely with students so that they would journey with you -- themes that have stayed with him thoughout his career.

> Dr. N always talked about the awesome responsibility of being a teacher. He said, 'Come with me.' He said, 'It isn't so much the message as it is the messenger.' He was the kind of person who said, 'Let me in. I will let you in.' He spoke from the heart.

The rest of Ben's training involved a three-credit course with a master teacher who "talked about the realities" of the profession within a seminar format that also excluded working with actual students.

Ben didn't feel prepared to teach, but he did have poignantly brief mentoring by his first superintendent.

> I hit the ground running scared. The superintendent who hired me died that fall. He must have only been 38. I cried inside for days. He was an incredible guy, who showed me, despite my nervousness, a path I wanted to follow. He was into education purely for the joy of it, for the sense of responsibility. He was an unusual man.

When asked what he feels an ideal teacher education program would have been for him, knowing what he knows now, Ben emphasizes understanding the entire span of people's lives:

> In a perfect world, teacher training would start sort of slow, with sophomores climbing mountains and playing with kids...I'm thinking junior high and younger, so these college kids rediscover their own sense of play. I would have prospective teachers spend time with parents. I would put them in nurseries, change diapers, garden with senior citizens. I would have them spend a lot of time with social service agencies answering the phones. They'd get so many credits for that during sophomore year. Junior year they would go into the classroom to decide whether they were going to continue.

Professional Influences on Teaching

Six years into his teaching, coinciding with his move to his current school in the early seventies, Ben began a Master's program in liberal studies. While broadening, he sometimes chafed under what felt like an over-emphasis on classical disciplinary knowledge at the expense of a more pragmatic immediately usable kind. In the parlance of the day, he wanted it to be "relevant":

> The Progam was really wonderful for me. It allowed me to take a music course which opened the doors to something new. My anthrolopology class was memorable. We wanted the professor to give us insights into our kids and our society now, not all that junk about the basics of anthropology. At that time in the early '70's, those of us in his class felt that the sky was falling. If you've got a bear chasing you down a trail, you don't stop to say, ' wonder where that bear is coming from? Or, where the hell are we going?' I think that to his chagrin later on, our professor tried to give us insights into our kids, but I think he should have stuck to his guns. It would have been better in terms of my own structured learning. I would have understood anthropology better. The bear wasn't that close.

Ben's Master's program was an important influence on the direction of his teaching because it gave him access to materials and ideas he included in his classes for the bulk of his career, particularly activities designed to help students understand the nature of perception and material related to anthropology.[1] He was able to integrate these fairly easily because the curriculum at his new school was wide open and he had the blessing of a principal who believed in Ben's potential and trusted him to do what he thought worthwhile.

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[1] These are detailed in the sections, "History of the Perception Unit" and "Evolution of Ben's PCK of Instructional Representations."

When I came here I remember my department chair picking potato chips out of his beard and saying, in effect, 'Create your own curriculum, or you can use that pile of dittos over there from the election. We did that during last year's election.' So Andy [one of my social studies colleagues] and I said, 'Well, with [our principal] Steve Jensen's support, we have a wonderful opportunity to do what we want.'

Steve gave me freedom. He gave me a sense that I was doing OK. He was fair. He showed us how it could be in dealing with people. I don't think I would have stayed all these years, if I had had "Average Principal X." I would have headed for the high school or left teaching altogether.

In his seventh year at his current school (thirteenth year of teaching), Ben's team began taking all one hundred twenty students to an outdoor education facility in another state for three days of team-building activities at the beginning of each year. The way the staff at this facility encouraged students' innate problem-solving capabilities provided him a chance to see sides of his students not accessible through the methods and assumptions of his classroom.

What an impact the outdoor center has had on me. It really showed me how stupid my habit was of having to be the organizer and having things a certain way. There, the teacher stands back and allows kids to do! You see inordinate amounts of progress in two-and-a half days when you let them do things themselves. You see their willingness to tackle tough things, their understanding of themselves and others. Some of the measure of their experience comes on their return to the classroom, weeks later in things they say. If I were to design a teacher program, it would be interning in such a place. Day one, 'I don't care about your knowledge of history right now, but do you want to be with kids in this kind of situation?'

Between his fourteenth and twenty-fourth years of teaching, Ben coached T-Ball, B-Ball, A-Ball, and Little League in the town where he taught. The depth of these long-term relationships with local children kept him teaching at a time when he questioned his worth as a teacher. Further, he feels that working with early adolescents in something they loved had a significant impact on his understanding of how children grow.

These eleven years of coaching came right at that key point where I could have left. I had all those kids and all of their parents year after year after year. It was a really strong bond. I felt responsibility for them because of it. I knew most of the kids I would be teaching before they came to me.

The first couple of years was about ego: 'Look what my teams are doing.' But I got over that quick. It was like getting a trout membership in a trout club, and catching your limit the first year. At 37, 38, I was old enough to be over that macho business and just felt the joy of doing it.

Last night one of my Little League players, who is now a senior, was the MVP in the State high school tourney. I thought about the first time she scored at Miller Field. She ran around, I'm at home plate, and she jumps right into my arms with her legs around me -- this little child. The joy of that!

Another inspiration for Ben were the words and example of Christa McAuliffe, the teacher who was tragically killed in the Challenger space shuttle explosion.

I was burned out and wanted to quit. Christa said, 'No. What we do best is what we do everyday.' She inspired me before her death, just from having a teacher put back on a pedestal. That made me feel like, 'Yeah! Dad you were right!' Christa rekindled awe in me for this little speck we're on and made me feel that I, too, was making a contribution.

The most radical catalyst to Ben's development as a teacher was mentoring a very bright intern teacher named Barbara (the woman who collaborated with Dar on interdisciplinary presentations) in his twenty-fifth year.

My isolation was shattered by Barbara Kingston. Barbara brought Brown University to my classroom. Do I love her. I think every teacher should have to supervise a Barbara Kingston. Talk about bright people. I expected, as with my other three or four interns, that she would sit back for six weeks and take lessons from the master. Do as I did. After about six periods of sitting politely, Barbara says, 'I want to get to work. Furthermore, I think you ought to be journaling.' I think to myself, I know what a journal is, Barbara. What's journaling?' 'We need to do cooperative learning and role play and ...' she said. She was the first practice teacher who said, 'To hell with you, I want to take over these classes.' I wanted her to see how good I was, to see THE way. Well the way turned out to be something her supervisor saw as old fashioned. I was very stale at that point, and this thing [heart] was almost plugged. [He was to have a quadruple by-pass the following year.]

Barbara influenced Ben in at least three ways: She brought in new pedagogies and a greater sense of students' capabilities for constructing knowledge for themselves.

She very much helped me see things, and part of it she had no idea of. Because she took the students early on, I had a chance to sit back and watch. When she would give them assignments, I would think, 'Well that's stupid.' For example, 'Go find out about archeology.' She gave them some directions, and I'm thinking they're not going to do it, and by golly, they did! I'd be in the library and kind of eavesdropping, and they'd say, 'Now what are we supposed to do?' and I began to see that I still had not had enough confidence in my kids. Now when something key is coming up in the news -- this is going to sound silly coming from a 30+ experienced teacher -- I can say, 'Go find out about it. You track it. You be ready to write about it a week from now.' And it really tends to work. The kids found out about Menachem Begin through me, but now something happens and they go to the Internet and pull out the *Jerusalem Times*! How many in the class can do that? Five, on that particular thing, but they can come up with their own meaning.

Second, Barbara helped Ben bridge into the new world of technology.

With Barbara, who understands technology far better, the gap is not like it is for me. I'm not into computers; I can't offer my kids that world yet. Out of 45 staff members, I'm probably number 43 in ability to use technology. That's going to change, but I will always be behind.

The third major influence was that Barbara helped to emphasize the constructivist discourse-based community valued by teachers committed to teaching for conceptual understanding (Brooks & Brooks, 1993; Lampert, 1989) which has now become a regular part of Ben's teaching. During my second visit for this study, for example, I saw an eighth grade class in early December and had a chance to see this in action. As part of the segue into the "patterns of action" portion of the culture model he introduces to students, he built suspense by asking five volunteers to disappear into the hall while he instructed the rest of the class to watch closely as he called students in one at at time. After greeting and engaging each, he had a student mark with a piece of tape where each had stood. Then he had two boys measure the distance between the tapes and where Ben was standing. A constant of about 19 inches emerged. Then he asked the class,

I'd like to see if we can find something in common between the fact that you're all wearing sneakers, that women's fingernails seem to be longer than the men's, that women mostly have longer hair, and what happened when all five of these volunteers came in and talked with me.'

One boy offered a theory, which Ben asked the class to support or refute, then guided students' ideas into a definition of culture, incorporating concepts like "basic human needs," "senses," and "perception" with which the class was already quite familiar:

If we are brought up to think of things a certain way, when we ask ourselves why we behave as we do, it's not just because we have needs, senses, and perception; we're also taught how to act in what's called our "culture."

During another observation, this time of a seventh grade class, after students had generated categories for ways to address problems with working conditions in the woolen mills of the last century (e.g., "Can someone combine the problem Jeff pointed out with other examples that would fit this category?"), Ben had students resume their roles as members of a Congressional committee, begun the day before, to recommend and debate possible suggestions for laws to deal with the categorized areas of need. Before students began this portion of the class, to help them focus on their problem-solving process, Ben had his aide give the class feedback on her perceptions of what worked and what didn't from the session the day before. She suggested that one issue at a time be addressed, but complimented the class on the richness of their ideas. In this way, he helped support their thinking, instead of doing the the thinking for them, as he says he used to do. He empowered them to think of themselves as real lawmakers:

> What happened yesterday was pure democracy-- people getting together and deciding there was a problem. That's what a law is, a practical solution to a problem, not meant to pick on someone.

Under the leadership of a student Chair, the class dealt with one issue at a time, while Ben stood off to the side and acted as a process coach. It seemed like valuable practice for actual participation in town and city government some day, as students wrestled to bring up various details from their readings. I noticed that the Chair called on other people than those who responded when Ben was running the class, and that student responses were longer and more complex during this portion of class. One student made connections between the topic and a current situation; another struggled, at Ben's gentle suggestion that the Chair ask for it, to express a dissenting opinion.

As a result of a full semester with Barbara six years ago, and suffering serious health problems which prompted him to seek more support, Ben now approaches planning for class in a very different manner.

> Planning now is much more wide open. I'm able, despite the weight of those file cabinets, to see other possibilities. I'm more confident, not scared most of the time. If kids will buy into the lesson, then it meets my biggest criteria. Guilt comes from not necessarily having the goals so set. If students buy in, then a lot of things happen.

Having close contact with another intelligent colleague, he feels, offered a kind of companionship Ben has seldom known before or since and invigorated him at a time when he needed it most. For his part, he was able to share with Barbara his wisdom about students' needs, interests, and learning patterns, along with an array of highly refined lessons.

Perceptions of Himself as a Teacher

Ben's reflections on himself as a teacher cluster into four areas: thoughts about his personal qualities; his goals; immediate contextual issues; and the prevailing social and educational realities affecting his sense of his task.

Turning first to his view of his personal qualities, Ben sees himself foremost as caring.

> I feel for and with the kids. Sometimes I'm manipulated to let them get away with things, but I've always looked at children's faces, as I look at yours now, with a sense of wonder. I didn't really begin to understand this until I had my own kids. I come in each morning and look at them all -- fat, skinny, tall, short.

Like teachers in the Idealistic tradition, he shows his empathy for students and the people they study.

> The unplanned moments, the times of tears...I think those produce an empathy; and when I feel tears coming I let them go, especially with the Holocaust, or watching Miss Jane Pittman get a drink of water from the fountain.

During my first classroom visit in October of the year, before starting class, Ben asked a sleepy boy if he would tell the rest of the class why he was having trouble staying awake. The boy recounted that the night before his house had burned down. Taking a few minutes from the day's regular agenda, Ben gently elicited many details, helping students vicariously experience the smells, the timing, the danger, and the courage of the boy who spoke.

Ben's interest in nurturing the whole child is evident in the personalized photographs he posts of team activities. Half of one wall of his classroom is covered with them. Each trip is identified with its name inside a cloud. One senses playful enjoyment and attention to detail in the careful labeling aside various photos of special moments of the day.

> This school is a good place. You don't start off with 4,000 rules. I don't have any rules in here except to treat each other with respect.

Ben also characterizes himself as highly structured and "concrete" in his ways of thinking which he has found to be both a blessing and a curse.

> I have to have things in categories. They have to be clear. I have to understand A before I can go onto B, and so do many of my kids. I have to know at the end of the period where everything is for the next period.

Sometimes he feels constrained by his need for order and his reliance on often used lesson plans that worked.

> One of the things that allows me to continue is those GD file cabinets. But they ought to be burned because it reaches a point where their sheer weight brings down a wall between me and change. I don't want to throw away anything that's in there. The thing that's stifling me is that I am still back in what I felt worked, working with ideas I value. I can walk into Bill's room,[2] which is dusty from September, and he is doing great things, like taking kids to Russia, coaching his own children, and building his mind. I so envy him.

I used to teach language arts next door to Ben and remind him, at this point, of the ways his increasingly refined lessons taught me about how to structure activities with students' needs in mind. I recall a news column he had had students read in the early eighties, where he'd written questions in clouds on the side dealing with key ideas he'd underlined in each paragraph. It was the first time I'd seen a teacher take "adult" reading material and scaffold it visually to help students digest it. I asked him where he learned to do that:

> You have to be intuitive about the profession. When things work, something comes back and forth. It's in the looks of kids that say, 'That doesn't work a bit, and this does.' Then you have to have the energy to say, 'Yeah! And I'm doing that tomorrow,' or 'I'm throwing that out tonight.'

Based on students' reactions, Ben systematically builds his PCK of instructional strategies of the lesson plans he has used over time, polishing them to a high gloss. Seeing him in his room after school with the lights off, taking notes on what worked and what didn't after teaching a unit is what originally inspired this study.

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[2] Dar's social studies colleague in Case Three.

R - I remember you sitting down after a unit and writing down your reactions. In fact, I was inspired by that example to be more systematic myself.

B - Are you serious?

R - In graduate school I thought if there were other people like you who had chronicled the changes in the lessons and units they had often taught and had saved the various versions of those units, tracking the changes would make a fascinating study.

Hard work and pride in one's work are key values for Ben. Following in the realistic tradition, he feels his own standards for neatness and attention to detail inspire students' confidence in him as a teacher.

> Poor teaching is no connection between teacher and student. There's no two-way street. There's something dead. The pencil sharpeners are full, not because a lot of work is going on but because teacher doesn't empty them. The teacher is empty; there's no pride. Are you going to go to a doctor who's slovenly? 'Hey, how ya doin?' I want a doctor who stands tall. And when she says, 'Come with me,' 'Yes, I will!' I want to inspire confidence in students from the moment they walk in. The look of the room is part of that. There's some merit to saying, 'I am in charge of my room,' and what happens within it is largely a reflection of me. I can change the atmosphere like that [snaps]. If I'm positive and encouraging daily and react to things like a responsible adult and have a sense of joy and laughter and do different things, that helps.

On the back wall of Ben's room hang antique children's toys -- hoop games, a wooden triangle with pegs, and games the students make. Windows cover one side, their sills covered with plants. The opposite wall bears photos of a team mountain climb and information about the end-of-year trip to Canada. Atop the bulletin board are laminated front pages broadcasting key events from years like 1912 (WWI declared), 1945 (WWII ends), 1953 (Julius and Ethel Rosenberg's execution), 1963 (JFK's assassination), 1989 (Berlin wall falls) and 1991 (Invasion of Kuwait). Plastic globes hang from long fluorescent ceiling lights, along with a metal airplane mobile. The day's agenda is written neatly on a carefully washed blackboard. The carpeted floor is spotless; desks are in straight rows facing front. Ben's desk sits off to the side, papers neatly stacked. Calm, comfort, and content prevail.

Ben uses the concept of "going the final inch" to describe his commitment to excellence in teaching.

> In teaching it isn't just an expert and material. I think of Solzhenitsyn's philosophy of 'the final inch.' Under surveillance in the gulag, Ivan [from *A Day in the Life of Ivan Denisovich*] is building a wall with bricks and mortar. Later that night he sneaks away and redoes it because the temperature is changing and the wall's only half built. He chooses not to report to roll call so that he can have the new cement not show the crease, so the parts of the wall match. That's the idea of the final inch.
>
> Using an analogy with professional baseball: Roger Clemens can deliver. A college professor can deliver. They've both got high quality fastballs. But Roger Clemens isn't going to make a dime if he isn't painting the edge of the plate. As college professors or classroom teachers we should have that same standard. It is saying, 'What we are teaching is worthwhile.' You cannot get every one of your kids to open up at any one time, but if you keep saying, 'Come with me,' enough times, most all are going to, especially if you have a program like we have at this school where we have two years with the same kids. They will come with you. The heart opens.

When pressed to give an example of how the philosophy of going the final inch might translate into classroom practice, Ben comes up with a bit of PCK -- a vivid instructional representation students can immediately grasp to illustrate the fragility of human life.

> If I'm teaching driver training and I'm talking about, 'Here's a [toy] car and here's the cliff [pointing to the edge of the table]: we've got to drive so we keep the car on the table,' the final inch might include putting an egg in that car and driving it off the edge. The egg in the vehicle says, 'Come on; understand this.' -- You can say, 'I want you to picture history,' or you can stand with a Civil War gun and say, 'They're comin'. [whispers] They're comin'. They're comin'!' If the bridges are there, I believe that students are more willing to try to step across on their own.

When he introduces new material, he treats it as new territory for all of them to explore together.

> B- I say this is our story. When I first studied it with kids, it was a journey for the first time. And that journey for the first time will continue this Tuesday.
>
> *R: So, the ways that a new group of kids interact with the material create a new trip for you.*
>
> B- Yes! They say, "Come into MY world." And if they don't, you see the eyelids and you know that the street's closed. It's the worst feeling.

Ben personalizes the content; he makes a connection between himself, his girls and boys, and the targeted understandings. For example, during my first classroom visit, Ben asked his seventh graders to empathize with the life of a young girl who worked in a 19th century woolen mill from 5:30 AM to 7:30 PM with only two half-hour breaks in between. He had them "read between the lines" of a euphemistic letter she had written comparing the noise of the mills to a waterfall, asserting that she found the highly repetitive work interesting, and didn't mind the long work day. From that he had students generate categories of problems humane law-makers might want to address to improve her working conditions, noting several times how much less the women were paid than men would have been in those same jobs.

In keeping with sensitivity to gender issues (both in the content and process of the class), during the question and answer portion of class, instead of the 3:1 ratio of attention to boys over girls commonly found in classrooms (Sadker & Sadker, 1986), Ben was more balanced in his attention, calling on 8 of 14 girls to speak a total of 18 times and 10 of 13 boys, who spoke 24 times. Inclusive language strengthens the bond between himself and the class. "These are our basic human needs... ." "Be with us," he says to a student whose attention has strayed.

Creating trust and respect so that students willingly enter the world Ben wants them to explore means being open with them about himself.

> If I let them in that I'm hurting right now, they will let me in. If I don't, they aren't going to let me in. So much of the way I teach depends upon me. I set the mood. If I'm in a good mood, they are in a good mood. If I'm respectful, courteous, on time, and my papers are corrected, their work is done, generally.

On his end-of-year surveys, consequently, Ben is primarily concerned about whether he has been able to help students forge a personal connection between themselves and their learning.

> Others think that I should be asking, 'Did you like this unit? Is the homework too much? Too little? Am I a fair grader?' But what I want to know is, 'Is there a connection? Do you feel that you are learning? Do you like my way of teaching?' It sounds like I'm in it for me, but if the connection's not there, all you're doing is showing up and spending time in the same room.

One feels a moral imperative, in this regard, in Ben's unwillingness to treat key parts of the curriculum simply as something to be gotten through.

> I would think it a mortal sin to study the Holocaust and not try to get the kids to sense that things were out of proportion.

Ben has come to cherish those moments when the class comes together as a whole and bonds with him and the ideas they are sharing.

> The real serendipity is laughter, laughter that is felt in the soles of your feet. It produces a sense of well being, a unity, where we're just people understanding something together. It brings down the barriers. They go up again. But for a while, the kids forget about themselves.

The teaching power of laughter is evident in the way he helped students focus on the concept of cultural patterns during my second classroom visit. Clowning around at the start of class amid growing giggles, Ben put his foot up on the desk and pulled his socks over his pant leg, donned a hat with streamers, asked about the colors on the ends of one girl's fingers, blew his nose into a hankie, wondered about "that piece of metal" in another girl's hair, lifted the locks of one boy into a pony tail, wondering why he didn't wear it that way, then asked his mesmerized class, "What's going on?!"

Ben castigates himself for the fact that he cannot always sustain the level of engagement students come to expect of his classes. His health, family, correcting, lesson planning, and refining all compete for his attention. Yet he is unwilling to take the easy way out, even if it would make life simpler.

> When I go in and I know that I've got a great lesson planned, I'm six feet off the ground! But moments of having a meal that really tastes good make the bland even more bland. I really feel the contrast. For days we are dealing with nuts and bolts -- tired kids, tired teacher, a blah part of the curriculum. I know if I put them in their damn seats and said, 'Do these worksheets,' students would have lower expectations, be more on an even keel.

He feels guilty that he can't keep up with his own standards for written feedback.

> I go home and fill the well to drain it tomorrow. But to go home and correct and correct and plan and correct is draining too. Why don't I do it on the weekend? Well, I do, but it's not enough. So there's a lot of guilt involved with me and this profession because I don't correct anywhere as much as I see the language arts people doing, or as much as I used to. When your eyes go...

Intuition plays such a deep role in the way Ben teaches that he's inclined to believe that "teaching knowledge" cannot be adequately taught, rendering him somewhat skeptical about the usefulness of trying to catalogue his PCK for others through a study like this one.

> I don't think that I could teach what I believe to anybody else. I don't think that your finding patterns of teaching, once they are even uncovered, is something I could copy. I really don't, because good teaching is a feeling. It's like teaching somebody else how to balance. How can I tell them when to shift their weight, other than within certain parameters? It's got to be you finding your own...now you shift!

A second theme in Ben's reflections on himself as a teacher is the nature of his goals for students. These include broadening students' awareness of the possible so that society can effectively overcome its problems.

> As teachers we are in the business of developing better lives. Social studies has to try to help us understand ourselves. I want kids to see that they *can* understand history. I want those minds to stay open to the social sciences. If they are, they're going to continue learning on their own. There is cause and effect. Individuals make a difference.

Ben teaches specific topics like "the four punishments" that may result if one fails to follow the culture's established "patterns of action" and expects students to learn them. What is more important to him, however, isn't whether students remember them forever but that they leave the unit thinking, "This does help me understand my world."

Asked whether his goals have changed over the years he suggests that he is working for a greater understanding of the way facets of the world are integrated: since nothing exists in isolation, nothing should be studied that way. Students need time to process and connect what they are learning to other things and to themselves.

> My goals have gone from "name the products of Venezuela'"(kidding!) to, I don't know if it's any more in depth, but I want students to see that everything is connected to everything else. We're all part of the ecosystem. I guess there is a place for knowing the products of Venezuela, but it's like the outdoor center where we take the kids. You just don't have an activity and go on to another activity. You have down time, discussion time. You have 'What did you think?' and 'Why didn't that work?' time to connect what you're learning to other things.
>
> There are values I believe in pretty firmly, even now. I want students to get those, too. I also want to impart a sense of fun and joy; and that history is our story that they ought to know as their ABC's. The more I teach, the more I realize there are things that if I don't provide for them the opportunity to learn, they're not going to get, because they are found nowhere else in the curriculum.

Themes in Ben's academic commitments have come into clearer focus over the years: the nature of perception and its sometimes faulty relationship to meaning-making and judgment are central.

> The Perception unit is an eye-opener for the kids. After we study that, then watch Farley Mowat's, *Never Cry Wolf*, students will pick their own topics to write about, and many write about what's important in life.
>
> Other key ideas that we come back to are that there is no free lunch and nature does know best. Those ideas really have to keep reappearing. It's sort of like chiseling. Realizing the need to reiterate themes fell into my lap. I didn't understand that when I began teaching. I understood Jerome Bruner's *Toward a Theory of Instruction* -- that was my teacher education.

With the emphasis on core themes and linking material, Ben's practice has becoming increasingly oriented toward teaching for conceptual understanding (Brooks & Brooks, 1993; Prawatt, 1989, 1993).

Turning now to the third area Ben addresses in his perceptions of himself as a teacher -- the immediate context in which he works -- three themes emerge: his professional isolation; his coaching; and his health. Ben feels that even though the school is divided into academic teams with team teachers meeting several times a week about shared students' needs and team events, he has little time and space to talk with colleagues about teaching. Extracurricular concerns and staffing for special needs students have precluded many opportunities for substantive in-school exchange; and personal circumstances have left him with little discretionary time later in the day:

> For fifteen years I had to leave here immediately after school, so that my wife Amy could get to work. Or, I would head to the baby-sitter's to pick the kids up because she had to go to work early.

Consequently, collegial exchange happens on the fly. For a decade I taught in the next room, yet neither of us knew how we had influenced the other.

> B-The gap between you and me was the gap of the Grand Canyon: The difference in years, the difference in where we were in our lives, the distance of three feet. We were doors apart. But I learned to use multiple modes in planning which I got from you. I had no idea about that until you taught me.
>
> *R-Really? I always saw it as being the other way. I remember coming in and saying, "Nobody studied for my test! What do I do?" You'd say, "Well did you give them any advance warning? Did you review the material beforehand?"*

B-Maybe the first year, but after that....

R- All the time. I was always picking up things around corners, listening through the wall....

Both of Ben's sons will be off at college next year, giving him space and time for the first time in his life to engage in some professional development.

> With an empty nest next year, it's going to be interesting to see if I back up my words in the next few years and push to become better and not just rust. I think I've got five or six years more. I hope I have. Beyond that, I want to go out with a sense of pride.

A second contextual theme is that Ben taught both his children and coached them in Little League, allowing him to get to know their peers, many of whom later became his students.

> I taught both boys. It was their choice. It was absolutely wonderful from my perspective because I could spend so much time with them. I also had them in Little League for four years. They and their friends were used to me being around. Being so involved with kids and not having them until I was 31, I think I was old enough to appreciate their changes and those in my students as they became more confident.

That he was so well known to many students before they even set foot in the school allowed Ben to cultivate an unusually high level of trust, where students did "come with him," allowing the occasional traps he set for focusing on key ideas and events to pack particular punch.[3] Further, teaching his own children, he feels, allowed him to sharpen his PCK of purposes of instruction by focusing in on what he wanted his own children to learn.

The last contextual theme which has influenced Ben's sense of himself as a teacher in the last five years has been his health. Heart problems forced him to take off time, prompting him to reassess his feelings about his work.

> Six or seven years ago, I told myself I was just going to do the best I could. I had lost sight of how key my attitude is to everything. Part of using the file cabinet as a crutch was the lack of energy I had as a result of heart disease. I couldn't be myself for 3 years and really, really missed it. I don't know if I'll ever be who I was. It's probably good, because that led to heart disease. The

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[3] Seventh graders, for example, participate in a stock market simulation and some never recover from the "crash" Ben creates to help them understand what this experience was like and how deeply it affected peoples lives.

last three years being kind of laid up, I realized how much I did love my work. I've been blessed with a good principal, a good school, supportive teammates -- incredibly good people. And whenever I was down, something came along. My wife working was my ticket to keep teaching. I love what I do most of the time. But there are times when I go home and say, 'I am not doing anything tonight. I don't care what happens tomorrow. I don't have the energy.'

His health issues have prompted Ben to become more relaxed about seeking help when needed.

> I feel supported. I know much more where to turn, and I'm willing to say I need help with students' behavioral issues because I don't have to be perfect.

A final area of Ben's thoughts about his teaching involves today's cultural educational realities. Culturally, Ben feels that students are, in some ways, harder to reach now than in the past when schools were a place to experience opportunities not usually found at home.

> You could go to school and get an ice cream! You could show a movie with a movie projector! Well, some folks couldn't afford a movie projector. You could tape off television! When I first came here, they had reel-to-reel. I remember with horror, as recently as ten years ago, when we got our first remote and before that, using the school's remote and saying, 'Watch this!' and the kids just sitting there, 'The guy's crazy! We've got seven of those at home!' and I couldn't afford *one*!

Ben sees the American family in flux and talks about the enormity of social problems students bring to school -- problems his academic team helps to offset through a deep commitment to team-building through many extracurricular activities, but problems he feels personally helpless to fix.

> Some of the problems are so overwhelming. I had a physical a couple of weeks ago and my doctor said, 'What's wrong?' I burst into tears. It was Joey. He saw his father commit suicide. The father was still alive when the medical people came. Then in late summer, Joey was in on thousands of dollars of damage [vandalism]. This is a seventh grader. His court date was coming up. He was one step away from being taken from his mother. And I did nothing for Joey, because of lack of energy, except try to give him a smile.

Creative solutions to some of students' personal problems are hard to implement at the building level because the school is filled to capacity and people, he feels, are stuck in old patterns.

> This school is pretty much the way we've been for 20 years. It's hard to be creative in trying to solve some of these problems because we have become so crowded in the building.

Ben struggles with the sense that the culture's apparent concern is that children are happily occupied rather than truly learning. This sense coupled with greater numbers of special needs students has made it harder, he feels, to hold students to high academic standards.

> In some ways, I am expecting less of my kids than I did 15 years ago, and I am very uncomfortable with it. I want to be able to demand of my kids that you have so much more to give. I don't think education is important in this culture. I don't think kids are important. David's parents have two jobs and don't want to be bothered. If kids are coming home happy and not complaining about the teacher, grades are good... . The idea of somebody failing at this school is becoming a no-no. I'm disquieted by it. There is no standard that the kids are being pushed to achieve. The idea of this being win-win is a contradiction. There's too much, 'Hey man, my parents get upset if I get upset, and don't push me too hard.' Not from all kids by any means, but I see that. People don't work as hard in school. Learning is not valued as it was because everybody has everything they need.

Ben yearns for clear guidance regarding what should be taught from a culture concerned about the collective good and an explicit standard to which teachers should be held.

> What does this culture want from us? If individual parents want XYZ -- a comfortable kid who comes home and likes school -- is that what's going to benefit all of us? I used to think that having a statewide curriculum was the worst thing that could happen. I'm not so sure now.

Lacking such guidelines, Ben wonders about the quality of his curriculum.

> Some of my curriculum is garbage -- not well planned, not well presented, didn't work. It's what my colleagues and I came up with, and I think it's exciting in places, but is it the best that these kids could be getting? We are alone in determining what's valid. There ought to be a bit more of a push for shared core content that all kids are expected to know and if we can come up with a testing device, tested on. We need someone to kick our butts. Instead of each teacher inventing for herself, it's got to be what the culture supports by saying, 'This is what we want, but we recognize that you need freedom to implement it.'

In the last three years his principal has encouraged teachers in the building to move toward integrating curriculum across content areas -- to "do less, but do it better." This also leaves Ben uncomfortable.

> It's like "quality time" when you're a parent. This is quality time: I'm bouncing you higher on my knee. Was that a quality class I just had? I did my best with it.

Ben's sense of current educational realities affects his perceptions of himself as a teacher; he feels inadequate about his knowledge of subject matter because of lack of sufficient financial incentives to expand it. State regulations require teachers to take 50 clock hours of workshops and courses every three years to maintain certification. At Ben's school these staff development opportunities are tied to a professional growth plan which is revised for each recertification period.

> I have not taken a three-credit course since my Master's. I have taken only those workshops that interested me and gave me 50 clock hours, which is not a lot of time. But given the demands of raising two kids, a working wife, and wanting my energy for my classroom, it's what I could manage.

He would have been more inclined to add to his knowledge in a formal way had there been greater financial incentive to compensate for the time he would have had to take from other priorities. Because there haven't been, he is less able to take students to places he feels many are ready to go, to climb mountains with them instead of hills.

> If you don't have a basic understanding of your subject and a way to get that, no amount of new pedagogy will help. We keep looking for new pedagogy...we want to climb that hill. We keep looking for new tires to help us climb it when the problem may be that maybe I don't know how to drive. I can drive on a basic level now with some units. But I have a group that can climb a mountain, and I've got them climbing a hill. If I could put on snow tires, we could go there together.
>
> We put teachers in the classroom and we say, 'Get your 50 hours,' and that's what I do. But if I did that with my house, it would fall apart. We should be brightened up during the summer and not only because I'm low on motivation. We need other incentives to put on the snow tires.

Consequently, he sometimes feels that his effort to teach conceptually lacks necessary substance.

> There are a lot of things that I feel very inadequate about in my teaching. In trying to be conceptual, I feel I sometimes miss the substance [laughs]. It's like, 'Where's the beef? You attracted me to the dinner. You had me open the bun. Now where's the meat of all this?'

Difficulty accommodating some of his quickest and slowest students prompts him to wonder about class loads and the wisdom of heterogeneous instruction.

I'm at a point where I'm questioning heterogeneous instruction a bit. We have got everybody included, from kids reading at first grade level to kids ready for the Ivy Leagues. They are all in that room and the disparity is sometimes huge. I think in social studies it's important for them to be there. But here's the clash: on the one hand, they've all got to learn to get along and see the value in everybody, and they can't do that in an ABCD grouping. On the other, with 120 kids to teach, some students are not getting from me, in any way what they could be getting, even opportunities to explore on their own. I am thinking of one child whose mother is on welfare. The mother said to me, 'My kid will be on welfare and damn you teachers for keeping him after school.' Yet that child, with some real hands-on, could go from a second grade reading level to fourth or fifth grade. But will he get it? No. So, does one have a child like this in a classroom and just ignore him? How do you plan for that?

How Ben plans for the challenges of heterogeneity is by offering a range of experiences in the classroom that will meet the needs of a range of students. In recent years he has come to see how much kids can learn given the chance.

I used to put the kids in those categories: 'I'm sorry but you're not going to college. I'm sorry but you're not going to graduate from high school.' And boy did they show me wrong. I am more aware in the last 10 years of the possibilities of the kids. They are so capable. That's why you provide a whole variety of movies and discussions to accommodate them all. I don't have to channel everything anymore. Students are, in many ways, far more capable than I am. Some of the kids will understand from what we've done, better than I have, because I sometimes don't even go through the material anymore and forget. Then they make connections and ask questions that force me to rethink my material. I understand and am more aware of what they can do and allow for those differences. But I don't have it planned that my slowest students will know X at the end of the period. Pretty damn presumptuous of me to think I know what they're going to know at the end of this period. But is there an opportunity to learn? I hope so.

In an age where honoring multiple realities is a new value, Ben wonders where to draw the line between imposing structure and drawing it out of students.

I'm still very much structured, which is a dirty word for some, maybe for many. The frameworks I offer...are they for me or for the kids? It makes sense of my world, and I think it makes sense of theirs, but how much of it is an imposition? How much is necessary? For example, I don't see lectures as lectures, I see them as story telling. I'll give students a preview of the Perception unit to provide a skeleton. Then, as they are going through all these different reasons for faulty perception they'll have that to tie into. Or I'll end a unit with, 'What have we done?' and it doesn't mean that everybody learns that way.

The evaluation which Ben's principal wrote about a class she observed the day after I observed recaps some of the "patterns of action" examples he'd introduced the day before. She notes, as I did, how skillfully he has the students make connections between the examples and the framework they'd been studying; how he gives signposts to clarify pivotal shifts in direction of the discussion, and to bridge between where students had been and where they were going next with the unit. This came across to both of us as needed guidance rather than a rigid imposition, as able to meet students' needs for structure without underestimating their abilities.

Ben has mixed feelings about the current push toward cooperative learning which he sees as muddying the issue of individual student accountability, over-stressing interpersonal relationships at the expense of disciplinary substance, and leaving little justification for other kinds of teaching and learning which also have merit.

> Hard work is important. Taking responsibility for your own work is important. That's why cooperative learning is hard for me to embrace. I see kids more and more able to function in groups, and less and less able to function on their own. Do the kids need cooperative learning? Yes. They need both individual and teamwork skills and teachers need to feel not only okay, but encouraged to support both.

Consequently, in the prevailing climate of student-centered classrooms, he seems almost apologetic when he assumes center-stage to give students notes.

> *R: Do you feel pressure to do less story telling?*
>
> B: Yes. That may be self-imposed. I do that very rarely now. I think there should be more of it. Tying things together maybe for ten minutes, and "This is where we go" is what I do now. But there's a difference between "chalk and talk" and story-telling -- using your abilities to say, "Come on, let's go down this road."

Reflections on Professional Development

Several themes emerge from Ben's professional history. First is having to construct his knowledge of his subject matter and teaching almost single-handedly within a working and personal context where pursuing more education was not practical and collegial exchange difficult to achieve. As a consequence of this isolation, sorting out the many viewpoints he has about prevailing trends in teaching and society is difficult for him, yet he comes across as focused and grounded in the classroom where mind and heart converge. Here one feels Ben's desire to recreate his original excitement in learning the material. He wants his students to see that history and culture are about real people, not 2D images in a text. The high of a good class breeds emotional and cognitive breakthroughs, on the one hand, but restlessness on the other -- students' appetites for more sometimes strain Ben's ability to produce.

Second, with the singular exception of his intern Barbara, what has helped Ben in the classroom have often been experiences outside it, like coaching and lessons learned about children's strengths at the Outdoor Center. There's a sense of living off the land, nourished by what was available, hungering for support from the chance comment in the supermarket. After twenty-five years of going it alone, it is striking how open Ben was to Barbara's ideas; he didn't realize how starved he was and was fascinated by what she taught him. His commitment to excellence and his concern for his students seemed to override any defensiveness.

Third, echoing the concerns of many about cooperative learning, Ben wonders about the appropriate place for teacher-centered instruction and teacher-created frameworks for understanding content. Have prevailing educational trends thwarted him from using some of the best aspects of his repertoire? Or is he merely reacting to necessary growth? Or both? He has evolved a structure over many years which makes sense to him. Skilled at highlighting the signposts and turning points of the journey, like the high knowledge math teachers Leinhardt et. al. (1991) studied, he leaves students with one way of connecting the pieces of history. Yet, he also creates spaces for conjecture and is open to serendipity. One feels his pull between not feeling innovative enough on the one hand, yet being a dependable and known entity, on the other -- someone with whom parents look forward to placing their kids.

There's an irony: inventing curriculum feels wrong to Ben, yet some would say it is much less so than relying exclusively on a text which can be epistemologically simple (Wineburg, 1990) and lets teachers out of taking responsibility for curriculum -- something

Davis (1983) sees as "a major part of their professional role." At the same time, Ben feels that what he offers is unique; that no where else will students have an opportunity to confront the basic awarenesses he helps them to build. Because he is committed to teaching concepts, making personal bridges between content and students' lives and giving time to think about how a process has turned out, he clearly values depth over breadth, but apparently doesn't give himself credit or perhaps questions whether this is always a good thing. He struggles with issues of core knowledge, wishing the culture would detail this so that he knew how well he was addressing it. Complicating this is that the culture is not monolithic -- something he (paradoxically) seems to yearn for so that he wouldn't have to struggle with fragmenting a core culture by including "everybody" and their history.

Faced with huge social problems, Ben is resigned that he cannot provide all that is needed, that he must be realistic about what is doable so as not to dry up his own well. Yet he feels frustrated at attempting to maintain an inherently flawed system (large teaching loads filled with growing numbers of special needs students). Is the professional remoteness which has characterized many of his years in teaching partly about preserving some tranquility amid the clamor of social need? Does he keep to his own patterns as a respite? Responsibility and guilt surface and resurface in his remarks.

> In a day and a half, this class might have even understood with a lecture and some examples what I took a week and a half for and there's guilt in that. It was an exceptional class.

Like those belonging to others in this study, many of Ben's observations come across at the level of feeling and intuition, having had little occasion or encouragement to articulate what he does or to read research which would have given him a vocabulary with which to name and analyze his experience. What comes through strongly is his affection and enjoyment of his students, his desire to nurture their awareness of themselves as thinkers, and a commitment to building character through empathizing with the stories of others who have gone before.

History of the Perception Unit

First Version: 1972-1989

The unit began when Ben started teaching in his current school. For many years it was not a complete unit but a growing series of activities that had started with several which piqued his curiosity in an undergraduate course on psychology. One of these, "Horses and Riders," he found particularly frustrating and fun, so decided to use as part of his eighth grade "Introduction to the Social Sciences" curriculum.[4] Ben hasn't seen it anywhere since, except a recent example with a bull and two riders. The representation entails cutting out horses and riders and trying to fit the riders on horses (Appendix II).[5]

The next summer (after Ben's seventh year of teaching), he took a course in discussion as part of his Master's program in which the professor gave the class a 35-question quiz on a very short story called "The Robbery." This was designed to surface flaws in our deductive logic based on faulty assumptions. When Ben tried it with students the following fall, they got mad.

> I began to think there was something here and I didn't understand it. I'd sit there trying to find examples of perceptions. And I'd use my own -- when you think something is one way and it isn't. Why is it we have that, I wondered? I began to do simple research.

Ben went back to his college texts that dealt with perception, browsed through three or four years of *Psychology Today*, to which he subscribed and found an article from *Scientific American*. These resources gave him a sense of how perception can be faulty and a collection of illustrative activities, like having students close their eyes while he held up a vial of "peppermint oil" in the back of the room and asked them to raise their hands when they thought they could smell it. The vial actually contained water. From there he held up a picture of a head in his college psychology text and asked, "How do we know anything?" to start a discussion on sensory perception.

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[4] This includes psychology, geography, and anthropology.

[5] It is described in the section titled, "Evolution of Ben's PCK of Instructional Representations."

In 1984 a student periodical called *Read Magazine* to which the school's language arts department subscribed featured an article on perception. This offered more of a framework around which Ben could organize his ideas and activities, but he didn't fully understand the material or how to use it until five years later when he pulled the activities into a coherent unit around a clear conceptual framework.

> Eventually I had so much stuff that for a couple of years the unit was getting a little long. I was thinking, 'Gee, you're going to love this, you're going to love that.' Well, it was just more of the same stuff after awhile.

Activities included rebuses (see Appendix JJ),

> The kids love the word rebuses because those are mostly in their world. Once they begin to see how to do those, they like to practice.

They also included an ambiguous street scene in which students could observe how one person's interpretation of the picture was different from another's (see Appendix KK), [6] and several tactile illusions. For example, he had students hold their index fingers horizontally in front of their eyes and unfocus; this produced a "floating sausage" between the tips. Another example involved locating "the hole in your hand."

> You roll up a paper telescope and everybody looks at everybody through it. Then you look through it with your right eye closed and bring the palm of the hand up against the end the telescope. When you open your other eye, you see right through your hand.

Describing how he chose his activities, he replied,

> My means and ends must jump out at me. If something tickles me, trips me up, if I have a feeling about it, then I sense how my kids might feel, otherwise it's bland, I don't want it.

Ben also showed students the movie *The Miracle Worker* to illustrate the centrality of the senses for gathering information about the world and the fact that they can be limited.

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[6] The history of this representation is detailed in the section, "Evolution of Ben's PCK of Instructional Representations."

Influences on Development

Initial influences on the unit were Ben's college and graduate courses in psychology, discussion, and anthropology as these brought to his attention the central way sensory perception affects meaning-making within the individual -- a key idea he felt belonged in his social studies classes. These courses also put him into contact with materials he brought directly into the classroom. Further research from texts and popular journals added to his growing collection of illusions. Students were also a source of additional materials, many of them coming in with examples from their own lives, once they had experienced the illusions Ben shared with them.

Second Version: 1989- Present

By 1989, Ben felt he had a handle on the concepts embedded in faulty perception and was able to present a more complete unit.

> The Perception unit has been piecemeal since I arrived here. Sometimes my file cabinet collects stuff that sits there and I'm not sure where it might go. Eventually I find a way to make it fit with something else, if it's going to. As I began to understand the reasons for faulty perceptions, I could see where 'Horses and Riders' could fit with the concept of "mental set."

He tried to be carefully intentional about setting the unit within the context of the whole year and referring back to the lessons it taught throughout subsequent units of study so that students could apply what they had learned.

> We start the year with a cursory look at geography -- the basics we'll need for setting the stage, and it's done bit by bit all year. Then we move on to psychology. If we're going to look at other people, we must understand that the meaning is in our minds. Depending on the kids each year, the first unit in the psychology section, perception, lasts a week and a half and is intended to offer a foundation for the rest of the year. First we study basic human needs then we learn how we meet those needs through the Perception and Learning units, but that doesn't explain our behavior, because we live in cultures. So we study patterns of action, then the cultural model which involves values, social control, technology, and other aspects relevant to why we behave as we do. Then we shift into enculturation -- during which the kids really begin to use the terms for the concepts we've studied and understand them. For example, they discover the change in children's books from 1949 to 1958 and how attitudes of their parents were set.

Gradually removing the scaffolding offered most of the year, like teachers committed to teaching for conceptual understanding, Ben encouraged students' independent use of the skills, vocabulary, and concepts they have been working with as a group (Anderson & Roth, 1989; Prawat,1993).

> We end the year with Africa and Asia, and the kids are on their own. I've done my thing, and it's now up to them. Could I teach like that all year long? No. But after a while, the final inch requires change.

For the last three years, Ben has had students keep a journal during the Perception unit of what they did each day and why. He has sharpened his focus on the concepts embedded in the notion that we construct our perceptions and to stay open to others whose perceptions may differ from ours. He begins the unit by focusing on the notion that senses bring in information -- an overriding understanding that kids are not generally aware of.

> In the last five or six years, instead of using a picture of a head in a book I start with a volunteer up front because it's more fun. I ask, 'How does she know anything?' Within eight seconds, the kids start to say, 'Because we know.'
> 'Well how do we know?'
> 'We have senses.'
> 'What are the senses?' And we review them. 'Ears --they're weird, aren't they. These are amazing!' Then I ask them whether they think they can see color in front of them. 'Of course. Can you see color off to the side? [with peripheral vision]. Of course you can. No you can't!'
> With colored markers, you show them they can't. You see shape here [points to the side of his head] but you do not see color. You think you see color. If they look straight ahead and someone else watches their eyes, making sure they don't vary, they'll start guessing.

Ben now uses *The Miracle Worker* to illustrate how difficult it was, with Helen's limited senses, for her to meet her needs. His PCK of students' prior knowledge around the concept of how we literally see comes through in the following observation:

> The kids don't realize that what they are is a ball of senses and that the light from the sun sped 186,000 miles per hour and took 8 1/2 minutes to hit their eyeball. That light comes from an exterior source is sort of scary for some, just as it's scary for them to think about the world as a little tiny cinder in the midst of nothingness, and if it were a little further away from the sun we'd freeze, a little closer we'd burn up. It's remarkable to me that some kids find this unit, which should be fun, a bit threatening. It challenges the way they think things are.

From there, Ben has students explore the senses in action. A volunteer sits up front, eyes closed, and is offered a bag of items, including Noxema. He has her palm open and another student drops a cotton ball on it; this is usually hard for the volunteer to recognize.

> Kids begin to see that it's so obvious to them that there's a piece of cotton falling on the person's hand. Why can't she tell what it is? The point is if the meaning's not here [in your head], you can't find it. You don't know what is going on.

Assuring students that their perceptions are usually correct, Ben teases them by putting up cartoons on an overhead projector, in which the point is obvious, like showing a giant "13" and asking, "What page is this?"

> I have the volunteer look at an overhead transparency of three butterflies and a pig, and ask, 'Which one doesn't belong? There are subtle differences you have to look for!' There're a bunch of those I found in a coloring book. You say to them, 'If I hit this wall real hard, it's going to hurt. We could not exist unless our perceptions fit the world.'

After joking around, Ben asks students, "If our perceptions are usually accurate, how come they can be wrong?" This leads into an overview of six reasons Ben has culled for why perceptions may be faulty. Once students understand that they will be introduced to different influences on perception and provocative representations of them, Ben finds anticipation and interest in the unit rising. In addition to discussing the example of Helen Keller, Ben's PCK allows him to illustrate the first reason, that we may have limited senses, by making comparisons with the eyesight of hawks, who can see eight times better than humans and the hearing of dogs whose abilities exceed human ability on the high end.

To illustrate the second influence on perception, that our sense-making can be tricked as a result of the way the brain processes visual data, Ben now plugs in the "floating sausage" and "hole in your hand" illusions. From here Ben introduces the third notion -- that our expectations or "mental sets" can influence perception, using one of his original representations, "Horses and Riders," along with the "Street Scene" exercise[7] and the peppermint oil illusion. Additional representations of the way expectation can influence perception include Rorschach ink blots, Escher prints, and flashing the words "Paris in in

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[7] This is described fully in the section titled, "Evolution of Ben's PCK of Instructional Representations."

the spring" written inside a triangle and asking students to write this on their folders. Out of the whole class Ben finds that there will seldom be anyone one who spots the repeated word.

This set of examples had a profound impact on one of Ben's students this year, revealing that, far from a simple set of experiences with visual tricks, these representations could have a much deeper impact. His way of connecting with her about it hints at his original interest in guidance.

> I had a girl this year who has probably been abused, whose mother told her when she was 4, 'I don't want you anymore,' and sent her to her grandmother. She had some other problems and has done lousy in school. After this set of examples, she came up to me and said, 'You mean if I expect to not do well, I probably won't?' Now I'd love to say she ended the year doing beautifully, but she began to try. She was so far behind, but sometimes, you give kids information, help them gather information, and you meet your goals in a way you never thought possible. She really was applying what she had learned to her own life.

To illustrate how emotion can influence perception, the fourth reason Ben shares with students, he uses a visual representation in the form of a cartoon of Calvin and Hobbes. Calvin is in bed imagining a monster about to devour him until he remembers his buddy Hobbes is with him and will protect him from the monster.

> I use Calvin and Hobbes whenever I can because Calvin says clearly what might otherwise take hours. You do this on the overhead and I've found that kids don't laugh. This cartoon shows another night deprived of sleep. The little drip-drip becomes a monster creeping. Calvin read scary stories before he went to bed. Now he's scared. When his parents come in in the morning they're going to really be sorry for the shape he's in. He imagines his gravesite: 'Here lies Calvin, devoured in his bed by a monster. If only they would've treated him better.' And he yells to Hobbes, 'You stupid creature. I'm going to be eaten.' Then he realizes the monster knows he's not alone: 'There's an animal in bed with me, a beast you did not see.' Now his needs have been met; the monster runs, and Calvin goes to sleep. At the end, the kids tend to laugh, but I have to be careful with it. Do you believe that?

Ben shows how physical needs can affect perception by having students cluster into groups and identify what their needs are. After this, he reads excerpts from the book *Alive* which details the experiences of a sports team whose plane is downed in the snowy Andes and they begin hallucinating because of hunger. Since 1994, Ben has been showing a video of the making of the movie of *Alive*, to support student understanding of how desolate the setting was to have prompted the ensuing cannibalism.

Finally, Ben illustrates the point that perception can be influenced by lack of experience, which he sees as particularly key in the study of social studies because if students don't know about the practices of a particular culture, they may judge and shut down. His rebus exercises come in at this point as a way to illustrate this awareness.

> Once they begin, some sit there thinking, 'Oh Lord, I'm so stupid.' Then they begin to understand that there is a way that you approach these rebuses. They are illustrating common sayings like, 'corner the market,' or 'Bermuda triangle,' or 'mixed bag.' Now some of them, like 'shrinking violet,' students've never heard. We look at the ones they can't get, which are the ones outside their experience.

From here, Ben gives students a more complex opportunity to apply this effect. He uses the movie of Farley Mowat's *Never Cry Wolf* to illustrate a variety of influences on the perceptions of the characters, including the way hunger can start to make mice look tasty and a 180 degree change in the main character's assessment of wolves.

> At one point Tyler is walking on a frozen lake, doesn't realize it, and crashes through. Why didn't he know where he was? An Eskimo child sitting on the shore would say, 'Hey, get off!' It was lack of experience. Then I can make the point that lack of experience shapes our perceptions of other cultures. We lack experience in knowing why someone in India has that dot right here [pointing to his forehead] so it seems odd to us. If students can remember that what's here [pointing to his head] is not necessarily what's out there, then they can understand how different patterns of action make sense in other places to those people in meeting those same needs that we've introduced before.

At this point, Ben reiterates that what he wants students to realize is that the way they see the world is based upon their perceptions of it which he illustrates by holding up a poster a student brought in of the word "think." Reading the negative space around the letters, one can also discern the word "fly," the implication being, if you can think, you can fly, but only if you can see more than one way.

> I also use a cut-out of a guy pointing at a large globe and standing on a lizard -- but you can't tell because it's only showing the lizard's back. He is intended to represent all of us thinking we know where we stand. I ask them where the guy is. They'll tell you he's on the moon. They'll come up with something logical for those bumps. No one ever says that he's standing on a lizard!

Ben closes the unit with a review of where the class has been and where they are headed, skillfully bridging between just introduced concepts such as becoming conscious of the constructed nature of our perceptions and how these interact, for better or worse, with judging; and to-be-introduced concepts like the components comprising a culture, such as "patterns of action" and how these are based on people's perceptions of their basic needs.

Ben then shifts to a different cultural setting where students are offered an opportunity to observe the way their perceptions are affecting their reactions to that culture and how one might respond, given a different way of making sense of it.

> Sometimes we'll look at a film of the Kalahari bushmen, which I first saw in my anthro class in grad school. I can make that fit most anywhere. It's the one where it takes 20 minutes to kill a giraffe by hand. I have students watch something they didn't have any idea about and have them compare initial perceptions with later ones. I ask them to consider if they are more aware of this shift and if so, how? For the slower kids, that's really beyond them. So you find other things that they can write about.

Ben also uses students' own culture to help them see it as a foreigner might, when he has them learn about the "sacred rac," an anthropological take-off on America's deification of cars.

> That one begins as if you're an anthropologist and you're studying in India. You say, 'In India they've got a strange pattern of perceiving the cow as sacred.' Meanwhile, an Indian anthropologist is studying a culture that also has an animal that is sacred, "the rac."

The next day, after reading about this culture, students find out it's referring to Americans. Some students feel cheated by the deception, refusing to appreciate how our culture might actually appear to others with a different set of values. On a more subtle level, Ben helps them confront their expectations of school work as being simple and unprovocative.

> They answered the questions on the dumb handout and they had to do the homework. They didn't think. I set them up in order to say there's another way of seeing ourselves. But I have to be careful because they may not go with me if I trick them too many times. Some get angry. In 7th grade, the stock market crashes on them and some never recover from that. Some take it very seriously -- it's a shock to their desires to see the world in a safe way.

From here, Ben has students move onto the next unit in psychology which deals with behaviorist learning: operant and classical conditioning and trial-and-error learning. Students are helped to connect their earlier experiences with observing Helen Keller and the new concept of operant conditioning -- Helen learned when her behavior was rewarded. Then students look at what the cigarette companies do in attempting to appeal to "mental sets" based on stereotyping -- a form of classical conditioning. In this way, Ben builds layers of understanding, weaving in earlier concepts to augment an understanding of later ones.

Ben has students transition into anthropology by making the point that other cultures have learned to act in certain ways because behaviors we might find strange have been rewarded. He also explores patterns of action and enculturation in American culture, which he illustrates in part with children's stories.

> Students can now can look at these stories with the perceptions of a four year-old. That's part of the assignment. When they look at nursery rhymes, 4 and 20 blackbirds baked in a pie, the cradle did fall -- what's going on here? They look at the way women are portrayed in children's books, even recent ones, and how perceptions are created about how women should act, how boys should act -- when Goofy minds the house and can't do it... . It's great when it ties together, yet this is a lot to ask of the average 14 year old.

In these ways, ideas built within the Perception unit become a context for viewing the rest of the year.

Influences on Development

The *Read Magazine* article on perception laid out a framework of the ways our perception can be influenced and examples of this, which helped Ben understand how his pre-existing examples could fit.

> The reasons are really very simple. I just never found them listed in a way that is easy for kids to understand. I had to understand them first which took awhile.

Ben relates that while many of the representations have been the same from year to year, the students change and every class is different, which is what makes it fun.

> You look back and you wonder, 'Why do I keep doing this?' Because it's fun! If it weren't fun, it would be drudgery.

Reflections on the History of the Unit

The Perception unit came into its full power when Ben spelled out the reasons for faulty perception, then selected among his many activities those which best represented them. The unit built momentum as a result, he feels, because his PCK of how to preview the framework and students' initial experiences with provocative and enjoyable representations built anticipation, excitement and subsequently, greater understanding of the core ideas.

In a highly interactive, experiential way, Ben's unit addresses prior knowledge head-on in having students unpack their "packing mechanisms" before giving them new material in the form of other cultures on which to practice noticing their perceptual processing. This places attention precisely on students' "mental models" of content so that students may become more conscious of them.

Ben's experience with teaching this unit for the last twenty-five years seems to illustrate the notion that we teach what we need to learn:

> I forget my own unit and get locked into thinking that you are what you are because I know you are that way, rather than that's the way I perceive you to be. I don't want the kids to be like me.

It's interesting that this is not a text-based unit and thus is rescued from the influence of possibly shallow, disconnected knowledge typical of the four social studies texts written for the upper elementary level which Sinatra, Beck & McKeown analyzed (1992), and the potential naiveté students might bring as readers (Wineburg, 1991). Despite these assets, Ben feels guilty because he wishes he had greater confidence that he was teaching what the culture wanted him to.

Ben has wrestled with his subject matter knowledge of cognitive psychology.

> I can take content to a certain level, but in order to teach it to somebody else, I have to take time to think through it. I could've taken that class further than I did, but to do that, I've got to give up something: energy, time with my family... .

Like the literature in social studies education has suggested, Ben was not fully prepared to teach his subject and had to rely on available materials and his experiences of students' experiences with them over time to guide his PCK development.

Stages of PCK development of instructional representations based on Ben's path might look like this:

Stage One:	Attraction to an activity with certain features: hands-on, fun, surprising.
Stage Two:	Not understanding what is significant about an activity that provokes a strong response (frustration, amazement) in teacher and students triggers a desire to develop knowledge.
Stage Three:	Activities become true representations as they become contextualized inside a conceptual framework worked out by reflecting on students' experiences with the materials over time.
Stage Four:	Greater flexibility in the way a representation is used; different salient features are highlighted to illustrate different aspects of the core ideas.

The Evolution of Ben's PCK of Instructional Representations

The representations Ben has used to illustrate the core ideas in the Perception unit are found in Table 7 (next page). PCK growth associated with one representation is detailed.

Table 7: Selected Representations Of Core Ideas Associated With The Perception Unit

A = Analogy (auditory/visual); D = Demonstration (hands on, visual, auditory); S = Simulation (auditory, kinesthetic, visual); E = Example (auditory, writing); I = Illustration (visual); M = Model (hands on, visual)

CORE CONCEPT	REPRESENTATION	FIRST USED	SOURCE
We have basic human needs	(I) Movie: *The Making of Alive*	1994	Wife taped it.
Our senses help us perceive	(S) Sensory Bags	198?	Teacher's own idea
	(I) "Subtle Differences" cartoons	1983	Children's coloring book
Our senses can be faulty or limited	(I) Movie of The Miracle Worker	1972	School library
	(E) Cotton ball falling on one's palm can be hard to identify.	1984	Own idea
	(E) Comparisons to hawk's eyes/dog's ears	Mid 80s?	Own idea
Our perception can be tricked	(S) "The Robbery" -- 35 question quiz on a short story which students make erroneous assumptions about.	1973-1976	Graduate course in discussion
	(I) Hole in the hand	Mid 80s	*Read Magazine*, student periodical
	(I) Floating Sausages	Mid- 80s	
	(I) Optical illusions	1989	Student brought in a book
Perception can be affected by emotion	(I) Calvin and Hobbes cartoon of a nightmare	1989	Newspaper
Perception is influenced by mental set/expectations	(M) Horses and Riders	1972	College psych. course
	(S) Peppermint Illusion	1972	College psych. course
	(S) Street Scene	1984	
	(I) Paris in/in the spring triangle	?	
	(I) Escher prints	?	

Table 7, continued

CORE CONCEPT	REPRESENTATION	WHEN USED	SOURCE
Perception is influenced by physical needs	(I) *The Making of Alive*	1994	Wife taped it from IV
Perception is affected by lack of experience	(I) Rebuses	1983-	Some from students; some from a trade magazine.
Perception is constructed	(I) Fly/Think illusion	1989	From a student
	(I) Person standing on a lizard	1988	In the children's section of a local bookstore.
Culture influences perception	(I) Kalihari hunters	1973	Graduate anthropology course
	(E) The Sacred Rac	?	?
	(I) *Never Cry Wolf*	?	?
	(E, I) Childrens' books	199?	School library?

Horses and Riders

Initially Ben was attracted to this as simply an intriguing activity to illustrate perception in a general way.

> Horses and riders was an eye-opener for me as much as the kids, especially in the early experiences with it. 'Why were you wrong? Because you thought you knew it and you couldn't do it because of the way you thought.'

At first, students try to put riders on the horses as they are, but the riders don't fit. They must discover that they have to combine the front end of one horse with the rear end of the other and lay the riders across these combinations in order to solve the puzzle, in effect, altering students' notion of the "horses" needing riders.

> Originally I presented it, asked students to see the meaning that they were providing, and that somebody else was providing a different meaning.

> I pointed out that that's perception and for students to realize that they will find their perceptions here [points to head]. That was the extent of it.

When asked whether he had noticed patterns in the way students responded to the representation, Ben replied that the major variation has to do with the fact that it is already familiar to some students because older siblings who've already had him as a teacher have shared it at home.

> It's somewhat difficult because of their brothers and sisters. Quite often a child will say, 'I remember my sister showing my parents this last year or four years ago.'

Consequently, its teaching value is somewhat compromised because students already know the trick and don't experience the frustration and subsequent elation which accompany shifting their point of view. Because the exercise is both tactile (involving manual manipulation) and visual, most students are captured by it and engage with the problem. Because the activity is so straightforward, he has not had to modify it for special needs students.

Street Scene

First used in the mid-'80's, this representation involves a deliberately ambiguous picture of a variety of buildings and people on a city street (see Appendix KK). Two boys are crossing a street. They seem to be carrying baseball bats. A girl in front appears to be leading a dog, which may be on a leash. But on the other end of the leash there appears to be a football instead of the dog. Other anomalies are that the dog has no front legs and the girl has no face. A bicycle and laundry cart sit in the background in front of a row of buildings. Somebody is leaning in the doorway of one building wearing what appears to be an apron. There are people or jack-o-lanterns in the windows.

Ben's PCK of how to use this representation has gone through several stages.

> I made an overhead of it and asked the entire class, 'What is this?' It was okay. 'I see this; I see that. I see why you see that.' Then we moved on.

At this point, he was still not focusing on it as a representation of more than the general notion that people sometimes see the same thing differently.

The next year, he decided to enliven the representation by integrating it with a version of "the rumor game." While stating that his impetus to this revision was to make the activity "more fun," intuitively he seemed to understand that this would lead to a more sustained, thus deeper interaction with the representation, increasing its heuristic potential. Ben selected five volunteers to stand in the hall. He signaled to the first person to come in and observe the scene projected on the overhead. The student had a full minute to observe, then privately told the next person standing in the hall what (s)he had seen. The first person rejoined the class and became part of the audience, while the second came in and, without looking at the picture, told the class what (s)he had heard was there, and so on, until the last person gave his/her description, again facing the class and without looking at the projection.

> The serendipity comes when you get that fifth kid in there. I now say, 'Ladies and gentlemen, we've brought in this expert to tell you what's in this painting. You will be explaining this to the public when we open our doors, so pay attention.' Now all of a sudden the expert is introducing a painting, but has never seen it and then it's fun. The class laughs. It's only poor child number five who really is in the dark.

At first, Ben felt he had to take notes on what individual students "saw" in the picture, so that he could track for the class the shifts in meaning as information was shared. In this way he hoped to use the representation to illustrate the subtle point that communication between people is potentially fraught with faulty assumptions about taken-as-shared understandings because we operate out of unique mental sets.[8]

> One person would see half a curtain and a one-quarter shade; another half a shade pulled down a quarter of the way. The next would say that it was one quarter of the way up and the window shade was half the way up. Referring to another part of the picture, one person said, 'There are two boys chasing a girl. The dog has leash, missing the front leg.' Now that's rarely ever said. Then it became, 'only two back legs.' Then it became that she was hopping. Then it became that the boys have jeans on and that wasn't mentioned. The man in the doorway became a grocery store manager standing in the door smoking....Then the last one, Cheryl, didn't mention

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[8] I'm reminded of the constructivist maxim: "I know you think you understand what you thought I said, but I'm not sure you realize that what you heard is not what I meant."

> him at all. But what I felt I had to do was take the notes. I had to make it make sense to them.

Ben's PCK development during the last five years of how to use this representation involved first letting students be the ones to take notes, thus taking him out of the role of mediating the meaning of the representation for them. Eventually he dispensed with note-taking altogether.

> Now I realize they understand this. I don't have to browbeat them with it. With the laughter at the end, it's clear that they get it. Now all I use is the overhead.

He also learned to stack the deck by choosing a very observant student to go first, so that the representation's potential could be ensured.

> I learned not to let the kids line themselves up. They used to volunteer, but sometimes a student wouldn't remember much or would have stage fright, because we do this early in the year. I learned that the first person has to be perceptive as the dickens, otherwise the stage is not set properly. So I'll just say, 'How about you, you, you ...' and it works.

Ben's PCK has evolved to include themes in what the first student overlooks because of their "mental set."

> There are things in that scene that are so ambiguous. I will often predict to the audience before we hear the first person's observations, that the dog's lack of front legs won't be mentioned; and the girl's missing face won't be mentioned. Her left hand is a wand. That has never been mentioned. Never. And on some of the doors there are lines which could be just the shape of the wood but sometimes that comes out as a hospital, because somebody sees it as a cross. Somebody else sees it as bookstore. Some see the background as a shopping mall.

Other themes involve what students add; some reveal stereotyping and more ominous assessments of the tone and overall meaning of the picture.

> Is that a baker or is that a black man standing in the door? For a kid to call that a black man, where is he coming from? One year somebody said someone who'd been abused was looking out the window. It sets a tone. Instead of three kids going to go play baseball, it's two boys chasing a girl whose dog has stolen something. If something is thrown in by the first person, it seems to put a monkey wrench in. The task for the other four becomes trying to make sense out of a different world.

Depending on the tone set by that first observer, Ben finds that sometimes classes are not fun; other times students' interpretations have set him and the class laughing for days.

Throughout the year, Ben's PCK of instructional strategies allows him to refer to the ideas embedded in the representation.

> Perception fits so many different times, be it a values unit ten weeks later, or be it Africa, or interpretation of archeological artifacts. The concept -- that we do provide meanings and somebody else had a different meaning for that than I did -- once ingrained enough to operate on doesn't require going back *per se*; but we are so much an unthinking product of our experience, that we close back down. So occasionally we have to re-open ourselves by remembering this experience. This is my goal for the kids; that they will think about how perceptions are formed, avoid stereotyping, and be open.

Because of the nature of the representation, students truly become co-creators of it, echoing the recommendations of constructivist math educators about the most effective use of representations by concept-oriented teachers (Ball,1990,1991; Lampert,1989).

Reflections on the Nature and Use of Ben's PCK of Instructional Representations

It seems that Ben's PCK of how to use the "Street Scene" representation evolved in the following way:

Stage One: With increased understanding of his subject matter Ben was able to devise a coherent conceptual framework for himself and his students and to place the representation within that context so that it would better anchor the key idea that people may perceive the same thing differently depending on the meaning they assign to it.

Stage Two: A desire to make the representation more fun and more effective prompted Ben to layer the rumor game into the observation phase.

Stage Three: As a result of the layering, Ben felt the need to guide students' attention to details supporting the key idea that we may physically see the same things, but assign different meanings and tone values as a result of the way the first perceiver made sense of what was seen.

Stage Four: Ben began to trust that students would construct usable and relevant understandings of the representation without his guidance by giving them more space to draw their own conclusions about what they were learning from it. The key ideas the representation illustrated took on additional complexity, generating more opportunities for Ben and students to tie them into later parts of the curriculum.

Summary of Influences on Ben's PCK Development

From Himself

His Experiences as a Student

Ben's "apprenticeship of observation" seems to have been most heavily influenced by teachers who followed the philosophy of Idealism, i.e., saw teaching as a calling and attempted to develop caring relationships with their students. This influence shows up in the playful way he connects with students' lives: a bond of genuine affection and deep sense of responsibility is evident between him and his students which seems to be the basis for him to find ways to keep the street "two-way." The bridges he builds are concrete and familar, e.g., inferring our culture's pattern of action around personal space through actual experimentation.

Ben's experience of school as a well-ordered environment has a more Realistic flavor, which carries through in his meticulous note-keeping on ways to refine his teaching.

His Subject Matter Knowledge

Ben is largely self-taught and has relied on a slow-reader text for teaching his students twentieth century history, supplemented by information from current events and his graduate courses on anthropology and discussion. His representations preceded his subject matter understanding, appearing first as activities and only later, when his subject matter understanding jelled, became true representations of core concepts.

His Teacher Education

From his education professors, Ben learned to lead wisely and fulfill the "awesome responsibility" of teaching. When asked about his memories of his courses, this exchange took place:

R: Do you think your teacher education was long enough?

B: Mine sure has been!

From his sense of responsibility came a dedication to improve on his lessons, developing his PCK of instructional strategies each time he taught them.

His Philosophy of Education

From the sense he received from his teacher education that, "It isn't the message, but the messenger" that is important, his high academic standards, value for hard work and concerns about accommodating the needs of the brightest have a Classical quality. His concern for core knowledge -- "history is our story which students ought to know as their ABCs" -- and the idea of school as an instrument of citizenship have more of a Realistic tone.

Fascination with understanding people, the sense of responsibility to lead wisely; opening one's heart to students to invite them to "come with" him; the moral imperative in teaching the Holocaust; emphasizing empathy and building character in order to develop better lives; his sense of fun and joy; and teaching as partly about story-telling, all fall into a more Idealistic tradition.

Emphasis on the developmental/life span and debriefing experience with questions like "Why didn't that work?"; accommodating special needs; and teaching as coaching are Pragmatic in flavor. But Ben struggles with cooperative learning, which also has Pragmatic commitments behind it.

In summary, Ben's PCK development around representations seems to have been affected most by Idealism and the more Pragmatic elements of his philosophy -- illustrating concepts which build on students' current understandings so that they could be transferred and used in new contexts in morally sound ways.

His Inner Representations of Core Ideas

Ben seems to view geography as a stage and cultures as the people on it. His inner sense of the Perception unit, in particular, feels to be a list inside an idea that perceptions can be faulty. It seems linear and concrete, but flexible, open to happy accidents. He talks about teaching as a balancing and shifting in order to keep kids in contact with important ideas like, "There's no free lunch," and "Nature knows best."

His Epistemological Commitment

Ben focuses on the way knowledge is constructed, yet also sees himself as "giving" information, and learning as a kind of "chiseling" which have both "*Received Knowing*" and behaviorist overtones. But his epistemological assumptions about the learning process have undergone significant change since the arrival of his intern Barbara. He has come to trust students to be more capable of learning (constructing knowledge) without him "channeling" everything. He works at helping individuals locate where and how meaning originates as a counter to prejudice and as a counter to confusing their own meanings with "reality" (essentially a *constructed knower* concern in Belenky et. al.'s scheme, see Appendix A). From a *committed relativist* viewpoint in Perry's scheme, context is everything in shaping judgment, something his representations in the Perception unit are precisely involved with.

From the Context

School

Inadequate staff development funds, and time to think and exchange ideas about teaching limited the rate of Ben's PCK development. On the up side, the support of a caring administrator encouraged Ben to believe in the value of his work. Having a building with low teacher turnover and a team approach, and two years with the same students provided overall a unique environment for teacher growth.

> Without the team approach here, I wouldn't have survived. Longevity in teaching has to do with the colleagues you are fortunate to find and an administration that you happen to have. I think it's true probably of most professions.

For many years Ben led his academic team, which emphasized service to others and the whole child. Despite feeling unable to respond effectively to the pressing concerns students bring into school, from my observations at the school over the ten years I taught there, Ben's team helped many students to become sensitive to the needs of others while having their own basic needs met; they felt connected to the school and to each other because of the team's efforts. In this way, Ben had less affective ground to cover than teachers without the coordinated efforts of a group of people helping to socialize a group of students into a shared set of values. I believe this contributed to a stable and caring environment in which Ben's PCK could grow.

Students

Students have had contradictory effects on Ben's PCK development. He has learned over the years that they are more capable than he realized, but are less inclined to work hard, he feels, because their families, for the most part, have "everything they need." They are less impressed by school, stimulated by multimedia opportunities at home, demanding more and more from their teachers in order to stay engaged. Families in flux have created tough problems (the efforts of his team to mitigate them notwithstanding), reducing the amount of energy Ben has had for PCK development, yet at the same time, forcing him to develop his PCK to "go the final inch."

Novice Teachers

Mentors and novices can develop each other mutually. Barbara brought, not just the cutting-edge insights from her M.Ed. program at an Ivy League school, but confident brilliance which allowed her to break through the norms surrounding power-relations between mentors and interns and model ideas Ben would have dismissed as unworkable. His PCK was advanced by learning what kids are truly able to do, given the chance: Barbara brought in journaling, student-run simulations, and constructivist discussion. He shared with her his insights into students' lives, their emotional needs, and interests.

Collegial Collaboration

Striking is the effect of a department chair who said to Ben as a young teacher, "Create your own curriculum," which reverberated through twenty-five years of teaching. Mostly, however, collegial exchange had a minimal effect on Ben's PCK, happening in bits and pieces around the edges of the day.

New Resources

It seems that activities have been a driving force in developing Ben's PCK: he has been attracted to those which involve students getting out of their seats and are visual and provocative. Only after experimenting with them, it seems, has their potential as intentional representations become clear to him.

Computers are a bewildering new territory for Ben, crashing through all sorts of barriers which have heretofore kept people apart. He is just beginning this leg of his teaching journey.

Synthesis

Several influences vie for top billing in Ben's PCK development: uppermost seem to be the expanded awareness of students' capabilities and the strategies to allow their conceptions to be more center-stage which Barbara helped to stimulate by functioning as an in-class coach; second seems to have been the Outdoor Center for the same reasons. Ben could observe the Center's staff and students' behavior in a semi-structured non-classroom setting, which revealed problem-solving capabilities not tapped by his more traditional classroom format. Coaching helped Ben's PCK development by creating trust among future students who were then more willing to come with him on the journeys he wanted them to experience. Coaching also provided shared prior experiences which offered a basis for Ben's PCK of bridge-building. Fourth was his on-going openness to his own experiences in the classroom, his concerns about staleness notwithstanding. He had the self-discipline and commitment to excellence to hone his work with students based on intimate knowledge of their response patterns to earlier versions and an intuitive gift to say yes to activities and ideas, the potential for which he only fully realized later.

Serendipity is a theme in Ben's reflections on his teaching. The New American Webster Dictionary defines serendipity as "an assumed talent for making discoveries by accident." [9] Such accidents are a richly satisfying part of the magic of teaching, producing new insights in teacher and student alike. Lacking support for more intentional development, Ben's case prompts me to think about how much the profession has relied such accidents to advance itself.

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[9] *Time* (1972)

Cross Case Patterns

Merriam (1988) states that the "universal can be found in the particular" (p. 175). This section addresses potential universals found in patterns across the four cases relative to professional histories, the nature of unit revisions, choice of representations, and refinements in knowledge surrounding them. These patterns are used to build a set of PCK developmental continua for concept-oriented teaching addressing the question -- What have these teachers learned? In Chapter 5, I take up a discussion of ways PCK might be more intentionally nurtured in both preservice and inservice teachers.

Patterns in Professional Histories

Themes in the professional histories of the four participants cluster around personal characteristics, life circumstances, and changing perceptions.

Personal Characteristics

In terms of personal characteristics, all of these teachers are *hard on themselves, driven to excellence, and view themselves to varying degrees as "works in progress."* All express a passion for their subject or a keen desire that students develop an open mind using the subject as a vehicle; all have a well-developed sense of humor. All are concerned with developing an authentic relationship with students and don't back down from high standards for student work. All are creative -- using a variety of teaching modalities in their classrooms -- and all seek to establish a democratic and caring atmosphere.

<u>Life Circumstances</u>

In terms of life circumstances, *three of the four attended liberal arts colleges and were certified through the same independent teacher education program.* These same three held a variety of jobs before teaching and had traveled outside their region or lived abroad for periods of time expanding their perspective on life. All four have spent the bulk of their teaching careers in the same school, affording the stability necessary to refinement, but perhaps a narrower view of the teaching enterprise than they might have had otherwise, something Kit tried to address in visiting other schools and Dar realized when she changed school districts in her ninth year. All four describe a working context with little or no time to reflect on their work or to collaborate easily with others.

Becoming a parent has had a significant impact on each of the four: for Ted by providing a personal lab to observe the learning process; for Dar, by taking time off to let ideas for the Intolerance unit incubate and give her a chance to read many W.W.II novels; for Kit, by compelling her to cut back to a half-time job, which allowed her a chance to take workshops in cooperative learning and adolescent development, but now has precipitated her leaving teaching as the half-time position is no longer available; for Ben, by viewing his goals for teaching through the sharply focused lens of what he wanted his own children to learn as they came through his classes. Coaching his children allowed him to build a deeper relationship with his students, many of whom came to trust him as their coach before they ever entered his classes. One feels the sacrifice and guilt involved for several of these teachers in having to take time away from family to do the work needed to support high performance in students, raising questions in my mind about the ethics of a profession which depends on such time to rescue it from mediocrity.

Changing Perceptions

In terms of changing perceptions, *all four teachers have undergone a shift in how they see the nature of their subject as an object of study*: Ted went from viewing school math as discrete, solitary, and incomprehensible to some students to panoramic, collaborative, and accessible to everyone at some level. Kit went from viewing science as a comfortingly fixed catalogue to an evolving, uncertain, integrated mass of information which could be approached through "a series of logistical steps." Dar shifted from viewing composition as something other people learned about, but she had missed, to a constructivist process in which grammatical labels are given meaning as students invent a need for them en route to finding a unique and coherent voice. With literature study, Dar shifted from viewing it as a process of covering up the text with a variety of scholarly opinions to uncovering it through shared inquiry, where teacher and students are on the same level, each learning from the other "to find what they needed." Ben went from viewing history as unreal to seeing it as a venue for helping students develop compassion, wisdom, and democratic processes through learning about the stories of their forebears and ways other cultures live. For most of these teachers, content has become less and less what teaching is about, yet their students seem to be learning more, because content is more highly integrated within frameworks and teachers are placing a greater emphasis on the processes which help students actually use the knowledge for themselves.

All four teachers have undergone *a shift in the ways they view their roles*: Ted has gone from being a "scanner" to an orchestrator who expects students to think, not simply remember; Kit has gone from being an uncomfortable "dictator" to a facilitator and resource person who delights in learning along with her students; Dar has come increasingly to trust students' abilities to teach each other and to be a "co-creator" not "a giver" of classroom knowledge; Ben has gone from "channeling" classroom knowledge for students to honoring their capabilities to find the answers to questions he raises and to surpass him at times in their understanding of targeted content.

All are engaged in *shifting their students' ideas about the nature of school learning*, wrestling, in varying degrees, with using constructivist approaches with students socialized to think of knowledge in objectivist terms. In not allowing algorithmic knowledge to pass for an indication of mathematical literacy, Ted is forcing students to ask real questions and use native abilities to solve real problems; Kit is expecting students to activate prior knowledge in hypothesizing, and forcing them to excel by breaking down assignments into doable bits; Dar strives to liberate students' deepest thoughts and feelings by creating an authentic and challenging learning environment, by rewarding genuine connections to text, and by forcing students to take a hard look at their responsibilities to each other; Ben startles students into thinking by designing experiences which frustrate their habit of viewing the world in conventional ways.

They all experience *some degree of frustration* in this effort: Ted's brightest students resent not being able to rely on their computational excellence to do well in his classes; Kit finds that students experience having to use personal opinion in problem solving as a foreign request; Dar finds that some of her simulations are too alienating--students just aren't ready to confront their own inconsistencies; Ben knows that if he tricks them too many times, students won't come with him down the path he would like them to travel.

All have shifted *in their appreciation of what students can do.* How capable are kids? These cases suggest that teachers' answers to this often stem more from beliefs than from knowledge. Their beliefs changed because of breakthroughs, most always in the form of outside influences. For Ted it was the NCTM Standards; for Kit, learning about cooperative learning first through her student teacher Nora, later through workshops; for Dar, listening closely to her students as a result of professional reading and courses; for Ben, the influence of his intern teacher Barbara, who modeled constructivist practices for him, allowing him to see more deeply into the extent of students' capabilities. Three of these teachers began teaching by attributing student performance to factors over which they had little control. Over time they have come to see that they have more influence over the depth of students' learning and seem increasingly to feel that most students are capable of higher level thinking, given the right supports.

Because of changes around these teachers' understanding of what students can do, they have turned over greater responsibility for assessment to students: Three of the four stress self-assessment which they see as integral to creating autonomy. This is a primary goal for teaching conceptually -- having students be able to know when and how to use a skill, as opposed to depending on the teacher or text to tell them (Brophy, 1989).

Thus *teaching for transfer has become an increasingly visible outcome.* Students are encouraged to learn concepts within realistic contexts, which permits a greater likelihood that they can apply their learning in subsequent ones. Perkins and Salomon (1989) distinguish between two kinds of transfer: "low road" (a.k.a., "hugging") and "high road" (a.k.a., "bridging"). "Low road" transfer entails simple replication of knowledge across settings possessing the same cues or contextual features, similar to what Ted had aimed for in offering ditto after ditto repeating the same problem type with new numbers. "High road" transfer entails inferring a basic concept and applying it to a new form, situation, or setting. These teachers increase the odds for "high road" transfer by having students think about their thinking in the context of real problems.

Conclusion

Returning to the variables which have been found to affect a teacher's professional knowledge mentioned in Chapter 1, we see that some seem more salient for these teachers than others. Social identity seems to have been a non-issue for Ted, but somewhat of an issue for Ben who felt his life choices had been compromised by a lack of guidance. Guidance by whom? Probably from the middle class White people in his hometown who might have opened doors to a more rigorous school for him, had their own horizons had been broader. Kit mentioned glancingly that she was glad to be able to supply a role model for students of a woman in science, but didn't make an issue of it. Yet one senses that her interest in students' emotional needs stems in part from having been squelched as a student and regimented as a daughter in her father's household. For Dar, having established a separate identity from her friends as a teenager by virtue of having moved and having attended a formerly all-male college, her awareness of her social identity as a middle class White woman and as a thinker and artist seems to have predisposed her to want to take students seriously as thinkers in their own right and to develop her PCK of ways to support their thinking and feeling.

For Kit, Dar, and Ted (in college), reflections on their experiences as a student were important in prompting them to develop their PCK of ways to support meaningful connections between students and content; yet Ted and Kit needed outside validation for these intuitions before they felt free to exercise them -- a validation which was a long time coming for Ted, who was at the point of giving up teaching math altogether because it seemed so intrinsically unrelated to students' lives.

All four majored in a discipline other than education, though none felt particularly well prepared in their subject. Ted had actually majored in English not math; Kit's zoology was only a small part of her curriculum; Dar saw relatively little connection between her English classes and teaching students in junior high; Ben majored in psychology and minored in history, but had never studied the twentieth century which he has taught now for twenty-five years. So all have had to teach themselves their content, gradually learning to unpack it by breaking it down into ever smaller pieces in order to help students build up their understanding of it.

Three of the four were certified through the same independent teacher education program which emphasized total immersion, though they went through at different points in the history of the program -- Ted ten years earlier than Kit and Dar. All were strongly influenced by the values and methods of their mentor teachers.

Ben was certified through university coursework during the spring of his senior year and the following summer -- coursework which inspired him, but never actually provided access to students. This start cut him off from any sustained mentoring around his first experiences with real students, inclining him to go his own, sometimes anxious, way, guided mainly by his intuition and a deep compassion for students until his gifted and assertive intern Barbara shattered his isolation in 1989.

The influence of subject matter type on PCK development is somewhat protean as two of these teachers radically shifted their views of their subject after teaching for awhile because of changes in the way researchers conceptualized the content for school learning (Ted) or because of changes within the substance and syntax of the discipline itself (Kit). These significantly altered the pace and direction of their PCK development. For twelve years, Ted's view of math -- as linear, sequential, individualistic, computational -- reflected the way he had experienced it in school, been trained as a teacher and the way available materials portrayed it, a view which thwarted his PCK development around students' needs and the strategies required to bring about usable learning. Kit's background inclined her to view science as a stable body of knowledge which involved locating main ideas from a text and creating questions and activities to address them. Her first practicum challenged this to some extent by introducing a greater emphasis on discovery, but she needed more than this and more time than she had, to develop the materials needed to support a way of teaching she could imagine as better. In the absence of alternate models and time, she spent several early years in frustration, feeling like she was already "stagnant." When her understanding of the nature of the discipline changed, so did the direction of her PCK development, away from content for content's sake which she had always questioned deep down, toward a range of content, process, and attitude outcomes focused on empowering students as capable and confident decision-makers.

The nature of English as an object of study, as Atwell (1987) and the Great Books Foundation portrayed it, significantly overrode Dar's "apprenticeship of observation," deeply affecting the direction and pace of her PCK development. Ben's view of psychology as a central but elusive way of understanding human nature allowed him, early on, to help students develop sophisticated awarenesses of how they build their opinions; nonetheless, it took seventeen years to place these awarenesses into a coherent framework. I think the nature of the subject was intrinsically challenging and difficult to make meaningful to students. It's amazing that Ben took it on with eighth graders. Ironically, it almost seems that his not fully understanding the nature of his subject is partly what kept him interested in having students engage with it.

So, generalizations about differences in developmental patterns among teachers of the different subject areas -- something Lambdin (1988) has called for -- are hard to make with this small sample set within this era, as scholarly views of all four academic disciplines have undergone significant change in the last quarter century; these changes have, in different ways, affected all four teachers. Dar's concept-oriented PCK development has been the most rapid, however, largely due to the early support she found for listening to students. This suggests the impact powerful early interventions can have in shaping the pace and direction of novice teachers' concept-oriented PCK.

Patterns in Unit Revisions

Patterns in unit revisions fall into four major categories: Changes in substance, structure, processes and epistemological commitments.

Changes in Substance

Core ideas have become increasingly visible to these teachers as a way to connect knowledge: Ted realized that for students to understand fractions they needed to understand the concept of equivalencies between fractional parts and how all these parts related to the whole. Kit saw that students' questions about life on other planets required an understanding of the concept of light year and a sense of the structure of the universe; that their understanding of the movements in the heavens depended on understanding rotation and revolution; that their understanding of the importance of cooperation to the success of the space program required immediate opportunities to practice it. Dar realized that students needed a familiar structure to help them organize and anchor their ideas; and that they had to experience coercion first hand to begin to appreciate what it was like living under Hitler's regime. Ben realized that students would become more sophisticated and compassionate observers of culture if the perception exercises were more clearly tied to the notion that our sense-making equipment, which we count on to inform judgment, can sometimes lead us astray.

During my observations several core ideas were visible in each classroom, some content-, some process-oriented. Ted's classes intentionally stressed the idea of multiple paths to solution and high standards regarding precision of work, speech, and thought. One of Kit's classes dealt with the concept of rotation and revolution with the moon phase lab. Dar's classes both had to do with student empowerment: student as researcher in the first and student as writing critic in the second. The first of Ben's classes dealt directly with the issue of judgment making around patterns of action; the second modeled democracy in action.

Another important theme across all four paths of unit development is the *increasing emphasis on the humane goal of urging students to take the perspective of others*: be it in math, where students struggle to understand each other's solution paths; in social studies, where the emphasis is on understanding how our individual perceptions shape the meaning we give to things and that these can differ in legitimate ways; in science, where students contrast the differing perspectives of life with and without gravity, entertain the multiple values different cultures would bring to space colonies, or struggle with getting along fairly in groups; or in English, where students are helped to internalize how fear affected the choices of German citizens in the time of the Third Reich. In this respect, all the teachers have come to push students toward more advanced epistemological awarenesses, away from a right/wrong approach to knowledge toward negotiated meanings and "consensual interpretations" (Wood, Cobb & Yackel, 1991, 606).

The units have become increasingly oriented toward taking students' beyond their immediate circumstances and time and beyond the usual scope of the subject matter. Ted ties in current events such as what is happening with the budget deficit or corporate downsizing to current topics in class; Kit emphasizes "de-centering" in many ways, for example by looking at the relationship to technology of different generations or helping students to appreciate how people of other generations created myths to explain human and non-human events; Dar has extended language arts class to include the discipline of history and has students step into the world of teenagers in W.W.II Germany. Ben encourages students to view our own culture as it might appear to someone outside it.

At the same *time all four units have become increasingly oriented toward self-knowledge.* Ted does this by helping students focus on their personal strengths and giving them a "boost" in the areas where they are weak so that they can function independently and with confidence in the world. Kit encourages students to study their own behavior and gives them a way to represent themselves to themselves as successful science students by structuring processes so all can achieve. Dar places the content of students' inner lives center stage, making it visible and analyzable, and attempts to help students overcome "knee-jerk reactions" by getting them to think about what it really means to put *your* life on the line for *your* beliefs vs. living life egocentrically or with ambivalence. Ben asks students to carefully observe their processes of perceiving when watching the Kalahari Bushmen (for example), noticing how they first responded (reactively) and how their views shifted when they later tried to understand Bushman culture on its own terms. He also helps students to see that perception is constructed by us individually within a context of experience and to take responsibility for our constructions when we communicate with each other.

Changes in Structure

All the units have become more integrated over time, therefore more structurally complex, mirroring theory-based recommendations of researchers interested in teaching for conceptual understanding that teachers reinforce core ideas in multiple ways and link core ideas from earlier lessons to those in current assignments, while also anticipating later ones.[1] Ted's framework for the fraction unit, for example, has gone from a pile of hard-to-remember decontextualized ditto sheets organized around adding, subtracting, multiplying and dividing ever more complex fractions which he then left to move on to other math topics, to a braid in which he weaves opportunities to develop students' understanding of fractions, decimals, and percents in the context of real problems all year long. This provides a background to the unit itself, set in mid-year, whose structure is more like a set of steps with curved ramps on the sides connecting equivalent levels. He starts with wholes and steps down to ever smaller fractional parts, giving students a chance to think about them in different representational formats. Kit's framework for the astronomy unit has gone from an unintegrated list (planetary information, the physics of toys in space, a project on astronomy of the student's choice) to a bow tie-shape, with Earth in the middle; she begins with the largest structural elements in the universe, works down to Earth, then moves out again to the moon and topics around space colonization, reinforcing key concepts throughout and seizing opportunities to show how the sciences relate. In the Intolerance unit, Dar has gone from a collection of writing types and diverse examples of intolerance to essay-writing and novels and films set within an particular time and place.

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[1] In this they resemble expert math teachers in Leinhardt's research (1988) who made more numerous and explicit connections between aspects of fractions than did novices.

Her framework for the essay has become an increasingly articulated house; for the literature portion she has focused on a set of five core questions which students approach from various fictional, non-fictional, and autobiographical perspectives. Distilling it further, one might think of each question as a multifaceted gem which students turn in their hands, before synthesizing the views. Ben's structure has gone from an aggregate of provocative activities to a list of reasons supporting a main idea that perception may be faulty, which can help or hinder the way we see our and others' culture. In these ways, the units reflect the literature on teaching for conceptual understanding which supports the importance of clearly articulated conceptual frames, especially in the absence of a text (McKeown & Beck, 1990).

The design of these units and the placement of the units within the year reflect *a PCK of developmental variables* which shape students' understanding of the targeted content. Ted sees how to "scoop" underneath where students are to bring them closer to a particular target, how to structure particular discussions so that students at different points in their understanding can participate, how to time the fraction unit later in the year after students have already had multiple opportunities to think fractionally, and that the class as a whole is more able to bring the fabric of mathematical understanding to problems at the end of the year than at the beginning -- "knowing with," as cognitive psychologist Katharine Nelson (1977) has put it, rather than simply "knowing that" or "knowing how."[2] Kit sees how a child who has more geology information than they need for their planet brochure can "give it away" to another who doesn't have it, how to have students good at punning help others who aren't, and how to create more flexibility in the astronomy unit as it's the last unit of the year and students have become more independent learners. Dar is aware of stages in students' coming to terms with perspective-taking and personal

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[2] She distinguishes between propositional knowledge or "knowing that," procedural knowledge or "knowing how," and the synthesized experience of expert problem-solvers who know "with" -- a set of distinctions Papert (1980) also makes in contrasting the problem-solving behavior of mathematically sophisticated adults who "*get...to know* an idea, *explore...*an area of knowledge, and *acquire...*sensitivity to distinctions" (p.136) with the behavior of novices who try to apply the discrete facts schools teach. Ted is now intentionally focused on developing the former.

responsibility as well as stages in their understanding of how to become effective essay writers. Ben creates ways for students to have more autonomy at the end of the year, when they have internalized the concepts embedded in the perception, learning, and culture model units and can apply them to the study of Asia and Africa. Thus, the units now have a justified (conceptually linked) position in the curriculum rather than being placed randomly or according to an external authority in the form of a pre-set curriculum.

Changes in Processes

Over time, *the goals of the units have become more process-oriented*, without sacrificing the importance of substance. In varying degrees, these teachers all appear to take a more organic approach to their units than at the start, responsive to student interests, needs, and teachable moments -- able to recognize or invite what Ben calls serendipity rather than imposing a preset idea of what students should know and how they should learn it. They have come to believe, like concept-oriented teachers highlighted in other research, that students' natural learning patterns are more effective guides to shaping instruction than imposing an external structure such as the table of contents of a text (Brophy, 1989).[3]

Ball (1990) speaks to this in discussing the need to balance between learners' spontaneous questions and conjectures, and maintaining focus on key features of the topic in question. In this way, these teachers avoid lockstep approaches to learning, such as insisting, "that a child who has not mastered word recognition is not 'ready' for higher level reading/thinking materials" (Fink, 1993, p.5), yet they are carefully sequential in helping students to forge links between what has been learned and what will be learned. Prawat (1989) calls this dance between students' interests and teachers' objectives "negotiation,"

[3]In fact, texts have seldom played a major part in any of these units, with the exception of Kit's at the very beginning.

both as in bargaining -- having teachers and students work out their mutual agendas,[4] and as in managing new terrain, with teachers acting as guides. Negotiating emphasizes discourse for bringing students' ideas to light and into line with those shared by scholars (Brophy, 1989; Giroux, 1988; Paul, 1987; Shor, 1986) All the units have increasingly helped to develop the classroom as a learning community by emphasizing discourse.

Another of the process goals is oriented around *increasing students' autonomy.* The units have fostered this in several ways: first through the development of a specific technical vocabulary; second through systematic self-evaluation; and third, through many opportunities to make decisions of various kinds -- about the quantitative aspects of life (Ted); about the difference between fact and fiction (Kit); about personal responsibility (all four); about the adequacy of written communication (Dar). Goals appear to be mutually established between teacher and students within some units more than others. Kit and Dar intentionally rely on self-analysis to empower their students within the astronomy and intolerance units.

The approaches these teachers use within each unit have varied over the years. *All four units have become more balanced and/or more tightly integrated between direct instruction (deductive) and discovery (inductive).* Ted and Kit started in a primarily didactic mode: Ted taught the fraction unit in this mode for fourteen years until the NCTM Standards validated discovery mode. Now he is so committed to this he is uncomfortable imposing any disciplinary knowledge which students have not yet constructed for themselves. Introducing the cooperative strategies like the communication exercise and the "*Toys in Space*" experiments suggests Kit's attraction to discovery mode earlier on, which she supplemented with a didactic delivery of content through multi-media lectures. In the most recent version of the astronomy unit, Kit has increased her reliance on discovery mode for delivering content based on the strategies of “Education By Design”; students,

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4 recalling Bauersfeld's comment (1988) that "Teachers and students *constitute* the *reality* of the classroom *interactively*." (p. 37)

however, seem to rely on didactic approaches to teach each other, which I suspect may be why she would like to model more varied strategies for students to emulate. For writing, Dar moved from a reliance on discovery mode (wide open writing and reading assignments) alternating with didactic (mini-lessons) to a blended approach involving a co-constructed essay building process (discovery) reinforced by disciplinary syntax which she gives at the end (didactic). In this respect her work echoes the beliefs of researchers like Willson (1987) that "theory-building" approaches are more appropriate for those new to a field of study, "theory-confirming" for veterans. By the time students have built their theory of essay, they have become more expert, which Dar helps them see when she confirms their knowledge with her outline and when they begin to apply their criteria to evaluating the essays of others. Ben seems to have used didactic strategies with the perception unit when he relied on story-telling to amplify points coming out of students' experiences with the perception exercises (discovery mode). Like Ted, he has become increasingly uncomfortable with didactic approaches, but for the opposite reason: he feels that some of the best aspects of his teaching repertoire have been devalued by the current press, of his principal and others, for him to use cooperative strategies.

All four units have *changed in how they respond to the heterogeneous learning needs of students*. Ted's fraction unit went from accommodating the different rates of learners by having everyone learn separately at their own pace, which precluded some students ever learning about some topics, to unifying the class through shared discussion on the same topic and asking questions at different levels of complexity so that all could participate. Kit went from little accommodation of special needs beyond allowing students to pick a project of interest to them, to paired reading of the text, offering readings at different levels of difficulty, taping readings, and creating very clear, concrete steps within limited project options and frequent due dates, so that all could succeed. Dar came to offer several novel options within a limited topic to accommodate a range of reading levels, yet connected them to each other through discussion of shared themes. She gave increasingly clear expectations for oral and written work, essay topics at varying levels of abstraction and, like Ted and Kit, chances for students to teach each other. Accommodating special needs came across as more of a concern in a general sense for Ben than with the other three teachers. His perception unit, however, has always involved very concrete multi-sensory activities which mostly do not rely on reading, so many kinds of learners could comfortably participate. When he has relied on reading, he has made efforts to scaffold it visually, so that students could more easily extract main ideas. This practice sprang from an intuitive understanding of what students needed and has been part of his teaching at least since the early eighties.

Changes in Epistemological Commitments

The epistemological commitments of these teachers have shifted within their units and this shift is reflected in both choice of content and method. As teaching for meaning entails an approach to knowledge as successive approximations, *multiple points of view are an integral part of both the learning process* (students perceive in different ways) *and target content* (diverse voices within the discipline have particular experiences and issues that need acknowledgment for students to have a well-rounded view of material). Some feel that teaching more than one version of reality can be difficult. Real life, of course, is full of ill-structured problems embodying diverse interests and frames of reference -- with which schools seldom give students regular exposure. The results can be dangerous:

> Students prepared in an academic environment of certainty and clear answers, face a world of confusion, apparently unanswerable questions, and ambiguous personal choices. Masters of trigonometry, macroeconomics, or Steinbeck's contributions to American literature close their eyes and pick wildly when asked to vote on Proposition 13 or a local nuclear power plant. (Miles, 1982, pp. 5-6)

Science writer Stephen Norris's (1984) response is to affirm the value of "temporary dogmatism" -- where ideas are held as true long enough for students to construct a sense of the neighborhood in which they sit and determine for themselves if they are useful.

Based on their research, Ball (1991) and Lampert (1986, 1989) would respond that students as young as nine or ten can be helped to spot key ideas, evaluate varied views, and make sound arguments addressing complex life problems. To varying degrees, all the units offer students practice with these skills.

Ted, for example, portrays mathematical knowledge as both personally constructed and as abstractly synthesized by mathematicians into algorithms which students can "test." Kit's students grapple with the fact that scientists don't know if Pluto has two moons, or whether there is life on other planets: she shares that it has been statistically proven both ways. Dar's students face differing views of Hitler to complicate their understanding of why various people responded to his dictatorship the way they did. Ben's students cope with subjectivity head-on and how our views of the world must be addressed in communicating effectively or in making assessments about how others live.

In these ways, the units of these teachers reflect a view of the epistemological nature of school subject matter closer to Perry's *multiplicity* or Schommer's view of knowledge as "tentative and evolving" (see Appendix A). The shift away from *dualism* was more pronounced for Ted and Kit; Dar and Ben seem to have had a more complex understanding to begin with, Dar because of the way she was raised and her early exposure to constructivist teaching methods; Ben because of the nature of his content.

Patterns in Influences on Unit Revisions

These teachers' PCK was shaped significantly by their relationship to materials at first, later by students. Ted, Kit, and Ben began using available materials and viewed the nature of learning, to a greater or lesser extent, as suggested by the way the material was structured. All went through a process of adding materials. At some point they each took a look at the actual impact they had on students and began to question whether means fit ends -- Ted, because of the NCTM Standards and being challenged by teachers at the next grade level; Kit, because of her growing knowledge of adolescents' needs and her attraction to activities which spoke to a semi-conscious value for constructivism embedded in characteristics like "hands-on, social, interactive, make students take a bit of a risk, and have surprises at the end"; Ben, because his subject matter knowledge grew.

In several cases, this means-end analysis prompted a shift in understanding the nature of desired ends. Ted went from seeking algorithmic competence to inviting a "panoramic view" of math; Kit from having students acquire planetary knowledge to a wide range of cognitive and affective outcomes, including, amid today's rapid explosion of information, "finding a piece of themselves to be true to." Ben went from simply having students forge a connection with him and enjoy the material, to intentionally helping them improve their lives by becoming more aware of possibilities -- for their lives personally and for the culture at large. Later still, students' interests and needs became starting places for creating materials or adapting existing ones, recalling the more advanced stages of curricular revision in McIntosh's (1983) scheme.

Dar followed a different developmental path. Her exposure to the Great Books workshop and Nancie Atwell's (1987) writing workshop inclined her, early on, to listen deeply to students' inner lives. This has created a practice which began with students' views of the world and has sharpened its focus on how to help students clarify and relate their views to those of other students and people in their school, town, nation, and world.

Conclusion

With an interesting caveat, revisions in the units in these cases support Brophy's (1991) contention that

> where their knowledge is more explicit, better connected, and more integrated, [teachers] will tend to teach the subject more dynamically, represent it in more varied ways, and encourage and respond more fully to student comments and questions. (p.352)

These teachers developed the conceptual knowledge for their units, a deeper understanding of the interrelationships with other units they teach, and the importance of the content in everyday settings. At some point they crossed over from using the units to fill the time, to some middle ground based on enough exposure to materials and methods to be competent managers, to being highly flexible in the ways they approached content, recalling Brophy's (1991, p.355) observation about the complex, non-linear yet coherent patterns in veterans' PCK. At this point, despite challenges, teaching became more consistently fun, lively, and genuinely meaningful.

The caveat is Kit's often expressed observation of how dynamic it has been for her students to watch her learn new material along with them; and Dar talks about the importance of asking real questions, those she genuinely wonders about too. *It seems that at a certain point in PCK development, teachers have an integrated enough view of the terrain to be able to revisit the joy and the challenges of learning content new to them along with their students and yet still retain their effectiveness as guides in offering useful ways to think about the new learning.* It's as if intuition and structure now arise mutually, allowing the novice and the expert aspects of the teacher to mingle freely.

Patterns in Refinements of Knowledge Surrounding Representations

Patterns in refinements of knowledge surrounding representations across the four cases fall into three categories: The placement and nature of representations and the knowledge gained through using them.

The Placement of Representations

Isolating core ideas seems to have come from two sources: seeing what students needed to understand first, in order to understand something else*; and working with* *appealing activities over time whose potential to illuminate parts of a larger picture gradually became clear.* Three of the four teachers seemed to have evolved their units based on the former approach -- understanding what students needed in order to understand something else. It was at these critical junctures of need that they inserted representations. For example, over time Ted realized that helping students understand the concept of equivalencies involved helping them see what fractional parts actually look like relative to each other. For Kit's students, understanding celestial relationships required seeing and moving the way celestial bodies do within the context of the night sky represented through their constellation posters. For Dar, the gap between students' abilities to organize and support their thinking about a topic in written form and their ability to remember standard essay structure prompted her to develop a visual image on which they could literally place the pieces of their thinking.

Ben, on the other hand, appears to have been guided more by the structure of his activities than by a sense of students' needs. His many exercises showing various aspects of perception in action only began to cohere where he fully understood what the factors influencing perception might include and harnessed his representations to them. At the same time, it seems likely that his PCK expanded because he was observing patterns in the ways students responded to the activities, suggesting that, like Dar, his representations were not just the expression of a pre-existing idea, but a mode for developing his own thinking. Well placed representations provide small conceptual frameworks yoking learner (including teachers) and content in a focused and dynamic way.

The Nature of Representations

Table 8 (next page) depicts nine characteristics associated with a sampling of the representations each teacher used at some point during the course of their units in this study.

Table 8: Overview of Attributes of the Representations Used in Cases One - Four

Represent-ation (X Used)	Concept	Source	Mode	# of Modes	# Studs. Involved	Salient Feature	Structure	Epist. Assump-tion	# of Uses
Stock Market Conver-sion Strip (5)	Deci-mals & fractions are related	Math conven-tion	H-O, V -- D.	3	All	One-to-one spatial corres-pon-dence	Small to Large; Compare/ Contrast	Absolute knowl. bound by rules can be useful	Price conver-sions; other kinds of P/S
Fraction Kits (18)	Different sized fractions look a certain way; & may relate evenly	Col-league (Master Teacher)	H-O, V -- G (color-ing in shapes& D (play-ing w/ pieces)	3	All, but given pre-made	Color & size relate; smaller & larger may relate	Part/ Whole; Compare/ Contrast	Absolute knowl. bound by rules can be useful means to an end	Problem-solving during the second half of the year
Toys in Space (10)	The effect of gravity on motion	NASA resource center, liberal arts college recom-mended by a col-league from a different school.	H-O, V (2 forms),[1] -- G, & D (read-ing)	4	All: in pairs, then whole class	Real toys' behavior w/ and w/out gravity	Climactic (hypothe-sis and confirm-ation); compare/cco ntrast	Activates personal and taken-as shared know-ledge	Applied to problems of micro-gravity w/ space city; knowl. of gravity's effect on body structure; life in general

[1] Students observed the toys and watched a video of their behavior in space.

Table 8, continued

Represen-tation	Concept	Source	Modes	# of Modes	# Studs Involved	Salient Feature	Structure	Epist-emology	# of Uses
Earth Dance (3)	Diff. between rotatn & revol.; celestial rels.	Teach-er's own idea	K, V, A (G)	3	3 moving; 12 standing w/ posters	Clarifies dynamic spatial rels.	Cause-Effect	Certain know-ledge	* Connects seasons & Earth/ Sun/stars * Clarifies moon phases
Lollipops (3)	Moon phases	Science Conven-tion	H-O, K, V, (G)	4	All	Spatial/ visual corres-pondce.	Cause-Effect	Certain know-ledge	Moon phases; solar & lunar eclipses
House as Essay (4)	Essay struc-ture	Teach-er's own idea	V, A, (G-pic) (D-outline	2	All	Visual frame-work	Subordin-ation	Con-structed know-ledge	Non-fiction writing in class and beyond
Sneetches (1)	Power of greed and peer pressure	Col-league	K, A (G)	2	All?	Unques-tioned greed & exclu-sivity	Cause-Effect; Compare/ Contrast	Subject-ive know-ledge	Amplifies points in novels, films, history
Horses & Riders (24)	Expec-tation can limit percep-tion	College psych. text	V, H-O (G)	2	All	Horse can be seen in two ways	Cause-Effect	Con-structed knowl.	Many uses in studying cultures

Table 8, continued

Represen-tation	Concept	Source	Modes	# of Modes	# Studs. Involved	Salient Feature	Structure	Epist-emology	# of Uses
Street Scene (13)	*Shared meaning is not always shared * Same scene can be "seen" variously depend-ing on the view-er's interp.	Student maga-zine	V, A (G)	2	5 directly; the rest observe (took notes at first)	Visual ambi-guity	Simple listing; Climactic	Know-ledge is subject-ive and idio-syncra-tic	Many, based on no absolute reality leading to tolerance for other viewpoints when studying culture; or communi-cating w/ each other

KEY:
K= Kinesthetic; HO= Hands-on;V= Visual; A= Auditory; G = Global; D= Discrete; P/S = Problem solving.

Generalizing, one can see that the most common source for this set of representations was a colleague, followed evenly by conventions (another form of collegial exchange), available materials, and the teacher's own idea -- suggesting the central importance of nurturing professional ties to stimulate PCK development for representations. These representations are predominantly visual, followed by hands-on, but are supplemented by at least two other modalities indicating either an intuitive or an explicit attempt to appeal to a range of learning styles. Rather than discrete, the majority are global or continuous, suggesting the need to augment the usual sources of content delivery in secondary classrooms (reading, lecture and discussion) with approaches appealing to other parts of the brain. Almost every representation includes all students simultaneously, limiting the amount of "down time" associated with being a passive observer.

The representations follow seven different structural patterns. More than half contain at least two, either intrinsically or in the way they are used. Compare/contrast and cause/effect are the most prevalent, suggesting that these teachers have found them to be particularly useful for helping students construct an understanding of target concepts.

The different ways knowledge is portrayed within each representation vary, influencing the way students develop their conceptions of this content in particular and knowledge in general. Portrayals of knowledge based on the features of these representations range from objective ("Stock market conversion strip," "Fraction Kits," "Earth Dance," "Lollipops"), through subjective ("Street Scene"), to subjective influenced by compelling outside forces ("Horses and Riders," "Sneetches"), to constructed ("Essay as House").[1] How each is used, however, sometimes reflects a different set of epistemological assumptions and is a likely influence on how easily students could use the represented conceptions in a new setting (see below).

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[1] Taught to consciously consider their representations in this light, teachers could see more clearly whether they have struck the type of balance needed in their approaches to knowledge which most closely fit means with desired ends, an issue taken up in the next chapter.

Use of Representations

Ted's equivalencies strip and Dar's house are actually developed by the students, underscoring a sense of knowledge as already within the self and needing to become conscious through structured discovery and discussion. Reinforcing this sense, students are then encouraged to use the representations to come up with their own unique ways of thinking about particular problems or topics, but within the specifications of disciplinary syntax. Finally, they have a chance to listen to others' ways of thinking based on their experiences with these representations, so that all might synthesize a more complex view (knowledge as multi-faceted, both personally and socially constructed, framed by disciplinary parameters). The "Sneetches" representation portrays knowledge as socially constructed; Dar uses her representation to portray knowledge as multifaceted (reflecting the diverse nature of the experiences of German citizens during W.W.II). Ben's "Horses and Riders" and "Street Scene" help students confront the notion that subjective knowledge can be handled more responsibly if students live by certain values such as staying conscious of the need to keep an open mind. Thus, both Dar and Ben use their representations in a way which portrays knowledge as evolving.

The salient feature(s) for some of the representations in Table 8 shifted slightly over the years as teachers' understanding of students' needs or the nature of the concept evolved. For example, during the years when students constructed the fraction kits themselves, the kits helped them associate particular fractional sizes with particular colors *and* increased their ownership of this content. Ted sacrificed the second feature when he saw that students needed a visually accurate way to show equivalencies between different fractional sizes, which their idiosyncratic approaches tended to preclude. The salient features of Dar's house -- its structural familiarity to every child and the way it provided space in which students' could place pieces of their thinking -- have become more refined as she has noticed more aspects of the concept needing representation: houses now have more rooms to accommodate longer essays; students are now "real estate agents" trying to sell their property based on strong and more interesting foundations (lead paragraphs). The original feature of the "Sneetches" simulation, to reflect unquestioned greed and exclusivity, would have been supplemented the next time through with a feature emphasizing the self-policing aspect of belonging to the inner group, reflecting a refinement in Dar's PCK of ways to make it represent more accurately and completely what it was like for teens belonging to Hitler's youth groups.

The histories of use for each representation vary from one go round to twenty-four, the PCK surrounding them developing more slowly in some cases, more rapidly in others, depending on teachers' degree of subject matter knowledge about the content in question and their starting assumptions about their purposes for instruction. Ben learned, relatively early, that to maximize the impact of the "Street Scene" he needed to select a very observant student to go first and weave in a version of the rumor game to "make it more fun" (i.e., illustrate perception in a more complex and engaging way); while Ted, on the other hand, spent many years not seeing the value of the equivalencies strip because it didn't seem to serve a purpose, until he began to understand how it could support students' efforts to convert fractions into dollar amounts in the stock market unit.

While all of the representations *now portray knowledge as a means to an end, not all began that way.* For example, isolating just the content piece, Kit initially used the "Toys in Space" activities simply to illustrate differences in the movement of objects with and without the influence of gravity. Over time, aided by knowledge from the Soviet cosmonaut studies and her growing awareness of adolescents' emotional and cognitive needs, she began to see how she could have students weave this knowledge into their planet brochures and their space city designs. By helping them see the influence of gravity on them personally (on the shape of their bodies for example) she feels that she has helped them come into a much deeper relationship to the concept.

Ben began his use of the perception representations as a way to provoke and entertain students. Over the years, his understanding of how they could more intentionally support the way he wanted students to approach their study of cultures became clearer to him. In these ways, these teachers' use of concept-embedded representations have come closer to Schwab's (1962) observation that "conceptions are guiding principles of inquiry, not its immediate fruits" (p. 198).

Over the course of the history of use, *each representation has become more integrated within subsequent unit versions* (and with other units during the year) because teachers have learned how to layer it with other representations. For example, Ted has students use the stock market equivalencies strip all year long whenever it seems useful, not just during the stock market unit, playing it off of other representations like decimals depicted by coins and the large number line above the blackboard. Kit weaves multiple opportunities to practice cooperation through representations like the "Lost in Space" and "Toys in Space" --activities with opportunities to reflect on personal development in this area through journals and self-evaluations. In one way or another, all three of her representations discussed here deal with gravity (itself a kind of celestial cooperation) and so support each other -- something only possible within the last three years, when all were in use. Dar encourages students to keep their "Essay as House" notes until high school, printing the image on day-glo paper so students will not recycle it; she moves back and forth between movies and novels depicting conformity and nonconformity with simulations like the "Sneetches" and "Bear in the Woods" to increase the depth of students' emotional engagement and understanding of how various players responded to the atrocities of the Holocaust. Ben begins his year with the perception unit and has increasingly come to ask students to take its lessons into consideration in subsequent activities and units they explore together -- lessons like remembering that we learn to meet our basic needs in culturally influenced ways which are often neither more right nor more wrong than the ways of other cultures, just different.

Teachers have become more strategic in how they time the use of their representations: Ted's strip and Dar's house are not introduced until they have created a way for students to see a need for them. Kit now begins her unit asking students about their questions about space; students see that everything they will be studying comes from what they wondered about. The effectiveness of her "Lollipop" representation has been dramatically increased because it occurs late in the unit, when students can bring to bear their synthesized prior experiences with the "Earth Dance" and "Toys" representations. Ben builds suspense around his representations by foreshadowing their use through the framework he introduces after asking students, "How do we know anything?"

Finally, *all teachers have used the representations to reinforce the development of a precise technical vocabulary* which students acquire as they develop experiences with the representations. The terms now have a rich set of meanings because of the varied ways they are encountered, empowering students with some of the "cultural capital"[2] they need in order to become competent thinkers who have a greater range of choices for the direction of their lives.

Conclusion

All the teachers selected representations through which they could connect content with students' existing ideas and have students listen to each others' ideas as they interacted with the representations. Often these representations elicit cognitive conflict[3] -- Kit's "Toys in Space" exercises, or Dar's "Sneetches" simulation, or Ben's "Horses and Riders" -- a feature associated with bringing about conceptual change.

These teachers' representations are concerned not just with conceptual change of existing naive notions, but with conceptual development in the first place. They recognize that students may have rudimentary conceptual pieces -- what diSessa[4] calls "phenomenological primitives" -- in place, but not necessarily focused through the content

[2] (Delpit,1988, as cited in Ball & Wilson, 1996, p. 183)
[3] Perhaps this is part of the basis for Kit's and Ben's attraction to the element of surprise.
[4] 1981, as cited in Janvier, 1987b

in question. These teachers' PCK development has allowed them to become increasingly intentional about focusing such pieces through specified content, first by helping students identify them, noticing where there were alternate conceptions, then placing the representation as a bridge between these and teachers' targeted ideas.

Building effective representations requires going back to more rudimentary stages of thinking -- unpacking the building blocks comprising the teacher's current level of understanding and observing where students are in their process. Ted knows what it is like "to not get it and to continually not get it" and how to support students by finding out what it is they do get and building from there; Kit talks about remembering "what it is in yourself you found tricky" as a way to guide her PCK; Dar once commented that watching students struggle with something she was teaching for the first time taught her that there were really "10 steps between A and B" which she initially took for granted. These teachers have learned to integrate their knowledge of the small constituent parts of target material with overarching frameworks focused around core ideas. They now marry this integration to their ever-growing sensitivity to the emotional, social, and cognitive components of students' inner lives in order to bring about authentic connections between the students and the material. Their PCK of representations and greater student competence are the offspring of this marriage.

My focus here has been on teachers' PCK development around representations. The teachers in these studies use them, but don't think of them the way theory-based researchers have, with the possible exception of Ted, who was the only one who used the term as a regular part of his discussion of his work. What students bring to the content and how to help them *break free* of the teacher and become competent and caring thinkers are what these concept-oriented teachers are primarily interested in. So while this study focuses on what teachers have done, this was not necessarily their focus. This student-centered focus came through most strongly with Dar, who had the least amount to say about her perceptions of herself as a teacher and the most about changes in the way her students thought.

PCK Continua

Based on these case studies, the PCK of teaching for conceptual understanding has various dimensions: Purpose, choice and structure of content, methods, representations, and assessment of learning. This section sketches a PCK developmental continuum for each dimension. Each continuum is bounded by "near end" or beginning understanding and "far end" or more sophisticated expression of the associated attributes. Where the cases supply insights, some continua also sketch in middle phases.

Because I am dealing in generalities, it is difficult to be fully descriptive of the different levels at which PCK operates (unit level, lesson level, representation level, or the level of students' mental models). Actual PCK must be inferred, using the continua as frameworks. My intent in sketching these continua is to clarify which kinds of knowledge and experience could be made more intentionally part of preservice and inservice teacher education so that new teachers begin with more developmentally advanced PCK of concept-oriented teaching than they currently do. Since this is a rudimentary effort, it's not my intention to assert that these are invariant stages comprising a true developmental scheme, but rather to indicate the different phases of PCK teachers in this set of cases have gone through at different points in their careers.

Purpose

Near End: Goals are short term, lack connection to a larger picture, and are unclear to teacher and to students.
Knowledge is treated as an end in itself.
Teacher is oriented toward managing a classroom of individuals vs.

facilitating a unified learning community.
Performance goals are based on students following the bell curve.

Near Middle: Goals are more clearly articulated; are cognitive and/or affective, based on external recommendations like teacher's guides or pre-existing curricula.
Some attempt is made to communicate goals to students.

Far Middle: Goals are both cognitive and affective and are clear to the teacher and to the students.
The teacher has an inner sense of what particular content is about and uses this to meet ends the teacher or his or her department decide upon.

Far end: Long and short-term goals are mutually established with students and marry students' needs and interests with the recommendations of research-based experts, the teacher's sense of the structure of the discipline, and school philosophy.
Teacher overcomes personal interests to meet students' needs, even if it initially feels boring.
Emphasis is on putting syntactic tools into students' hands as a way to empower them to --
1) see they are not just consuming culture but also able to create it;
2) stay open-minded to themselves, others, and the material, as they follow discipline-based step-by-step processes;
3) become self-confident problem-solvers, who know where to go for information and how to evaluate it;
4) can and do apply material to problems and projects of interest to them.

Increasing emphasis is placed on self-knowledge as one prerequisite for becoming a responsible member of a learning community.
Knowledge is treated as a means to an end; evolving and multifaceted, not fixed and single-pointed; as something students see value in and use today, not just in the future.
High standards are established for all students who are fully supported to meet them.

Choice of Content

Near End: Teacher does not take responsibility for choice of content, adopting what's been done before, or teacher invents curriculum based on personal interests.

Near Middle: Teacher invents curriculum based on professional readings adopting recommendations lock, stock, and barrel.

Far Middle: Teacher adapts curriculum based on professional readings and makes changes to fit her and her students' needs better.

Far End: Teachers and students negotiate what is studied.
Existing curricula is adapted to students' needs and interests; and or developed by teachers and students together.
Teacher is aware that concepts are both socially-constructed products and socially-constructed tools of thought -- not simply ends in themselves, thus, which concepts are focused on may be less important than understanding how to use them.

Focus is on ways to empower integration of compassion and intellect through content.
Emphasis in on problem-finding requiring metacognition about how to frame materials, aware that the framing may influence the solution path/ outcome.
Teachers are comfortable learning new content along with students because they have a way of viewing it which can offer guidance to students and they trust that students will teach them and each other important insights.
Balance is present between content and process; between classical subject matter and what the teacher and students deem important of a more immediate nature.

Structure of Content

Near End: Teachers are attracted to activities with certain features: hands on, fun, surprising.
Core ideas are not explicitly articulated.

Near Middle: Structure of the activity becomes clearer. Core ideas begin to be articulated, but are not coherently represented.

Far Middle: Activity becomes a true representation as it becomes tied to a coherent framework worked out by reflecting the nature of the content and on students' experiences with the materials over time.
Core ideas are clarified at the start of the unit and represented intentionally during the course of the unit.

Far end: Teacher intentionally uses students' ways of thinking to help them shape frameworks for understanding via journaling, observation, and direct questions.
Teacher notes patterns and builds on them for future unit versions.
Teachers are conscious of their inner models of content and the part these play in shaping the way they portray content.
Students are clear about path ahead.
Teacher begins the unit with something relevant from students' lives, the media, other content areas.
Content is always connected to students' realities in some way, first by teacher, later by students.
The unit contains interdisciplinary dimensions because real world problems, which the units stress, are naturally multidisciplinary.
Core ideas are articulated, represented in a variety of ways, and referred to throughout the course of the year.
Students are encouraged to make links between them and new ideas, between them and experiences outside class.
The unit is timed strategically to take advantage of previous learning.
Students are asked to make their own frameworks using different lenses, self-chosen and not, leading to practice with perspective-taking and critique.

Methods

Near End: Materials/activities shape the methods teachers use. Teachers' needs dictate choice of activities at first.
Teacher views special needs students as slowing down the curriculum.

Teacher assumes students are empty vessels and teaching is a one-way street from them to the students. They do not trust students to teach each other. Emphasis is on didactic instruction.
Teacher answers questions which other students could answer; or answers questions students haven't asked. Corrects by imposing right answers on wrong answers.
Methods do not take into consideration patterns in students' responses to the material.
Tendency to stress a limited range of instructional groupings, e.g., whole class/teacher-led or individual seatwork.

Near Middle: Teacher has some success meeting the needs of some special needs students.
Teacher experiments with discovery mode for content delivery.
The importance of both cognitive and emotional links to the material is in evidence in the methods used, but not integrated in any intentional way around core ideas.
Teacher funnels student responses via a series of explicit questions aimed at a specific answer.
Some sense is present of patterns in students' errors, prior knowledge, or developmental progress through the material.
Teacher intentionally uses at least two instructional formats (individual and whole class) and several modalities (visual, auditory, writing, drawing).
More emphasis on "carry into" the classroom than "carry over" beyond the classroom.
Teacher begins to question if means fit ends.

Far Middle: Teacher begins to recognize special needs students as triggers for PCK which can help the general population as well.
Conscious effort is present to integrate cognitive and emotional responses to the material.
Clear patterns are emerging in students' prior knowledge, misconceptions, and developmental needs, which teachers take into account in the instructional approaches they take.
Students take increasing control of the delivery of content, supported by multi-modal methods the teacher makes available. There is an effective balance between teacher-led and student-led teaching.
Students are given enough time to construct understandings of core ideas.
Emphasis is on critical and creative thinking.
There is balance between structure and spontaneity.
There is a deliberate focus on building a discourse-based learning community where students from all performance levels can effectively participate.
Teachers use more varied instructional groupings and a greater variety of modalities (reading, writing, drawing, listening, hands-on).
There is a closer fit between means and ends.

Far End: Methods used are about "deflecting authority and participating in community."[5]
Teacher views meeting the needs of diverse learners as a trigger rather than

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[5] Observation of my committee member, Professor Charles Moran, during the proposal meeting for this study.

an impediment to growth.

Teacher is in touch with his/her own learning style and experiences as a student, consciously builds on these, and can take the perspective of students in class as a result. (S)he learns with and from students.

Teacher encourages students to teach each other.

There is balance between didactic and discovery methods.

Teacher alternates between controlling behaviors and letting students' energies dictate the direction of the class; between plans and spontaneous events in an attempt to merge students' energies and interests with the teacher's agenda.

Humor is a regular feature of instruction.

A wide range of instructional formats is in use, including small group and paired formats.

The teacher is familiar with cooperative strategies and accommodates people who work at different rates: is more deliberate, offering multiple opportunities for reinforcement for slower students; and additional enrichment for those who move more quickly.

Teacher and students mutually establish a democratic and caring learning environment.

Teacher creates real openings for students to conjecture.

Teachers honor students' sense making, gradually helping student constructions to come into line with those of disciplinary scholars.

Students are encouraged to think for themselves rather than parrot a right answer or memorized algorithm.

The teacher seldom provides answers, but validates questions and turns them back on the class, inviting genuine discussion by encouraging students to join in serious and legitimate inquiry.

There is a balance between letting students resolve conflicting points of view among themselves and guiding the class toward a consensus or synthesis.

The teacher has a strong sense of students' error patterns and developmental needs as they progress through the material and knows multi-modal ways (including kinesthetic) to respond supportively to students of all learning needs, believing that all students can learn if the teacher provides the right supports.

The teacher is clear about ways to integrate emotional, cognitive, and ethical responses to the material, intentionally linking prior knowledge with current learning and emphasizes using the knowledge beyond the classroom.

Current events and other sources of real world problems are intentionally tapped as media for practicing application of core ideas, skills, and attitudes worked on in class.

Students are encouraged to generate problems for other students to solve, which prompts them to think like a teacher about problem types and what supports others may need to solve them.

Teacher intentionally creates ways for students to hear multiple points of view on the topic, then asks them to create their own syntheses.

Teacher recognizes that even with a large repertoire of strategies, the chemistry of some classes precludes reaching all the hoped-for goals, so places her/his attention on the pieces over which (s)he has the greatest control.

Teacher resocializes students about the nature of school learning.

Representations

Near End: Representations are used as ends in themselves.
Students use them without a clear understanding of the core ideas being represented.

Near Middle: Teacher mediates students' experience of the representation, telling them the sense they should be making of it. Core ideas are more visible within representations.

Far Middle: Teacher has several students mediate the experience of the rest of the class by making them substitute teachers. Representations are increasingly interactive.

Far end: Teachers has students co-construct the representation.
Teacher is flexible in the way a representation is used: additional salient features are highlighted to accommodate refinements to the core idea.
Teacher gives students more space to draw their own conclusions from the representation.
Key ideas take on additional complexity, generating more opportunities for students and teachers to link them to other parts of the curriculum via a layering of representations against each other.
The teacher knows how to time the use of representation for maximum effect, whetting students' appetite for its need before actually introducing it.

Assessment

Near End: Teacher controls all assessment.
Does not ask students what they think they have learned, stressing instead, only what the teacher thinks they should have learned.
Uses conventional fact-oriented tests.

Far End: Asks students directly what they are learning.
Self-assessment is highlighted, using mutually constructed criteria into which the teacher weaves the parameters of disciplinary syntax.
Students monitor themselves en route as well as at the end of a process.
Final assessment stresses performance for an audience beyond the classroom and evaluation by others (not just the teacher, perhaps a jury panel of experts) on both process and product.
Testing formats are geared toward empowering students to recognize what they have learned, not simply toward finding out what they still don't know.
Teachers possess a high degree of knowledge about each student's current level of understanding and performance around key ideas, processes, and attitudes.
Students are rewarded for the authenticity of the connections they make to the material.

Conclusion

The cases in this study offer a picture of long-term growth in teachers' understanding of the academic and affective nature of their task. Mapping that growth process hasn't happened until now because researchers into effective teaching have looked at teacher knowledge primarily in terms of expert/novice snapshots. As seen from the teacher's perspective, these cases provide further detail about when, how, and why concept-oriented teachers develop their PCK.

In the absence of a theory of PCK development, I have generated continua reflecting different dimensions of the PCK developmental process. The "Far End" of these continua reflects what was found in these cases, but is not meant to suggest that this is an end point. For example, none of the teachers in this study talked specifically about taking into consideration students' mental models of content in selecting representations. None asked students for their personal representations of core ideas in graphic, musical, kinesthetic, or other non-verbal modes for other students to critique. Yet these could be valuable additions to a teacher's PCK of representations. Similarly, an advanced form of assessment not seen in these cases would include students generating their own analogies of core ideas to show they've internalized the deep components of the concept.

Because of the context- and content-specific nature of PCK, it is difficult to generalize about except at the level of principle. Having clarified some of these principles, it seems likely that these could be used to actively nurture PCK development for teaching for conceptual understanding using specific content in preservice and inservice settings. Chapter 5 addresses the prerequisites for this.

CHAPTER 5

IMPLICATIONS

Introduction

What are the implications for preservice and inservice teacher education based on the developmental patterns in teachers' PCK in this study? For preservice, I discuss those aspects of the PCK of concept-oriented teaching which can be nurtured more intentionally in subject matter preparation, methods courses, and field work; for inservice, I look at the contextual factors related to PCK development over which administrators, staff developers, and policy makers have greatest control.

Implications for Preservice Teacher Education

Sooner or later, all four of the teachers in the cases described in Chapter 4 came to the realization that the core of their work was about "making the knower's activity central, ... view[ing] knowledge as changing" (Ball, 1990, p. 48) and helping students use the tools of the discipline to become effective thinkers and doers. How do preservice teachers need to be prepared so that they can be more intentionally oriented to act on these insights earlier in their teaching careers? These cases suggest five prerequisites:

1) A solid command of subject matter frameworks and tools;

2) Practice with viewing subject matter in multiple ways;

3) Self-knowledge and a capacity for empathy;

4) A view of the teacher's role as facilitator of learning who thinks conceptually about content for teaching; and

5) An ability to use both discovery and didactic modes to teach concepts, so that students can use the concepts independently and with understanding.

Each of these is discussed below.

Subject Matter Frameworks and Tools

Typically, the fruit of majoring in a discipline should be a deep understanding of its basic principles and themes, fleshed out with rich details; an awareness of questions of current interest, areas of controversy, organizational paradigms of the discipline, and ways to evaluate what is held as true (Grossman, 1990). The subject matter preparation of the teachers in these cases suggests that even an undergraduate major in the subject area for certification, which only two of the four had, did not adequately prepare them for teaching the content for which they would be responsible. With the exception of Ben (who used material from his college psychology course in the Perception and Learning units), none of these teachers ended up using much, *per se*, of the material they were exposed to as undergraduates.

A straight match between college course content and what will be taught in school may never be likely, especially considering the rapid pace at which knowledge is growing within the academic disciplines. This implies that a better way to prepare future teachers in subject matter needs to be at the level of structure. That is, the PCK development of these teachers could have been significantly supported by undergraduate coursework which routinely included discussions of structural links between core ideas within the discipline, the ways knowledge is evaluated, how these ways differ from those used in other disciplines, and how to apply various kinds of disciplinary thinking to material of interest to students. This type of metacognitive activity would have positioned these teachers to apply broad understandings to the unfamiliar disciplinary content they would eventually have to teach, so expediting their understanding of it. Instead, these understandings had to be constructed slowly at a time when, in the midst of a bewildering array of competing demands, teachers were already supposed to have them.

Giving undergraduates a view of large conceptual frameworks, multiple views of material, and a clear picture of the nature and use of disciplinary syntax could be of considerable help to prospective teachers in three ways: first, by expediting an understanding of the constructed and evolving nature of knowledge, which the teachers in this study only came to over time; second, by reducing the cognitive load involved in teaching conglomerate subjects like social studies and middle school science by equipping graduates with ways of organizing disciplinary ideas;[1] and third, by helping to close the current gap between practicing teachers' subject matter knowledge and significant developments in the substance and syntax of science, math, English, and history within the last quarter century (Wilson & Wineburg, 1993; Langrall, 1994). By highlighting new developments and paradigm shifts, liberal arts faculty could give prospective teachers permission to think that these are appropriate content for school learning.

Because they either didn't know about developments in their subject area, or learned them in a way which did not transfer, the teachers in this study all needed validation from some external source (the NCTM Standards, workshops, colleagues, student teachers, professional reading and graduate coursework) before they felt free approach disciplinary substance and syntax in more sophisticated ways. Kit only came to see how the sciences relate after she had spent time teaching about the different

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[1] Putting new material in an already-built niche requires less of a new teacher, already beleaguered with synthesizing many components of the learning context, than having to build an entire structure from scratch.

sciences as part of her middle school curriculum; this was not a part of her original subject matter training. Ted's quick appreciation for the NCTM's support for integrating math topics in order to help students to think flexibly about different facets of a problem -- to develop a "panoramic view" of math -- came from his being a "mathematical person," not from having learned math in this way. Over time, Ben came to see how integrally related aspects of psychology and anthropology are, but he was not originally trained to think this way.

Ideally, concept-oriented teachers would begin their teacher preparation in their first twelve years of school, immersed in classrooms committed to conceptual understanding. Lacking this start, the operative assumptions embedded in the approach to content in undergraduate courses must be made more obvious to students; not just to benefit the future PCK development of prospective teachers, but to benefit the conceptual development all undergraduates. Using the ideas of Schwa (1963), teacher educators and faculty developers could encourage liberal arts professors to highlight the structural links between large ideas, and make syntactic conventions and multiple views of material explicit for students *at the outset* of the class. Each of these needs is discussed more fully below.

Structural Links

Teacher educators could help sensitize liberal arts faculty to the importance of being (more) explicit about the large frameworks for organizing ideas within their discipline by reminding them that the integrated understandings of experts permits much more efficient access to large amounts of knowledge, thus is not a bad starting point for helping students to organize material. Receptive liberal arts professors could also be encouraged to call attention to the frame surrounding their courses as a way to help undergraduates appreciate the constructed nature of the discipline. Literature professors, for example, might make a point of beginning their courses by asking students to consider the possible ways one might organize disciplinary content -- by era, genre, author, or theme for example, and conclude the course with of discussion of why the professor chose one way over.

Stepping down to the next organizational level, literature professors make choices about which novels, poems, plays, and short stories will be included in the syllabus and which will not. What are the values surrounding these choices? These should be made clear to students so that they can understand that the curriculum reflects a set of values and that another set would result in a different curriculum which the professor has consciously chosen not to adopt. Within specific works, the professor or the professor and students make decisions about which ideas to address and how. Who decides and what the decisions are could be made more explicit so that all students understand the choice-making at the heart of teaching and learning, even at the most immediate levels: Where do we place our attention? Why? Is there space to place it elsewhere at some point in the class? If not, why not?

Attention to Syntax

Syntax relates to the procedures used to evaluate whether information, concepts, and principles within a given field are legitimate, regulating over time what is added or dismissed as part of the field. Syntactic rules for each discipline have their own character: the universality of insight has guided the evaluation of knowledge in the humanities; logical consistency, the social sciences; the reliability of observation, the sciences (Rancourt and Dionne,1981). What feminist, minority, and critical theorists have helped to bring increasingly to light is that these rules are not value-neutral. Thus, which questions are raised and subsequently funded in science, for example, reflect prevailing cultural norms (Rosser, 1990); likewise for which literature is included in the canon, or whose history will make it into the textbooks. Attention to disciplinary syntax prompts one to consider the influence of point of view on the nature of knowledge, as discussion would illuminate why the discipline follows some rules and not others.

For the teachers in this study, *giving students practice with disciplinary ways of thinking became a central goal.* Dar and her colleague, Bill, for example, helped students to do what historians do by providing them with varied viewpoints on WWII and inviting them to construct a substantiated synthesis which made sense to them. Ben encouraged students to think like social scientists by having them take into consideration the nature of our perceptual lenses when making judgments about other cultures. Ted invited students to think like mathematicians when he insisted that they reason for themselves rather than simply recall memorized algorithms, and when he encouraged conversation among students about different solution paths.

When command of disciplinary syntax is a more visible goal, it's more likely that undergraduates will see that practice in how to use disciplinary tools on problems of particular interest can equip them with a set of ideas about how to approach problems in other contexts, such as teaching. Having had to contend with several disciplines within their content area, Ben and Kit, for example, had more pressure to teach themselves new content than did Ted -- a process which sometimes took years. It seems likely that greater consciousness of disciplinary syntax could have expedited their learning new content (and insights into how to teach it to others) by strengthening their ways of approaching and evaluating the content to begin with.

Multiples Views of Material

To become a humane and competent thinker about complex life problems -- another deep goal of each of the teachers in this study -- students need to learn, that "one embodiment of one attack on something is less than the whole of the matter under investigation" (Trowbridge and Bybee, 1986), and become skilled at "transcend[ing] their natural subjectivity" (Paul, 1987, p.131). All four teachers in this study ended up stressing the variety of paths people take in understanding something and the need for students and teachers alike to appreciate these differences, while synthesizing a personal, yet evolving perspective for themselves.

Prospective concept-oriented teachers need explicit practice in taking multiple views of material. In literature courses they might variously try on Marxist, feminist, deconstructionist or reader response approaches to text, film, and plays. In math they might collect different ways to solve various kinds of problems or become aware of disagreements among disciplinary scholars and take a well-supported position. In science they might learn about paradigm shifts in the history of science and current disciplinary controversies. In history they could learn about historiography and on-going areas of debate, applying acquired syntactic skills to tackle some of these questions for themselves. In all cases, the undergraduates' relationship to knowledge changes; they become agents, mimicking the invention of experts as they grow in understanding. This is important groundwork for treating their future students likewise, as the way they experience their courses can have a strong influence on their view of the teaching enterprise (Grossman, 1990). Ted and Kit, in particular, initially approached teaching by imitating the ways they had been taught; both felt frustrated and unfulfilled until they received permission to teach differently.

To support their understanding of the way different values and different views of learning can shape PCK at the unit and lesson level, prospective teachers might be given clusters of commercially-made, teacher-made, and student-made curricular materials with varying ideological commitments and epistemological assumptions in order to become familiar with what choices exist for approaching content and what each choice includes or excludes (see Appendix LL for a sample exercise at the lesson level using *Mary Had A Little Lamb).* Both these dilemmas and the types of curricular analysis mentioned above could help create what Schwab has called "polyfocal conspectus" (1978, as quoted in Gudmundsdottir, 1990), that is, an understanding that the "what" and the "how" of teaching involve messages about the nature of knowledge, learning, and what's worth knowing which are embedded in different approaches to content and learning. Asked to integrate their own values with hard data on the way children, teachers, and disciplinary scholars actually think about particular content would give prospective teachers practice in being systematic in designing units and lessons, something Kit felt she did not learn in her teacher preparation. In this way novices could learn to think of themselves the way concept-oriented teachers do -- as architects using conceptual structures to build powerful learning environments.

Developing more flexible views of their roles, not just the content is another need of programs committed to train teachers oriented to teach for conceptual understanding. For all of the teachers in this study, guiding students' ethical development eventually became an important, even passionate, part of their role, whether developing in students the highest personal standards for work so as not to let themselves down (Ted), an understanding of how to support schoolmates' learning responsibly so that all have an equal opportunity to learn (Kit), a clear-eyed look at peer group norms so that students could understand the real and potential impact of intolerance (Dar), or an unbiased view of how others think so that one could broaden one's mind (Ben). As a means to invite ethical and epistemological development, Lovell (1993), based on his work with Perry's scheme (1981), recommends that naturally occurring dilemmas be the focus of teacher training. Examining these dilemmas with inservice teachers at different levels of moral development could push prospective teachers to examine their deep reasons for coming into the profession -- something which could guide them powerfully through the throes of full-time teaching, when many distractions and fatigue might prompt them to forget. Such clarity could permit a more flexible approach to goals, as Ben had, where a variety of unpredictable outcomes might ensue *because* students had made genuine connections with the material.

These case studies suggest that the extent to which a prospective teacher resists the socialization into the profession they experienced as a student may relate to how quickly they will shift from viewing the teacher as the source of all knowledge toward the role of "co-creator" in Dar's words, and to a view of knowledge as less about fixed facts and skills and more about evolving competencies and open-ended meaning -- perspectives eventually shared by all the teachers in this study. For the many student teachers attracted to teaching because they did very well within classrooms which stressed didactic transmission of facts, professors of teacher education need to confront several widespread myths about school learning: that it progresses hierarchically through telling; that the teacher's role is mainly to hold students accountable for factual information they provide or require students to locate; that writing is a place simply to display knowledge rather than also a way for students to discover what they know before they display it; that most students don't need support to meet curricular expectations, which ask for only lower-level thinking because most students are not that capable (McDiarmid, 1990). Because teacher education often doesn't directly challenge naïve beliefs, many preservice teachers make new ideas fit old thinking or reject new ideas that relate to the teacher's role, pedagogy, learning, diverse learners, subject matter, content and learning to teach (McDiarmid, 1990). Because these beliefs can be mutually reinforcing, they need to be addressed not singly, but as a web (Cochran, DeRuiter & King, 1993; McDiarmid, 1990).

As all four teachers in this study eventually moved toward broader definitions of what constituted their content and their goals, I believe that all could have benefited from teacher education earlier in their careers that asked them to collaborate with a peer trained in another content area to develop an interdisciplinary unit, so that each could discover how one subject area's truth claims and core ideas might supply richer associations for those of another. (I think about how LeChatlier's principle of equilibrium in chemical reactions, for example, and shifts in Dick Diver's marriage in Fitzgerald's, *Tender is the Night* might illuminate each other mutually.) It could also offer them practice in bringing interdisciplinary thinking to the multifaceted ill-structuredness of real-world problems, with which teachers committing to conceptual understanding are concerned.

Self Knowledge and the Capacity for Empathy

Based on these four cases, both self-knowledge and empathy were necessary precursors for these teachers to learn about and build on students' prior knowledge and current constructions of target content -- necessary pieces of teaching for conceptual understanding. But these cases also suggest that teachers had to be ready to look at their own learning styles and to see the value of empathizing with students' constructions. The notion of readiness is echoed in a study by Hollingsworth (1989), who found that of the four factors which swayed student teachers' preprogram beliefs toward program developmental and constructivist emphases, two were related to teachers' social cognitive development: a flexible perspective on themselves and teaching, and more adequate empathizing with students' needs.[2] Despite variations in developmental readiness among prospective teachers for perspective-taking, however, teacher educators need to act on the belief that if students are more capable than many teachers give them credit for, given the right supports, the same holds true for preservice teachers. Teachers' thinking can be advanced, asserts Glickman (1990), if

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[2] These teachers saw themselves as evolving and capable of critiquing teaching practices; and they could recognize the inadequacy of earlier beliefs when coping with the organization and management demands of real classrooms.

confronted with novel materials and experiences. They need to be given time to "interact, experiment, observe other teachers, and self-evaluate" (Glickman, 1990, p.54).

Implications for preservice teacher education include structured interventions to support PCK development through accommodating different levels of development regarding self-knowledge and empathy. Examining the self as learner by looking through the lens of different learning style systems using a resource like Guild and Garger's, *Marching to Different Drummers* (1985), then writing one's intellectual autobiography and comparing it with others' is a start. Role-play, in which preservice teachers become students again learning something completely unfamiliar, to see and feel aspects of their own learning process more consciously, could provide an opportunity to compare experiences with those of other learners -- perhaps graduate assistants, inservice teachers, high school students, and professors of teacher education invited to sit in -- who might also offer perspectives at different stages of self-awareness.[3]

Along with pre-practicum exercises is the critical need for carefully structured fieldwork to cement the need to look at teaching from the learner's point of view. To begin to develop PCK at the level of students' models of content, for example, preservice teachers could be encouraged to engage in research projects very early on in their pre-professional training which involve *interviewing a variety of students* to discover patterns in prior knowledge and misconceptions in particular content, current ways students think about it, how these may have changed over time, and why.[4]

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[3] Sprinthall & Thies-Sprinthall (1983) have found that teacher development can be positively influenced by role-taking experiences.

[4] This would make intentional the behavior Putnam and Leinhardt (1986 as cited in Leinhardt, 1988) found in successful math tutors, who mentally flagged materials students found hard or approaches students found easy and kept records of what worked for the next time.

To begin to develop PCK at representation level, prepracticum teachers could also *interview a variety of experienced teachers* to collect a minimum of three strategies using different modalities and intelligences, which have helped students construct understandings about the same content they asked *students* about above. Preservice teachers could also be encouraged to track the often fleeting analogies teachers use (and just as often forget) and begin to analyze them in terms of salient features, how well they connect with students' worlds, and how fully they represent a core idea. Such collections could be made available to other teachers within the same subject area (both new and experienced) and become part of the permanent archives of the education department and the schools where research is conducted. Perhaps a data base could be established for particular points in particular material to which all could add, building a valuable resource for future teachers new to that particular content. In this way, some of the best ideas in teaching would not die with the teachers, or have to be laboriously reinvented by someone else down the line. Instead, they could become rich starting points for new teachers to develop repertoires of their own.

Finally, preservice teachers could be asked by their professors to generate concept-oriented lessons using their own creative ideas based *on the data they have collected* from both students and teachers, have these critiqued by experienced teachers, then used with actual students and reported on, before being shared with a variety of preservice and inservice teachers. In this way, well designed concept-oriented materials could be made available to both novice and veteran teachers, and preservice teachers would have a larger audience for their work than simply their professors, mirroring the commitment of teachers committed to conceptual understanding to have students learn from interacting directly with the real world.

A Teacher's Role: Thinking Conceptually About Subject Matter

To help prospective teachers avoid the random or lockstep approaches to instruction which ensue from naïve understanding, poor modeling, or cognitive overload, and move toward a more organic and conceptually integrated approach responsive to students' needs and interests, teacher educators need to employ a carefully structured conceptual change process:

1. Make preservice teachers' assumptions about key aspects of teaching and learning conscious.

2. If the topic is the nature of content for school learning, step two could include having preservice teachers create concept maps reflecting their own current ways of linking the large ideas within the subject area in which they plan to be certified and their current views of their role in helping students learn about these ideas.

3. During early fieldwork experiences, prospective teachers could be given a chance to ask students they tutor to draw concept maps to help demonstrate the way *they* think about ideas within a subject area.[5]

4. Experienced teachers could then be interviewed about the large conceptual frameworks they have evolved to help them link ideas within and among curricular units within the same subject, which prospective teachers could map.

5. Teacher candidates could also interview liberal arts professors for their conceptual views of related material, so that a variety of pictures emerge of different ways different people integrate disciplinary knowledge.

6. Prospective teachers could then compare all four sets of conceptual pictures, then draw conclusions about whether and how they connect, and/or how they might be made to connect better when appropriate, perhaps using such thinking maps as those devised by Hyerle (1996).

This process could help to build a strong foundation for PCK development for concept-oriented teaching by establishing a pattern in *which novice teachers begin unit and lesson design by considering students' constructions* (particularly those of special needs students), rather than simply what's available for materials, as most of the teachers in these cases did, and thus avoid wasting valuable time mistaking students as

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[5] Coburn (1991) has recommended such research tools as word sort; state sort; and dyad comparisons to get at students' mental models of content. One might also try Kelly's (1955, as cited in Shapiro, 1989) repertory grid, as well as Shapiro's (1989) "Classroom profile."

dull and/or unmotivated because of misguided teacher objectives and/or a poor fit between means and ends.

Facility with Discovery and Didactic Modes

All the teachers in this study use a combination of discovery (inquiry, constructivist) and didactic modes. Preservice teachers need to see these modeled both by cooperating teachers and by professors of education. The good modeling of both modes by inservice teachers, however, may be hard to find in all subject areas within easy reach of teacher education programs. Further, professors often do not model methods they purport to teach (Grossman, 1990), fail to provide adequate coaching on research-based behaviors that do have a high correlation with student success, and tend to talk about research rather than experiment with its findings in their classes or encourage student teachers to do likewise during field experiences (Champion, 1984; Marsh, 1987). *Changing what teacher educators are doing is within their control; changing what cooperating teachers do, may not be.*

Finally, an emphasis on process and nurturing student autonomy was found, to varying degrees, in all of the teachers in this study. These goals can be emphasized through the means and ends teacher educators adopt with prospective teachers.

Conclusion

A few points of emphasis: In terms of laying a viable subject matter foundation for future teachers, there's an irony about becoming clearer about the structure of one's discipline. One must do this, and yet be able to transcend it because of the multifaceted nature of real problems -- a major concern of concept-oriented teaching.[6] Interdisciplinary teaching is precisely aimed at bridging different disciplinary worlds, at developing what I call "interstitial consciousness" and a friend of mine calls "leap frogging between lily pads." Helping students manage these leaps is an essential outcome of teaching for conceptual understanding. First, however, one must have a clear sense of the borders of at least one of the pads before leaping which a *firm grasp* of disciplinary structure permits.

Second, teacher educators interested in changing the undergraduate educational culture in which student teachers are prepared need to confront head-on the Classical view of the professor as fount of all knowledge -- a view some feel is widely shared by liberal arts faculty (Hamm, 1981) -- and help interested professors in other disciplines to integrate what we now know about authentic learning into college pedagogy. Through workshops addressing concept-oriented teaching strategies (including collecting error patterns in typical undergraduate responses to disciplinary material and finding effective ways to represent ideas to help students change them) novice (and receptive veteran) professors of diverse disciplines could be shown that concept-oriented teaching can significantly expedite the learning students do within and beyond a content domain.

Third, conceptual change strategies need to be used in concept-oriented teacher education to address misconceptions preservice teachers accrue through "apprenticeship of observation" experiences about the nature of subject matter for school learning,

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[6] Differences between the humanities, social, and hard sciences have been cited as the source of difficulties members of different disciplinary communities have in communicating with each other; since their "reality images" (Rancourt & Dionne, 1981, p. 17) only permit them to see in particular ways, they experience phenomena differently. This paradigm is useful, I believe, as a starting point for tagging differences in value schemes; however, it seems to cap human capability and fails to attend to the evolutionary nature of knowing. The essays of Loren Isley and Lewis Thomas come to mind as examples of "metaphorical" treatments of traditionally "empirical" content. The work of Howard Gardner (Armstrong, 1994) suggests the range of human perception capable of development, given the right supports, a range which could be brought to bear on understanding each of the disciplines more richly.

teaching, and students. Necessary first steps involve activating these conceptions and working with them directly though exercises designed to:

1. view subject matter structurally and multiplistically,
2. support the development of self-knowledge and empathy, and
3. develop a view of the teacher's role as a facilitator of learning for students of all performance levels.

Structured experiences with observing how constructivist and didactic methods can be woven together to invite students' conceptual development at a very detailed level for some piece of content, later integrated into a larger piece of curriculum planning, are necessary next steps.

Some research (e.g., Wilson & Wineburg, 1993; Ammon & Hutcheson, 1989) has shown that, given the right supports, much earlier in their teaching careers, *novice teachers can be nurtured to transcend the usual learning pattern* Fuller (1969, as cited in Glickman, 1990) has found in teachers, away from the self-concerns typical of new teachers toward a more mature concern about the impact of instruction on students. Providing the right supports is key.

Implications for Inservice Teacher Education

What are the contextual factors most related to PCK development over which administrators and policy makers have greatest control? Factors are examined from the point of view of each set of players.

Administrators

After studying hundreds of federally funded staff development efforts, Sparks (1983) found that the support of superintendents and principals *was the major factor* *affecting success of staff development initiatives in schools.* Based on the patterns in PCK development of the teachers in these cases, there are several contextual supports principals could provide to encourage PCK development for conceptual understanding among teachers in their building:

1) Encourage staff to develop a unified vision for their school which embraces conceptual understanding and integrates curricula within and across grades around this goal.

2) Support collegial ties within and beyond the building aimed at developing concept-oriented teaching methods.

3) Support mentoring of novice teachers and their PCK-based action research projects.

4) Encourage the use and development of concept-oriented curricula based on these projects.

Each is discussed below.

Integrated School Vision for Concept-Oriented Teaching

In the midst of the plethora of information available at the touch of a computer key and clashing value systems about what constitutes core knowledge, a clear and unified vision of what should be taught seems very appealing to many members of the educational community. According to Stodolsky and Grossman (1995) who studied all teachers in 16 high schools over a three-year period, most teachers "do not share common views about what to teach" (p. 240). They agree slightly about what's important to emphasize and express somewhat more agreement about how to teach than what to teach. Interestingly, half of the original eight teachers interviewed for this study wished that they could be told what to teach (all men), so that there would be some standard against which they would be held accountable, and they could focus their energies on meeting it.[7] Even a mandated curriculum, however, will be experienced differently by students if their teachers hold unexamined divergent beliefs about subject matter (e.g., scientific theories as truths uncovered through rigorous experimentation vs. theories as tools to solve problems), about reasons for teaching it (passing tests vs. lifelong learning) and about learning (absorption, trial and error, or knowledge construction) (Brophy, 1989).

Thus, principals need to foster discussions in which differences in teachers' goals, methods, sense of the nature of learners, and learning are openly acknowledged and explicitly addressed in the context of personal and recent academic research. This is critical for several reasons. First, the sometimes highly influential, negative myths about what teachers can and cannot do with students circulated by a few unenlightened and disaffected staff need to be directly challenged. Second, students' experience with the curriculum should not be the current "haphazard diversity...based on [teacher] isolation and ignorance" (Wilson & Wineburg, 1993, p. 760-761).[8] And finally, teachers can be shown that their often deeply held orientations to content -- whether academic, self-development, critical, or life-role related -- can be *strengthened* when they use methods emphasizing meaning-making (Kegan, 1993). In this way, nurturing the PCK for conceptual understanding can unite and edify diverse faculties.

How can diverse teachers be helped to commit to learning about and using concept-oriented methods? Some evidence exists that rotating courses among department members allows teachers access to a wider range of students, thus increasing a sense of shared purpose within a department (Stodolsky & Grossman, 1995, p. 245). The experiences of teachers in the cases explored in Chapter 4 suggest

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[7] For other concept-oriented teachers like Kit and Dar, this distinction is specious, as method has become message; specific content is less important for them than how students can think and use the knowledge.

[8] I believe the haphazard nature of students' school experience (something Dar echoed when she mentioned that she'd never been taught *how* to write an essay) is partly what some of the teachers in this study are objecting to when they want to be told what to teach.

that when teachers have a chance to work together, synergy results, yielding exponential growth toward shared understandings of the teaching enterprise. Administrators need to take an active role in fostering these collegial ties by addressing the constraints (time, class size, material shortages, clerical help) which can stymie the efforts of even the most dedicated members of the profession to get together.

Just as the principal in Kit, Dar, and Ben's building used her position to support faculty to experiment with research-based "best practice" recommendations and encouraged a "less is more" approach to content, school leaders need to work toward a unified school commitment which focuses staff development efforts at guided practice with teaching methods aimed at conceptual understanding and support the creation and use of associated materials. By giving teachers real time to plan, encouraging risk-taking by communicating with parents about school goals and methods, infusing information about concept-oriented teaching into the school environment through regularly scheduled faculty meetings, training parents in how to support new pedagogies at home, supporting action research projects showcasing successes and failures in an atmosphere of shared inquiry, and reducing class sizes to reasonable levels, principals can support teacher efforts to analyze and adjust their methods to accommodate concept-oriented teaching -- to develop what Rubin (1989) calls "pedagogical intelligence," rather than express "habits learned with minimal awareness and implemented rigidly as if they were ends in themselves." (Brophy, 1991, p. 351).

Principals could link school and student evaluations to outcomes demonstrating students' conceptual understanding. Proponents for concept-oriented teaching argue for basing evaluation on the *cumulative effects* of a variety of experiences that students have had over their years of schooling, which teachers consciously helped them to connect (Wilson & Wineburg, 1993; Wineburg, 1991). An integrated and shared vision for student performance would be a necessary precursor, based on intentional reinforcement of ideas learned in earlier grades, such as when Kit, synthesizing several years of elementary social studies, had students in the astronomy unit reflect on ways the diverse holidays from different cultures could be celebrated by astronauts from different nations spending time together aboard space stations. A shared language for targeted ideas among both teachers and students would be another, echoing the emphasis in each of cases in this study on developing students' facility with a shared technical vocabulary.

Embedded in the methods of teaching for conceptual understanding is a view of knowledge as evolving, a view now stressed by the teachers in these cases, but not typical of school practice in general. Principals need to help faculty shift the way knowledge has been typically portrayed by school texts -- as static, decontexualized, unilateral, and remote -- toward the nature of knowledge in the "Information Age" -- as rapidly expanding, anchored to real problems, multiplistic, and instantly available. As seen in Chapter 2, one way to do this is through acquiring software which uses concrete images accessible to young thinkers to show how various manipulations of data will result in changes to a given conceptual system. Such programs allow the underlying pattern (concept) to reveal itself readily, permitting speedier accommodation of new patterns of understanding because results are immediate (e.g., Hakerem, et. al., 1993). Integrating such software into teachers' planning could help them help students come to see knowledge as part of integrated larger conceptual systems which can be manipulated or acted upon by the knower in order to solve problems of immediate concern -- a key value of concept oriented teaching.

Collegial Ties

The two principals mentioned in these case studies differed in the amount of encouragement they gave to teacher collaboration, but neither was talked about as specifically making this a schoolwide goal. It should be, given the amount of positive influence colleagues had in developing the PCK of teachers in this study[9] and the negative effects of isolation in limiting its development (as in Ben and Ted's cases). In both Ted and Dar's cases, the administrator with the greatest impact on their development was a department chair. Principals could be certain to invest resources in nurturing the growth of these key players, who are often closer to the teacher and more specialized in their knowledge and interests.

Other initiatives which principals could support to foster collegial ties could include peer supervision, where teachers, at each other's request, come in to observe for particular things, and coaching for concept-oriented teaching. Both could stimulate the exchange of ideas Kit cherished in her job-sharing and Dar yearned for when she moved to a new district.

Critics of teaching for conceptual understanding like to cite the resistance teachers and students offer to new ways of learning. Based on this research and my reading, I see teacher resistance as stemming mainly from a lack of time and support to develop the strategies and materials needed to teach differently. Kit's case, for example, reveals that she wanted to teach differently in her early years, but felt heavily thwarted due to lack of time, file cabinet space, and a room of her own.

O'Keefe and Johnston (1989) cite the importance of organizational and personal support systems in which teachers can think and talk about practice as critical to their growth. Given opportunities to experiment and work together without fear of censure, the teachers in this study created synergy ;[10] but access to professional development and planning time was critical -- something all four teachers struggled to find. Successes happened in spite of their schedules, not because of them. Creating time inevitably means increasing the number of staff, so that more spaces can be created

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[9] e.g., Ted and the high school department chair who introduced him to the Standards; Kit and her elementary school colleagues with whom she co-wrote Eisenhower grants; Dar and Barbara with whom she collaborated on workshop presentations on interdisciplinary design; Dar and Bill who worked together on the W.W.II unit.

[10] e.g., Ted and his colleagues in the earlier grades; Dar and Bill.

within the day for teachers to collaborate. Principals could lobby for this, using research for ammunition, rather than depending on teachers to give up extensive amounts of personal time to rescue schools from business as usual.

Teacher collaboration in these studies was both fruitful and fragile. Dar and Bill, for example, counter-balanced each other; they needed time to acquaint themselves with the other's methods and materials, to figure out and supplement core ideas. But Dar was dependent on Bill's subject matter knowledge; when he was ill, the project lost richness. Along the same lines, Ted's monthly meetings with other teachers in the building were well received, "wonderful" in his words, but they died out because he had competing priorities, and his principal did not pick up on the meetings and help to sustain them. Finding ways to sustain such links could be made an administrative priority.

Dar's collaboration with Barbara was exceptionally growth-producing: It forced her to develop a conceptual understanding of interdisciplinary work, not just to do it, because she had to define and justify what she did for an audience. This was unusual, based on the stories of all eight of the teachers in the original study, as the opportunity to articulate what they do and why is rare. Consequently, most of the teachers interviewed struggled to explain their PCK. All of them expressed surprise that I would find the details of their teaching knowledge interesting, indicating a pronounced need for validation of intuitive insights because teachers typically have no other frame of reference, except the ones they have created, through which to view their work.

Inarticulateness and a hunger for validation are the byproducts of professional isolation; naming experience and comparing it with that of others would begin to undo its effects and go a long way toward establishing a true professional environment. Principals could invite greater reflection among staff by encouraging journal-writing, which makes PCK more visible and more able to be refined; encouraging professional conversations at faculty meetings based on insights gained from such writing and about topics of on-going interest to teachers, including their deep goals for teaching; offering cases of teacher development for teachers to examine together;[11] introducing research articles and encouraging action research projects among faculty -- in effect, transforming the school into a true learning community for students and teachers alike. Teachers would not have to listen through the walls in order to grow.

While logistically challenging, permitting job-shares would be another way principals could foster collegial relationships. Because she has young children, Kit has decided to leave regular teaching rather than return to a full-time job. This is a loss. How many other talented mothers who are also certified teachers are there in the community whose skills lie untapped because schools think they cannot accommodate them? Dar has stayed in teaching in part because her husband is a stay-at-home dad.[12] Principals could advocate for on-site child-care, uniting the generations, providing an arena for grade school students to learn competence and caring while helping mothers to stay in the classroom.

Principals can also encourage collegial ties with teachers in other schools by publicly supporting the kind of initiative Kit showed in using professional days to visit other classrooms and encouraging teachers to talk about what they find. Building on Ted Sizer's ideas,[13] they can develop school partnerships with sister schools in another

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[11] Spiro et. al., argue for case study analysis and cross study comparison as an excellent way to develop transferable knowledge into ill-structured domains, of which teaching can be considered: "Information that will need to be used in a lot of different ways needs to be taught in lots of different ways." (1987, p.188) They suggest an intermediate degree of well-structuredness in cases chosen, so as to produce less randomness, more speed, accuracy, and learning. "Multi-stranded weaves" (i.e., different juxtapositions of cases) vs. a single line of development permit a richer, more complex understanding. In selecting cases, these researchers recommend balancing between unique features and generalities between cases, and alternating between presentations of abstractions where cases are used for illustration and case-centered presentations, where the same abstractions are combined to describe the cases. The more teacher educators know about trends in the ways cases relate, the more ideas they will have about how to approach and represent a particular case. Visual representations of the ways cases connect can greatly aid transfer of knowledge, for, comment these researchers, "[it is] well known that the human perceptual system can represent large amount of highly complex multivariate information at a glance." (Spiro, et. al, 1987)

[12] Ben and Ted both have working wives and intensely busy schedules.

[13] Talk by Ted Sizer, "Good Small Schools for Good Small Communities," in a nearby town,

region, in which clusters of teachers come to learn about and evaluate the products and performances of students in the host school and develop a sustained view of how its system operates to share with colleagues back home.

Mentoring and Teacher Induction

The PCK development of three of the teachers in these cases was *strongly influenced by becoming mentors* for novice teachers. Ben's case shows that even after twenty-five years of teaching, dramatic development is possible when teachers nurture novices.

In conjunction with teacher education programs, principals could help *to coordinate clusters of preservice teachers within a building*, turning the school into a clinical site, where mentors and preservice meet regularly to discuss a wide range of aspects associated with teaching. One aspect, as mentioned above, specifically related to concept-oriented teaching, would be to have both groups clarify their inner models of particular content. Principals, in conjunction with teacher educators, could support mentors reflecting on the ways those models affect the structure of their units and how they do or do not reflect the current structures and controversies within the discipline, by creating time for them to locate and read research. Principals could give mentors permission to model more real world approaches to the way disciplinary scholars actually approach the material. Other topics for discussion could be built off the "strategic sites" Shulman (1986, 1987) and his colleagues located for understanding how teachers add to their PCK: how do mentor teachers teach themselves new material? Work with texts they disagree with? Answers to these questions could be made clearer to novices and to veterans mutually.

May 19, 1997.

Principals could have mentor *teachers analyze their curricula in terms of underlying core concepts* which could help to clarify deep objectives -- something several teachers in this study were only semi-conscious of for a long while. Then they could ask mentors to analyze a particular unit in terms of representations and have them experiment with having their students generate them. Asking students to do this for themselves could potentially clarify points of misunderstanding and solidify current understanding, generate potential future material teachers might find valuable for conveying core ideas to other students down the line, and help teachers refine their own understanding of subtle points in the content.

Some of the research on preservice teacher education indicates a gap between methods universities espouse and those progressive practitioners espouse, indicating a need to bring both groups together in an atmosphere of collegiality and mutual edification (Marsh, 1987). Along with novice and veteran teachers examining problematic, naturally-occurring cases together, they could engage in role play and simulation, which have been recommended for epistemological growth and PCK development (Barnett, 1990; Spiro, et. al. 1989; Lovell, 1993).[14] In this way, schools and universities could appreciate how closer ties could serve them mutually.

Coordinating action research projects between mentors and preservice teachers is another way principals could nurture PCK development in teachers. This could lead

[14] Role-playing may permit less developmentally advanced teachers to appreciate the need for empathy in the learning process (Barak, A., et al, 1987). Arbuthnot (1975) found that college students in an introductory psychology class, who were asked to engage actively in role-playing in the context of a moral dilemma with an opponent of more advanced reasoning level, experienced both short and long term gains in the maturity of their moral judgment, with greater shifts among those who began at lower levels. Thies-Sprinthall (1984) describes a teacher education program aimed at increasing the cognitive flexibility of would-be supervisors, which entailed having participants assume social and professional roles at slightly more complex levels than they were accustomed to, along with sustained and careful reflection via feedback, alternation between doing and reflecting, support and challenge, over a year of weekly meetings. On measures devised by Hunt and Rest, the whole group improved. They found that without structural change (which instruction with a specific developmental focus can bring about), new learnings are quickly washed out, applied randomly, or without real understanding. Generalizing from one skill, concept, or situation to another is hardest for those expressing social conformist ideas (Loevinger), and concrete thinking (Piaget, Hunt) according to Thies-Sprinthall & Sprinthall (1987).

to a view of teaching as "an ongoing inquiry into content and learners, and into ways that contexts can be structured to facilitate the development of learners' understandings." (Ball, 1990, p. 9) Because of the work of researchers like Peterson, Fennema, and Carpenter (1991), professors of mathematics education now know a great deal more about first graders' informal modeling and counting strategies to solve addition and subtraction problems, which appear to develop in clear stages, growing toward greater flexibility and efficiency. This research has articulated differences in problem types and the range of strategies children use with each. Guiding preservice teachers to collect similar data on students' thinking patterns and types of content with other subject areas, as well as what supports and what hinders growth in different learners, could significantly accelerate the development of their PCK and that of their mentors (with unfamiliar material). Making students' thinking patterns and stages of understanding visible to students themselves could allow them to see their own developmental landscape and begin to look at themselves as active constructors of knowledge -- an act of empowerment the teachers in this study came to emphasize and a rich way to prepare future concept-oriented teachers.

While intern teachers had a significant impact on three of the teachers in this study, these teachers also describe the considerable impact their mentor teachers had on them. In studying key participants in a clinical site, DiIorio (1991) has found that, for better or worse, mentor teachers influence novices profoundly, including their sense of students' capabilities. Consequently, intentional mentor training is critical since so much teacher training is left in mentors' hands. Training could include how to lead novices though "What if?" questions to help them test run lesson plans before actually conducting them (mimicking the type of metacognitive activity veterans engage in while planning), how to effectively engage in mutual problem/solving around immediate issues, and provide time to journal about what *they* are learning from the process of being mentors. Dar was particularly emphatic about the importance of good modeling at this early stage in a novice teacher's development and the value of journaling to her development later in her career, when she returned to graduate school.

For principals to gain the maximum benefit from having faculty become mentors, they need to lighten faculty teaching loads, giving mentors time to share their purposes with novices and how they focus material and why, instead of tacking this time-consuming, intellectually challenging job onto the demands of full-time teaching. As students are a powerful source for PCK development, novice and veteran teachers need time to listen to them and to discuss their differing understandings together (O'Keefe and Johnston, 1989). This could increase the likelihood of novice teachers emerging with a better sense of students' needs. They could learn, for example, not to confuse student performance with student ability; that most students are reachable through a multi-modal scaffolded environment; that what teachers do or don't do can make a significant difference in how well students understand; that connecting with what students already know is critical, if they are to remember what was "taught"; that kids think differently from adults and sometimes need content unpacked in idiosyncratic ways.

To expedite professional development, including PCK, principals could support mentoring of first and second year teachers by veterans who understand the different ways students see the world, have had time to read, digest, and test research findings of interest in their own classrooms, and can now share what they've learned.

Curricular Materials

All four teachers in this study *took time away from family and other priorities* to adapt pre-made materials or generate their own to suit their purposes. Anderson and Roth's (1989) research on middle school science teachers found that easy access to concept-oriented teaching materials could make or break a teacher's commitment to teaching conceptually. In the absence of good pre-made materials, principals could channel resources to support their development. By building school archives and creating data bases as suggested above, teachers could begin to establish a ready supply of materials for other teachers to evolve and refine, weaning those like Ben away from too heavy a reliance on "the GD file cabinet." Such resources could also help generate the specific data Brophy (1989) calls for to codify PCK for "all major topics at all grade levels" (p. 350). These, in turn, could help to inform future teachers' manuals in all content areas. As the texts now being generated by the University of Chicago School Mathematics Project do,[15] such data might eventually lead not only to powerful suggestions for instruction and assessment in the teacher's editions of texts, but also to information about students' likely prior knowledge and beliefs and useful multi-modal analogies and representations addressing them.

State and Federal Educational Policy Makers

The experiences of teachers in this study lead to several conclusions for policy makers at the state and federal levels. First, these leaders could recognize that giving teachers a student load of more than eighty students leaves them with inadequate time for reflection and planning, particularly when faced with high percentages of special needs students. Any conversation about improving teacher education has to be done with the recognition that progress cannot take place until there is a reallocation of resources to accomplish this.

Second, the majority of the teachers in this study completed an undergraduate degree before entering a teacher training program. Even with this background in subject matter, they initially lacked the "glue" to help material coalesce, falling back on

[15] available through Scott Foresman/Addison Wesley

weaker structures in available materials which were not tied to larger conceptual frameworks. As Duckworth (1987) has pointed out, most topics (even) in elementary schools are far from obvious. Without a grounding in ways to think deeply about subject matter needed to make the advanced pedagogical decisions to accommodate today's students and the demands of today's curricula, teachers are poorly positioned to be effective. This suggests that policy makers should require a four year degree in the certification area before professional preparation is undertaken. Liberal arts schools, however, following Ben's ideas, should offer pre-teaching coursework which allows interested undergraduates guided research experiences with younger students well before these undergraduates make the decision to pursue further training.

Third, state departments of education could substantially support teaching for conceptual understanding by integrating appropriate outcomes in their assessment "Frameworks" and providing state-wide staff development initiatives oriented in this direction.

Conclusion

The cases in this study are a testimony to teacher growth in environments not intentionally designed to nurture it. What would happen if the development of teachers' PCK for conceptual understanding were an explicit commitment of schools, colleges, and departments of education?

Futurists Land and Jarman (1992) urge change agents to take conscious advantage of the fact that, like the oak encoded in the acorn, we are self-organizing, self-creating beings. Self-organization is an attribute of natural systems which molecular biologists first discovered in their work with cells:

> The ability for natural systems to grow and change in extremely flexible, versatile, and creative ways occurs because no matter what the circumstance, every part of the system shares the same blueprint of the future whole. Through the natural guidance of autopoiesis, complex

> organisms can thrive in rapidly changing and turbulent environments. (p. 174)

In these challenging times, teacher educators, teachers, students, parents, legislators, and administrators might try to mimic the self-organizing nature of complex systems by clearly articulating a shared vision and using its pull as a powerful guide. As Jarman and Land point out, this is easier when we see ourselves and each other as evolving and mutually interdependent. The deep objectives of teaching for conceptual understanding -- learning to listen and co-create with people of different frames of reference -- can foster these perceptions, becoming both means and end.

APPENDIX A

OVERVIEW OF ADULT COGNITIVE DEVELOPMENTAL STAGES RELEVANT TO TEACHERS

Overview of Adult Cognitive Developmental Stages Relevant to Teachers

Piaget (1955) & Arlin (1975)	Kohlberg (1969) & Gilligan (1982)	Hunt (1966)	Kitchener & King (1981)	Perry (1970)	Belenky et. al. (1986)	Schommer (1993b, as cited in Hofer & Pintrich, 1997)	Loevinger (1969)
Space, time, causality	**Moral Development**	**Concept Formation**	**Reflective Judgment**	**Epistem- & Ethics**	**Epistem- ology**	**Epistem-ology**	**Ego/Self Development**
		(A) Knowl. is fixed, concrete	(1) Belief in reality as absolute	(2) Dualists	(2) Received Knowers	Knowl. is absolute, in bits, simple; authorities	(3) Conform- ist
(3) Concrete Operational	(2G) Self- sacrifice to please others (3K) Social Conformity		(2) True reality; false claims				(3/4) Self- Aware Transition
			(3) True reality; false claims, uncertainty	(3) Dualistic view of knowl.; some is temp. unkwn			
	(Transition 2G) Beg. to bal. self concerns w/ others		(4) Reality is given, but unknwble. K is idiosyncratic	(4) Multi- plicity • (a) All have right to their opinions	(3) Subjective Knowers		
	(4K) Authority Maintaining	(B) Awareness of abstrctns; more able to sep. fact, opin, theory	(5) Personal interps of indiv. realities	• (b) Supprted opinions are needed in some sits.	(4) Procedural Knowers • (Connected) • (Separate)		(4) Con- scientious
(4) Formal Operational • Prob. sol. w/deduc. logic	(5K) Social Contract		(6) Reality assumed; Evaluated per- sonal interps.	(5) Context influ. meaning			(4/5) Individualistic Transition
				(6) Self as meaning-makr			(5) Autonomous

Piaget (1955) & Arlin (1975)	Kohlberg (1969) & Gilligan (1982)	Hunt (1966)	Kitchener & King (1981)	Perry (1970)	Belenky et. al. (1986)	Schommer (1990, as cited in Hofer & Pintrich, 1997)	Loevinger (1969)
Space, time, causality	**Moral Dev.**	**Concept Formation**	**Reflective Judgment**	**Epist. & Ethics**	**Epistem- ology**	**Epistem-ology**	**Ego/Self Development**
(5) Problem-finding using creativity, synthesizing	(6K) Individual Principles and Conscience (3G) Morality of non-violence	Self-Directed Abstract	(7) Reality is never "given". Facts and assumptions constructed into eval. knowl. claims re: reality.	(7-9) Committed Relativists	(5) Con-structed Knowers	Knowledge is tentative and evolving, comprised of interrelated concepts, derived from reason	(6) Integrated

Overview of Theories

Space, Time, Causality (Piaget, 1955, as cited in Muuss, 1988; Arlin,1975; notes from G. Weinstein's Soc. Cog. Dev. class, 9/90). In terms of logic: (3) Concrete operational thinking permits performance of mental calculating and the ability to think the reverse of mental actions; to solve problems in a sequence; understand part/whole relationships better; separate physical and psychological causes; but not separate structure from content. (4) Formal operational thinking permits one to deal with abstractions, e.g., can separate form from content; consider more variables in problem/solving; can think about thinking and consider hypothetical and future possibilities. At the inductive stage, can think creatively, i.e., find problems, think laterally, come up new sytheses and original ideas. In terms of interpersonal communication: (3) Conc. op. allows one to take another's point of view; judge between appearance and reality; reason according to rules; cannot think in terms of potential or hypothetical situations. (4) Formal op. can see a range of possible responses to social situations; is capable of becoming self-aware and see the self from others' perspectives now and projected into the future.

Moral Development (Kohlberg, 1969 and Gilligan, 1982, as cited in Muuss, 1988; notes from G. Weinstein's Soc. Cog. Dev. class, Fall 1990). (3K) Conformity to others' expectations: emphasis on affection and approval in the immediate context; (2G) Pleasing others is emphasized, to the exclusion of one's own needs and values. (4K) Conformity to the social order, institutions are authorities which must be obeyed; systemic perspective. (5K) Concern with individual rights and the Democratic process; emphasis on mutuality of consent and rights as they relate to the individual's values. (6K) Universal principles based on equality and reciprocity guide the individual's actions and supersede conventional law; (3G) Ethic of caring involves consideration of which actions would minimize hurt for self and others, equally.

Reflective Judgment (Kitchener & King, 1981, as cited in King & Kitchener, 1985) is concerned with the way young adults and adults come to understand the process of knowing, evaluate knowledge claims, and justify their points of view concerning ill-structured (controversial) problems. Based on Perry's scheme, it tries to look strictly at epistemology (assumptions about knowledge and how one comes to know things), excluding issues of ethics and identity, which Perry also addresses (see below).

Epistemology and Ethics (Perry, 1970 as cited in Perry, 1981) (2) Dualistic thinkers believe that there are True Authorities outside the self, who are Right and Good; non-Authorities are wrong, different, bad. Theory is the embodiment of Truth. Knowledge is considered in terms of quality. (3) Truth still exists, but some things even Good Authorities don't know yet, but someday will. (4) Multiplicity a) Everyone's opinion about uncertain things is equally valid; no system or pattern to them. (4b) Sometimes supporting an opinion about something uncertain is necessary. (5) Context and theory shape interpretation, even for Authorities. Some interpretations are supported with more data than others. Knowledge is qualitative. (6) Amid uncertainty, I have to rely on my own best sense of things to make decisions. Internal sense of agency. (7) I am living with my first major decision; it opens some doors for me and closes others. (8) Balancing the number, depth, and degree of permanence of multiple decisions can be scary and/or hard! (9) The dynamic maintenance of this balance is what life is about.

Epistemology (Belenky, Clinchy, Goldberger & Tarule, 1986; Weinstock, 1989) (2) Received knowers see knowledge as absolute and coming from authorities outside the self; no sense of self except as defined by powerful others. (3) Subjective knowers believe right and wrong are relative to what the individual believes, as long as belief doesn't hurt others; unsubstantiated preference or personal experience are enough to validate one's opinion, which others should respect and vice versa; reject received knowing, while gut knowing is real; expressing one's differences is a good way to let others learn about you and vice versa; conflicts of belief should be avoided; stick to an opinion even in the face of contradictory data; accept, but don't understand differences from their point of view; focus is on the new experience of hearing their own inner voice, which necessitates shutting out others'. (4) Connected Procedural knowers see that different perspectives can be understood within their own contexts and values this for avoiding conflict and knowing the other; can articulate how to see the way another does; and sees that others' views expand their own; don't know themselves well enough to find points of connection between what or who they seek to understand and themselves. (4) Separate Procedural knowers value supporting opinions with facts and arguments; can do this and evaluate the quality of their own and other's arguments; can explain the processes involved in critical thinking; recognize that argumentation and evaluation can affect and even change one's thinking, but keep selves separate from the consequences of these processes (focus on objectivity). (5) Constructed knowers recognize the active and on-going nature of knowledge construction in themselves; they strive for more differentiated understanding of something rather than absolute Truth, using both separate and connected procedures; as they see the impossibility of being totally objective and the lack of health in excluding the subjective, the self is involved in the coming-to-know process; doesn't see truth as separate from the theoretical perspective/socio-historico-political context in which the object of study or person in question is found; tries to integrate a range of viewpoints (including reason, intuition, and the knowledge of experts) without harming the nature of each and sees that the nature of such a synthesis is dependent on which views are synthesized; moves toward "better" (i.e., more differentiated) understanding, recognizing that how one defines "better" is also open to revision. This group strives for a unique and authentic voice, outside conventional definitions of self -- there's a sense of flow between inner and outer worlds. They see the inevitability of conflict and don't allow aspects of themselves to be compromised to avoid it. Are preoccupied with acting on their spirituality.

Epistemological Beliefs (Schommer, 1990, 1993b; Schommer et al., 1992, as cited in Hofer & Pintrich, 1997) Her research "challenged the notion that epistemlogical beliefs were unidimensional and developed in fixed stages." (Hofer & Pintrich, 1997, p.106). Instead she looked at views of knowledge in undergraduates within four distinctions (stated on the naive end): Fixed Ability; Quick Learning; Simple Knowledge; and Certain Knowledge. She was interested in how these distinctions may have influenced students' perceptions of the nature of academic work and found there were correlations between epistemological beliefs, how students approaching studying, and how they performed. Those believing in "quick learning", for example, tended to oversimplify content, be overconfident about performance and tended to score lower on tests; those who subscribed to "Certain Knowing" tended to draw conclusions which were inappropriately absolute. In a study Schommer conducted with high school students (Schommer & dunnell, 1994, as cited in Hofer & Pintrich, 10997), she found that by the end of senior year, gited students were more likely to view knowledge as conceptually interrelated and acquired gradually.

Ego/Self Development (Loevinger, 1969, as cited in Oja, 1989; Loevinger, 1976). Her theory includes aspects of cognitive ability, moral/ethical judgement, conceptual level, and interpersonal behavior. (3) Conformist stage thinking is governed by rules society, the family or peer group condones. Belonging, appearance, social acceptance, and reputation are key issues. Behavior is seen in external and concrete terms; feelings come out in cliches, stereotypes, and judgments. (3/4) Self-Aware Transition stage thinking has a new awareness of possibilities in solving problems. Capacity for introspection is greater, though feelings are still expressed globally; and self-evaluated standards for behavior begin to replace group-sanctioned ones. (4) Conscientious stage thinking is concerned with conscience -- a mixture of achievement, long-term goals, responsibilities, rights, ideals and traits, defined by inner standards. Actions inconsistent with inner standards produce guilt; greater capacity to see exceptions to rules, with increased awareness of individual differences. Feelings, motives and patterns define behavior, rather than simply actions. (4/5) Individualistic Transition stage thinking features greater emphasis on individuality coupled with awareness of dependence on others; more tolerance for paradox; more complex interactions with others. (5) Autonomous thinking copes with apparently contradictory commitments, responsibilities, needs, and perceptions. While recognizing the importance of autonomy for others in making decisions and learning from the consequences, this stage also values mutual inter-dependence. Issues of justice, self-fulfillment, multiple roles, achievement and individuality are at the forefront. (6) Integrated thinking resolves inner conflicts and relinquishes unattainable goals. Consolidates one's identity; is "self-actualized", thus evolving, perceptive, attuned to one's inner life; spontaneous; tolerant of ambiguity; able to be both concrete and abstract; playful; accepting of reality; capable of objectivity and self-transcendence; and democratic (Loevinger, 1976, p. 140).

APPENDIX B

LETTER TO PRINCIPALS

Rebecca Langrall
14 Low Road
XXXXXXXXXXX

Date

XXXXXXX XXXXXX, Principal
IXXXXXXXXXXXXX
XXXXXXXXXXXXX
XXXXXXXXXXXXX

Dear XXXX,

We met several years ago, when I was working for XXXXXXX's Teacher Preparation Program. Having left XXXXXXXXXX to finish my Ed.D. at UMASS, I am writing to ask for your help in locating teachers who might like to participate in my doctoral research.

I am looking for veteran teachers, who are committed to developing students' conceptual understanding. Indicators would include the following: Students of such teachers, regardless of ability level, appear to have a particularly strong understanding of their teacher's curricular goals, have found them meaningful, reach them by and large, and are able to use what they've learned in the pursuit of their own interests. Teachers would use a creative array of approaches to make contact with the way students make meaning, work intentionally with what students already know or think they know, continually analyze students' experiences with content, make on-going adjustments as needed, and, if possible, strive to help students find real world applications for their learning.

My study is small in scope, entailing ethnographic case studies of only eight teachers: Two each in science, math, English, and social studies. It would include three meetings for participating teachers each lasting about 90 minutes each (approx.) and entail taped interviews centered on core concepts teachers have identified and represented in various ways throughout the years, both in a favorite unit and in one most students typically find challenging. My intent would be to conduct interviews this fall and make the case studies available to participating teachers in early spring for their critique.

If you have faculty who come to mind as clearly committed to teaching for conceptual understanding and would consider participating in a study of this kind, I would greatly appreciate your nomination of them. I have enclosed a self-addressed stampled envelope to expedite your response. Please feel free to call XXXXXXX or e-mail XXXXXXXX, if you would like further clarification of any aspect of the study. Thank you kindly.

Sincerely,

Rebecca Langrall

APPENDIX C

FOLLOW-UP LETTER TO TEACHERS

Rebecca Langrall
14 Low Road
XXXXXXXXXXX

XXX XXXXXXX
XXXXXXXXXXXXXXXXX
XXXXXXXXXX, XXXXXX XXXXX

November 30, 1994

Dear XXX,

Thank you for your prompt response to XXX's recommendation. I am delighted that you are interested in participating in my dissertation study.

Enclosed is some general information about the study, indicating its purpose and design. I will call in the next several days to set up the introductory meeting, where we can meet, discuss particulars, and I can collect a bit of biographical data.

In the meantime, if you have questions or need to reach me, my phone number is XXXXXXX. If you have easy access to E-Mail, I can also be reached at: XXXXXXXXXXXXXXXX.

Best regards,

Rebecca Langrall

APPENDIX D

INFORMATION ABOUT THE STUDY FOR PRINCIPALS AND PARTICIPANTS

INFORMATION ABOUT THE STUDY FOR PRINCIPALS AND PARTICIPANTS

Background

Within the last ten years, educational researchers have begun to delineate a concept in the literature on teacher knowledge concerning the way effective teachers transform particular content to reach specific students. Called pedagogical content knowledge (PCK), this concept marks a key distinction between the subject matter expert and the effective classroom teacher. While PCK overlaps with aspects of other teacher knowledge schemes, it differs from them in its subject-specific student-specific focus. Grossman has distilled PCK into four main elements:

- teachers' perceptions of the purpose for teaching particular content, which allow them, in turn, to identify key outcomes;
- awareness of students' prior knowledge and misconceptions of the content, i.e., recognizing what students find hard about the material, as well as accommodating individual needs, including particular learning strengths, interests, and backgrounds;
- curricular knowledge, allowing teachers to identify the materials best suited to address key outcomes;
- and knowledge of instructional strategies, which includes subject-specific representations of main ideas, through metaphor, examples, demonstrations, illustrations, and models

Recent research into pedagogical content knowledge tentatively suggests that, rather than simply a third knowledge domain which integrates content and pedagogy, PCK is more fruitfully approached as a developmental process ('pedagogical content knowing'), in which merging content and pedagogy over time, in response to perceived learner needs, results in qualitative transformations of the teacher's understanding of both content and pedagogy. This process intrigues me because little has been written concerning the stages of such development and possible attending influences.

This Study

My research would focus on one facet of PCK, instructional representations -- those concrete models, analogies, and metaphors teachers use to convey key concepts in particular units of study. Other aspects of PCK would be used mainly as a source of analytic categories for understanding the evolution of a teacher's choice of representations. Teacher-made, student-made, and commercially produced approaches could all come into play.

The design entails:

- Eight ethnographic case studies of teachers, some whose work I have known and admired as exemplary in the area of teaching for conceptual understanding, as well as others who have been nominated by their principals for the same reasons: Two each from math, science, English, and social studies; four at the middle school level, four at the high school.

• One introductory meeting during which I collect biographical data, clarify remaining questions about the study, and set up the first semi-structured interview.

• Two classroom observations which will be audio-taped.

• Two sets of semi-structured interviews of approximately 90 minutes each, focusing on instructional representations the teacher has used to convey core concepts over the years, within two units of study.

• In preparation for the interviews, participants spending some time browsing through files, unearthing earlier versions of each unit, if possible, to jog memories of changes made (including what teachers define as 'core ideas', as well as how those ideas may have been represented) and the various reasons for such changes.

• An eventual review and critique by each participant of the patterns I have been able to see within that teacher's PCK development, with particular emphasis on instructional representations.

Benefits For Participants

1) An opportunity to reflect on patterns in your professional knowledge development in such a way that they become more explicit and therefore more available for further development.

2) Copies of interview transcripts and logs, from which you could publish articles and/or curricular materials that might provide the basis for workshops in preservice and inservice teacher education.

3) Using with me as a possible resource for locating information and materials of particular use to you.

4) A summary of findings from the research conducted with members of the study detailing patterns, if any, within and across content areas, and within and across grade levels.

5) Fulfillment of staff development requirements in your professional growth plan through 'exploratory activities'.

Benefits For Others

Your participation in this study could:

1) Expand the availability of 'practitioners' wisdom' to prospective teachers, thus expediting their understanding of the distinction between subject matter expertise and what is involved in transforming it for learners. This, in turn, could help to achieve a variety of outcomes, among them lower attrition rates from frustrated underprepared teachers and better instructional practices resulting in some of the student outcomes many reformers find valuable.

2) Add the voices of excellent teachers (and thoughtful students) to the growing body of useful qualitative research in education, thus promoting the image of teachers as professionals who must exercise expert judgment in complex environments.

3) Reduce the isolation and resulting inefficiency which often curtail teacher growth by providing stories for inservice teacher development of insights that are often undervalued as not generalizable and therefore remain unpreserved.

4) Provide insights into those influences most linked to the development of teachers' PCK, for use by administrators and teacher educators to create nourishing environments for teacher learning.

APPENDIX E

AGREEMENT WITH PARTICIPANTS

AGREEMENT WITH PARTICIPANTS

In connection with the research project CASE STUDIES OF THE PEDAGOGICAL CONTENT KNOWLEDGE DEVELOPMENT OF CONCEPT-ORIENTED TEACHERS conducted by REBECCA LANGRALL, a doctoral candidate at the University of Massachusetts, I understand that this project entails case studies of eight veteran teachers. The purpose is to explore patterns of development of teachers' pedagogical content knowledge as seen in the way instructional representations have been used to convey core ideas in a selected unit of study. I understand that there may be a direct benefit for me in that I may clarify my understanding of my own development through my participation in the project. There may also be some indirect benefits in that the findings of the project may enable teacher educators to improve the design of both preservice and inservice courses of teacher education. It has been made clear to me by REBECCA LANGRALL that my participation will involve one introductory meeting, an additional minimum of three hours of interviews, two classroom observations, and a critique of the findings relevant to my case, if I volunteer as a participant. I understand that in accordance with the regulations concerning research conducted with human subjects at the University of Massachusetts, that no financial remuneration or claims may be made on REBECCA LANGRALL or the University of Massachusetts for any reason connected to this study. I further understand that:

a) my participation is voluntary and I may withdraw at any time;

b) any information by which I could be identified will not be revealed to any other person without my express consent in writing;

c) information that I share with the researcher may be withdrawn at any time, up to one week after the final interview;

c) all information will be treated with respect, and that pseudonyms will be used in any written reports to ensure my anonymity;

d) I can decide not to answer any question, or not to volunteer information on any topic, without giving a reason;

e) progressive and final findings and interpretations will be reported to me if I so wish;

f) findings will be disseminated in the form of the doctoral dissertation and possible associated publications, such as books and articles;

g) the researcher will explain the research process to me, if I so wish.

I am willing to be a participant in this study.

PROJECT PARTICIPANT RESEARCHER

DATE

APPENDIX F

QUESTIONS FOR THE FIRST INTERVIEW: PERSONAL AND PROFESSIONAL HISTORY

QUESTIONS FOR THE FIRST INTERVIEW: PERSONAL AND PROFESSIONAL HISTORY

1. Personal History
    - Age, birth order, parent now?
    - Travel/other languages?
    - Why teaching? (Any high points or formative experiences as a student?)
    - Amount of exposure to kids before teaching?
    - Amount of education/professional training?
    - Number of years teaching? What keeps you going?
    - Other background you consider important to mention?
    - (Social identities: Race, class, gender, nationality, religious affiliation, political commitments, community in which you teach....)

2. Self-Knowledge
    - What connections (if any) do you see between yourself as a learner and the way that you approach your teaching?
    - What do you see as your strengths and weaknesses as a teacher?
    - What do your students often say about your classes?

3. Major goals or outcomes for students in your classes
    - What do you hope students will use from your classes ten years from now?
    - What's hard about any of this? Easy?

4. Content Area
    - Why did you pick it?
    - What was your training in your content area like?
    - Have you learned more about your content area, per se, since college? What areas? Why? How?
    - How have your intellectual constructions of your content area changed since college? Why?

5. Professional Training
    - What stood out in your teacher training?
        - Philosophy in your pre-prac. course work? *(Transmission, pedagogy, critical rationality)*
        - What was your practicum like? CT? Supervisor?
        - Stages of growth or turning points?
    - What would be your conception of quality teacher education in your content area?
        - What metaphor would you use to best describe the role of the teacher: Guru,

caddy, tour guide, other?

6. Teaching History
    - As a beginning tchr., how did you construct and use academic and pedagogic knowledge to plan lessons and units? And now?
    - How did you develop criteria for the selection and organization of content? And now?
    - What were your assumptions about who can learn, when you first started teaching? What are they today?
    - How did you used to deal with the increasing pressures of coverage? And today?
    - Did multicultural and social-class realities enter into your planning and teaching when you first started? Now?
    - Have your conceptions of more thoughtful and less thoughtful lessons changed from when you first started teaching? If so, how?
    - What's your definition of a teachable moment? Has this changed since you first started teaching?

Thank you very much for your time.

Set date for second interview and discuss the need to prepare by browsing through files to review the history of versions of a favorite unit and one students typically find challenging. Secure permission to xerox various versions of units.

APPENDIX G

QUESTIONS FOR THE SECOND INTERVIEW: REFLECTING ON THE HISTORY OF A UNIT OF STUDY

QUESTIONS FOR THE SECOND INTERVIEW: REFLECTING ON THE HISTORY OF A UNIT OF STUDY

PRELIMINARY

a. How were the content and objectives for this unit selected at first and now?

b. What were some of the core concepts in this unit when first taught? Have these changed over time?

c. What is your subject matter background relative to the content and concepts in this unit, now and when you first started teaching the unit?

ORGANIZATION

a. What were your goals for the unit at first? Have these changed over time?

b. How had you started the unit? Now?

c. In teaching this material, what modes or models of teaching/learning did you favor at first? Have these changed over time?

d. What kinds of questions did you raise in the unit? Have these changed over the years?

e. What kinds of student activities did you stress when having students learn this material? Have these changed over the years?

f. Have you made changes to the sequence of activities over the years?

REPRESENTATION

a. What ways -- favorite analogies,metaphors, examples, diagrams, simulations, demonstrations and explanations -- have you used over the years to represent key ideas?

b. Where have these representations come from?

EVALUATION

a. How have you checked in with students' understanding during the unit now and during earlier versions?

b. How have you ended the unit now and in the past?

c. What types of assessment have you used?

d. After teaching a unit, do you self-evaluate? Reflect on the outcome of a unit? Have there been new insights or ahas, not mentioned above, which you have woven into subsequent versions of this material?

e. Are there other aspects of the process of unit revision not mentioned above that should be addressed?

Thank you for taking the time to reflect on these questions.

APPENDIX H

QUESTIONS FOR THE THIRD INTERVIEW: ADAPTATION TO STUDENT CHARACTERISTICS AND INSTRUCTIONAL REPRESENTATIONS

QUESTIONS FOR THE THIRD INTERVIEW: ADAPTATION TO STUDENT CHARACTERISTICS AND INSTRUCTIONAL REPRESENTATIONS

a. How much have you needed to tailor intruction to individuals? Since you first began teaching this material, have these kinds of demands changed much?

b. Which among the core goals[1] in this unit are hardest for many students to reach? Do you find particular misconceptions or error patterns that students bring to this material? Have these changed much over the years?

c. Research has suggested that some teachers use rules to help them match appropriate instructional strategies with specific student misconceptions. Have you found this to be true for you?

d. What are some breakthrough stories that you can tell about students who struggled and eventually reached the goals associated with this material? What seemed to help them most?

e. What accounts for some students reaching these goals more readily than others? Has this been the case pretty much from the start of your experience with teaching this material?

---

[1] Goals may be cognitive (concepts, processes) or affective (attitudes).

INSTRUCTIONAL REPRESENTATIONS

GENERAL

a. What are the sources of the representations (metaphors, models, analogies, simulations, explanations) you have used in various versions of this unit?

b. Are the core goals I have named complete and correct?

c. Are the ways I have indicated that they have been represented in different versions of the unit complete and correct?

d. Are there differences in the way you use representations now vs. in the past?

e. What have you learned while using these representations?

FOR EACH REPRESENTATION

Please think about whether and how much influence the following have had on your choice of instructional representations:

Student-Related

1) Nature of experience (prior knowledge) students bring to the core concept, process, or attitude being represented

2) The number of students involved

3) The degree of active involvement of students;

4) Student's idea

Teacher-Related

1) Teacher's subject matter knowledge

2) Teacher's preference

3) Idea of a colleague or student teacher

4) Came from a staff development experience

5) Change in your understanding of your objectives

Content-Related

1) Change in choice of core concepts, processes, attitudes

2) Shift in the defining characteristic of the core concept, process, or attitude (e.g., in defining a circle, attending to the curved edge, rather than the center as the salient attribute)

3) Shift in the epistemological assumptions embedded in the representation (e.g., away from a notion of the concept, process, or attitude as a priori and fixed to a notion of it as constructed and evolving...)

4) Amount of content integrated

5) The organizational structure of the representation (e.g., list, frame of reference, subordination, part/whole, climactic, cause-effect, comparison, compare-contrast, chronological, flow chart, systemic interdependence)

Pedagogy-Related

1) Range of modes used within the representation (auditory, kinesthetic, tactile, visual)

2) Range of intelligences invoked (verbal, mathematical,

spatial, interpersonal, intrapersonal, artistic, musical)

3) Representations consistent with what is now known about how students typically acquire the concept in question, in particular, and how students learn, in general.

4) Degree to which the representation/core idea is linked with other school learning and to students' prior knowledge.

Context-Related

1) Class-size

2) Class composition

3) Nature of the room, furniture

4) Availability of resources (time, money, curricular materials, computer equipment, experts, community, etc.)

5) Other influences on choice or opportunity to use (scheduling, staff development, TV...)

6) Sensitivity to multicultural and social class realities?

7) Moral considerations?

Other Influences?

APPENDIX I

NCTM SUMMARY OF CHANGES IN CONTENT AND EMPHASIS IN 5-8 MATHEMATICS

♦ ♦ ♦ ♦ ♦ ♦ ♦

SUMMARY OF CHANGES IN CONTENT

INCREASED ATTENTION

PROBLEM SOLVING
- Pursuing open-ended problems and extended problem-solving projec
- Investigating and formulating questions from problem situations
- Representing situations verbally, numerically, graphically, geometrically, or symbolically

COMMUNICATION
- Discussing, writing, reading, and listening to mathematical ideas

REASONING
- Reasoning in spatial contexts
- Reasoning with proportions
- Reasoning from graphs
- Reasoning inductively and deductively

CONNECTIONS
- Connecting mathematics to other subjects and to the world outside the classroom
- Connecting topics within mathematics
- Applying mathematics

NUMBER/OPERATIONS/COMPUTATION
- Developing number sense
- Developing operation sense
- Creating algorithms and procedures
- Using estimation both in solving problems and in checking the reasonableness of results
- Exploring relationships among representations of, and operations on, whole numbers, fractions, decimals, integers, and rational numbers
- Developing an understanding of ratio, proportion, and percent

PATTERNS AND FUNCTIONS
- Identifying and using functional relationships
- Developing and using tables, graphs, and rules to describe situations
- Interpreting among different mathematical representations

ALGEBRA
- Developing an understanding of variables, expressions, and equations
- Using a variety of methods to solve linear equations and informally investigate inequalities and nonlinear equations

STATISTICS
- Using statistical methods to describe, analyze, evaluate, and make decisions

PROBABILITY
- Creating experimental and theoretical models of situations involving probabilities

GEOMETRY
- Developing an understanding of geometric objects and relationships
- Using geometry in solving problems

continued on p. 7

DECREASED ATTENTION

PROBLEM SOLVING
- Practicing routine, one-step problems
- Practicing problems categorized by types (e.g., coin problems, age problems)

COMMUNICATION
- Doing fill-in-the-blank worksheets
- Answering questions that require only yes, no, or a number as responses

REASONING
- Relying on outside authority (teacher or an answer key)

CONNECTIONS
- Learning isolated topics
- Developing skills out of context

NUMBER/OPERATIONS/COMPUTATION
- Memorizing rules and algorithms
- Practicing tedious paper-and-pencil computations
- Finding exact forms of answers
- Memorizing procedures, such as cross-multiplication, without understanding
- Practicing rounding numbers out of context

PATTERNS AND FUNCTIONS
- Topics seldom in the current curriculum

ALGEBRA
- Manipulating symbols
- Memorizing procedures and drilling on equation solving

STATISTICS
- Memorizing formulas

PROBABILITY
- Memorizing formulas

GEOMETRY
- Memorizing geometric vocabulary
- Memorizing facts and relationships

continued on p. 73

SUMMARY OF CHANGES—*continued*

INCREASED ATTENTION

MEASUREMENT
- Estimating and using measurement to solve problems

INSTRUCTIONAL PRACTICES
- Actively involving students individually and in groups in exploring, conjecturing, analyzing, and applying mathematics in both a mathematical and a real-world context
- Using appropriate technology for computation and exploration
- Using concrete materials
- Being a facilitator of learning
- Assessing learning as an integral part of instruction

DECREASED ATTENTION

MEASUREMENT
- Memorizing and manipulating formulas
- Converting within and between measurement systems

INSTRUCTIONAL PRACTICES
- Teaching computations out of context
- Drilling on paper-and-pencil algorithms
- Teaching topics in isolation
- Stressing memorization
- Being the dispenser of knowledge
- Testing for the sole purpose of assigning grades

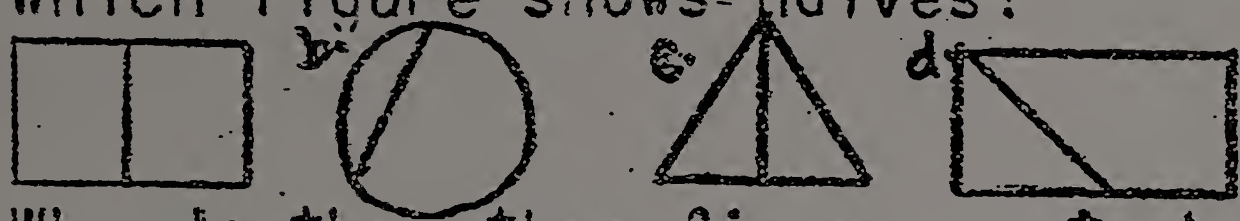
APPENDIX J

FRACTIONS!!!

Name ______________________ FRACTIONS!!!!!

1. Which figure shows halves?

a. b. c. d.



2. Why do the other figures not show halves

3. Which figure shows fourths? Why?

a. b. c.

4. a Show how many different ways you can divide a square into 4 equal parts. (3 ways)

b. Shade in one part of each square.

5. What fraction is each part of the whole?

6. Show how many different ways can you divide a square into 8 equal parts? (3 ways

APPENDIX K

EQUIVALENT FRACTIONS

Part of IMS days

EQUIVALENT FRACTIONS

Take six pieces of scrap paper, and design your fraction kit. On each piece, you will draw a 6 inch square. Then you will proceed as follows:

	Color	Fraction Name	Instructions
1.	Red	One Whole	None
2.	Black	Two Halves	label dimensions
3.	Dark Green	Three Thirds	label dimensions
4.	Brown	Four Fourths	do in strips label dimensions
5.	Blue	Six Sixths	use thirds to begin label dimensions
6.	Orange	Eight Eighths	use fourths to begin label dimensions
7.	Light Greens	Twelve Twelfths	use fourths & thirds label dimensions

Use your kits and find the following EQUIVALENT FRACTIONS.

1. How many brown parts equal one black part? __________

   Write the equivalent fraction that shows this. =

2. How many brown parts equal the red whole? _______

   Write the equivalent fraction that shows this. =

3. How many light greens equal one brown? _______

   Write the equivalent fraction that shows this. =

Write equivalent fractions for each of the following:

1. The number of blue parts that equal one dark green. =
2. The number of blue parts that equal two dark greens. =
3. The number of light greens that equal one black. =

Make up some of your own equivalent fractions using your kits. Tell how many of what color, and write the equivalent fraction.

1.

2.

3.

APPENDIX L

STOCK MARKET FOLDER DIRECTIONS

STOCK MARKET FOLDER DIRECTIONS

COVER- Design your folder cover with a Stock Market theme. Grade will be determined by creativity, neatness, and eye appeal. (15)

CHART OF CLASS PORTFOLIO - Complete your chart according to the weekly price of each company. Calculate weekly values including total for the week, gains or losses for the week, and gains or losses for the contest. Grade will be determined by neatness, readability, and accuracy. (15)

CIRCLE GRAPH OF COMPOSITION OF CLASS PORTFOLIO -Complete your graph according to the amount your class invested in each of the companies in your portfolio. To determine how many degrees of the circle each company represents, use the following formula: multiply the amount you invested in each company by 360, and divide the product by 10,000. Make a rough draft chart showing these quotients, and find their sum to be sure it equals 360. Using a proper protractor, draw a circle appropriately centered on a blank sheet of white paper. Draw a radius from the centerpoint of this circle to the "twelve o'clock" point. Beginning from this radius and moving in a clockwise direction, lay out each of your individual companies according to the rough draft chart above. Lay them out in the same order in which they appear on your CLASS PORTFOLIO CHART. Grade will be determined by neatness, coloring, accuracy, proper and complete labeling, lettering, and summary statement. (15)

LINE GRAPH OF INDIVIDUAL COMPANY WEEKLY VALUE- Complete your graph according to the weekly value of your company's stock. Grade will be determined by neatness, readability, lettering, accuracy, and proper and complete labeling information.(15)

BAR GRAPH COMPARING CLASS INDIVIDUAL COMPANY PERFORMANCE- Complete your graph according to the gains and losses for each of your class's individual company performance. Determine the gain or loss for each company. Determine the range of values (gains/losses) which will need to be shown on the vertical axis. Lay out the vertical axis with $0 (zero) as its centerpoint. Label the vertical axis as appropriate. Draw the horizontal axis across from this centerpoint. Plan the layout so that your class companies are evenly spaced along this axis. Draw the appropriate bars for each of the companies. Grade will be determined by neatness, accuracy, lettering, proper and complete labeling information, and following directions.(15)

LINE GRAPH COMPARING PORTFOLIO PERFORMANCE OF FOUR CLASSES-Complete your graph according to the weekly value of each sixth grade class's portfolio. Grade will be determined by neatness, readability, accuracy, lettering, and proper and complete labeling information. (15)

STOCK MARKET PROBLEM SOLVING- Considering all the information you have, which of your portfolio companies do you wish your class had invested all of their $10,000? If you had invested all of your $10,000 in this company, how much profit would you have made? Conversely, which company are you most glad not to have invested all $10,000 in, and how much of a loss would you have suffered? Finally, what is the difference between these two amounts? Grade will be determined by neatness, labeling, completeness of process, and accuracy. (15)

APPENDIX M

STOCK MARKET QUIZ

Stock Market Quiz

Name. ______

Place The following fractions in order from low to high, and convert each to its decimal equivalent. $\frac{1}{2} * \frac{3}{4} * \frac{1}{8} * \frac{3}{8} * \frac{1}{4} * \frac{7}{8} * \frac{5}{8}$

Fractions		Decimal Equivalents
____	=	______
____	=	______
____	=	______
____	=	______
____	=	______
____	=	______
____	=	______

When you record your stock's price on your chart, you notice it has gone up \$1.00 since your last entry. When you check The newspaper, it says The stock went down \$.50. Please explain how This can be.

Would you raTher invest \$10,000 in a stock priced at \$100.00 per share, knowing it will go up \$5.00 to \$105.00, or in a stock priced at \$5.00 per share, knowing it will go up to \$6.00? Please explain your reasons for your choice.

How many shares of a company priced at \$31.25 can you buy with \$1,616.00? Please show your work.

APPENDIX N

VALUE-BASED EQUIVALENT FRACTIONS

Value-based Equivalent fractions   Name: ___ ___ ___

What fraction of a dollar does a penny represent? ________

- a nickel? ________
- a dime? ________
- a quarter? ________
- a half dollar? ________

Use these fractions to answers these questions:

$\frac{10}{100} = \frac{?}{20}$ In other words, Ten pennies equals how many nickels? (   )

So.... $\frac{10}{100} = \frac{2}{20}$

$\frac{30}{100} = \frac{?}{10}$ In other words, 30 pennies equals how many dimes? (   )

So .... $\frac{30}{100} = \frac{}{10}$

$\frac{1}{5} = \frac{}{100}$: $\frac{3}{20} = \frac{}{100}$: $\frac{3}{4} = \frac{}{20}$: $\frac{4}{10} = \frac{}{20}$: $\frac{16}{20} = \frac{}{10}$: $\frac{5}{20} = \frac{}{4}$

Ma up five more (different) equivalencies of your own:

___ = ___ : ___ = ___ : ___ = ___ : ___ = ___ : ___ = ___

to The nearest tenth of a centimeter (mm), measure or calculate the following

	diameter	circumference	value/diameter
penny	______ mm	______ mm	______
nickel	______ mm	______ mm	______
dime	______ mm	______ mm	______
quarter	______ mm	______ mm	______
halfdollar	______ mm	______ mm	______

J... put a one dollar bill in the change machine. It returned quarter(s); dime(s) and nickel(s). Please calculate a possible mix of all 3 coins.

______ quarter(s) + ______ dime(s) + ______ nickel(s) = 1 dollar

NOW SHOW THIS AS A NUMBER SENTENCE ADDING UNLIKE FRACTIONS

APPENDIX O

PROBLEMS TO EXTEND AND ASSESS STUDENTS' UNDERSTANDING OF FRACTION CONCEPTS

Use for advanced

Problems to Extend and Assess Students' Understanding of Fraction Concepts

1) A box of firecrackers is 1/8 duds. There are 120 more good firecrackers than duds. How many duds are in the box?

2) We see that 3/5 of the children in the room are girls. We also note that if we double the number of boys and then add six more girls to the class, then there will be an equal number of boys and girls. How many children are in the room at the outset?

3) A car starts on a trip from city A to city B which is 120 miles away. It runs out of gas after it has gone one-third of the second half of the trip. How many miles still remain on the trip to city B?

4) Each morning Tammy walks to school. At one-third of the way she passes a grocery store and halfway to school she passes a bicycle shop. At the grocery store, her watch says 8:20 and at the bicycle shop it says 8:26. When does Tammy reach her school?

5) A fruit juice drink is 5/8 water and 3/10 fruit juice, by weight. Other additives (primarily sugar) make up what fraction of its weight?

6) A manufacturing plant requires lengths of wire which are 3 3/4 inches long. If the wire comes in 48 inch coils, how many 3 3/4 inch segments can be made from one coil, and how much wire is wasted? If your alternative lengths were: 60" and 72", would either of these result in less waste than purchasing 48" coils?

7) A person has 22 1/2 yards of material. If it takes 3/4 of a yard of material to make a pair of shorts, can the person make enough shorts for 30 children

8) A small office purchases bottled drinking water. The water comes in containers that hold 6 3/4 liters. (A liter is slightly more than one quart, which is 32 ounces.) Two-thirds of the office container was drained last week to put out a fire in the waste basket. How many liters of water are left in the bottle? How many 3/8 liter glasses can be filled with the water that remains in the container?

9) If the numerator and the denominator of a fraction are increased by the same amount, is the new fraction greater than, equal to, or less than the original fraction? Justify your answer. Read this problem carefully; it is not a trick problem, but you need to make sure you interpret the wording correctly.

10) The oil bill for a group house has just come in the mail. The bill is for the months of January and February. However, there is a problem. Four people lived in the house during January and a fifth person moved in on February 1st. Assuming that the same amount of heat was used each month, what fraction of the bill should each person pay?

Group PS challenges for the team (w/ fractions)

APPENDIX P

"BIRDHOUSE"

<u>two</u> pc^s of wood, added together:

$$16\tfrac{1}{2} + 9\tfrac{7}{8} = ?$$

"BIRDHOUSE"

Step. 1 ~ $16 + 9 = 25$

2 ~ $25 + \tfrac{1}{2} = 25\tfrac{1}{2}$

3 ~ $25\tfrac{1}{2} + 1 = 26\tfrac{1}{2}$

4 ~ $26\tfrac{1}{2} - \tfrac{1}{8} = 26\tfrac{4}{8} - \tfrac{1}{8}$

5 ~ $26\tfrac{4}{8} - \tfrac{1}{8} = 26\tfrac{3}{8}$

- This procedure he constructed in about 60 seconds
- Can you imagine his confusion if he should be asked to find the "lowest common multiple of the denominators, and then later in the classic algorithm to rename the improper fraction result to a new mixed number?

APPENDIX Q

FRACTION EQUIVALENTS

7

Fraction Equivalents

use pictures from P.④ or draw your own if necessary. P⑥ should give you a clue as to how to do these without pictures.

Fill in the blanks with the correct numbers:

$\frac{1}{2} = \frac{4}{8}$	$\frac{5}{6} = \frac{\quad}{12}$	$\frac{5}{6} = \frac{\quad}{18}$	$\frac{3}{4} = \frac{\quad}{8}$
$\frac{3}{6} = \frac{\quad}{2}$	$\frac{4}{3} = \frac{\quad}{12}$	$\frac{1}{2} = \frac{\quad}{6}$	$\frac{4}{3} = \frac{\quad}{9}$
$\frac{2}{3} = \frac{\quad}{9}$	$\frac{4}{8} = \frac{\quad}{2}$	$\frac{\quad}{20} = \frac{4}{5}$	$\frac{7}{8} = \frac{\quad}{16}$
$\frac{3}{2} = \frac{\quad}{8}$	$\frac{1}{2} = \frac{\quad}{20}$	$\frac{5}{10} = \frac{\quad}{2}$	$\frac{1}{2} = \frac{\quad}{4}$
$\frac{7}{8} = \frac{\quad}{24}$	$\frac{\quad}{12} = \frac{3}{4}$	$\frac{1}{3} = \frac{\quad}{9}$	$\frac{2}{3} = \frac{\quad}{12}$
$\frac{1}{2} = \frac{\quad}{10}$	$\frac{6}{7} = \frac{\quad}{14}$	$\frac{\quad}{15} = \frac{2}{3}$	$\frac{\quad}{4} = \frac{3}{2}$
$\frac{5}{9} = \frac{\quad}{18}$	$\frac{1}{2} = \frac{\quad}{16}$	$\frac{2}{4} = \frac{\quad}{2}$	$\frac{8}{16} = \frac{\quad}{2}$
$\frac{\quad}{16} = \frac{3}{4}$	$\frac{2}{3} = \frac{\quad}{6}$	$\frac{4}{3} = \frac{\quad}{6}$	$\frac{1}{3} = \frac{\quad}{12}$
$\frac{2}{3} = \frac{\quad}{18}$	$\frac{2}{5} = \frac{\quad}{15}$	$\frac{7}{3} = \frac{\quad}{12}$	$\frac{\quad}{24} = \frac{1}{6}$

Express as 24ths:

$\frac{1}{3} =$ $\qquad \frac{3}{4} =$ $\qquad \frac{5}{6} =$ $\qquad \frac{3}{8} =$ $\qquad \frac{5}{12} =$ $\qquad \frac{7}{8} =$

APPENDIX R

MINERAL TEST

Name:

Period: **Date:**

MINERAL TEST
"An Afternoon with Dave Diamond and Amee Thyst"

DIRECTIONS: There are six questions which are numbered and underlined in the text. All six must be answered in complete sentences, except for the chart in question #5. All writing and drawing should be on a separate sheet of paper. Staple the test to the BACK of the test answers please. Good Luck!!

Amee Thyst was on her way to visit her college boyfriend at his dormatory, when she stubbed her cowboy-booted toe on a hard substance and fell. After dusting herself off, Amee went back to take a closer look at the offending substance, and decided to ask her boyfriend, Dave Diamond, a geology major, about it.

"That's the mineral, quartz," he said, running his fingernail across the milky white crystals, "not a rock at all."

"How do you know?" queried Amee.

1. **Define what is a mineral for Amee and tell her why it is a mineral and not a rock.**

"So what are minerals used for, anyway, Dave?" asks Amee.

2. **Name three or more uses for minerals.**

"So," continues Amee, "tell me more about these tests or properties to help identify minerals."

3. "Okay." Dave begins to **name and explain at least 7 tests that anyone can perform or observe to help identify minerals**.

"Neato!" exclaims Amee. "You say anybody can do these tests? What kinds of materials do I need to identify minerals? What materials go with which tests? And you say these are all items found in anybody's kitchen??"

4. Dave **names more than 5 items that he just happens to have on his body or in his room which he could use to identify minerals. He also clearly explains what property each item helps test.**

"So, Amee, let me see how well you listened to me," says Dave. "Pretend you have a mineral in front of you to identify.

5. **Design a chart that could be used to organize the data necessary to identify the mineral." (Please use a ruler, Folks, and list at least 6 mineral properties in addition to the column entitled Mineral Name).**

Amee succeeds beautifully by drawing her chart in the frost of the room's window. "Good job, Amee! Now lets talk chemistry," states Dave with genuine admiration in his voice.

Amee Thyst moves closer to Dave Diamond, batting her eyelashes as she looks coyly up at his handsome features. "Err humpff," Dave clears his throat. "Not that kind of chemistry, Amee, but the kind on the Periodic Chart on my wall. See here." Dave points to a chart with colorful pictures of the elements that was a replica of one that hung in his favorite science teacher's room years ago. "An atom is made up of 3 basic parts. Do you know what they are, Amee?"

Amee, a pre-med major, replies, "Of course. In fact, in addition to

6. **identifying the three parts**, I'll also **give you their charges and tell you whether the parts are in the nucleus or in orbit around the nucleus. And I'll even draw you a picture for *extra credit*."** She smiles slyly.

Dave is impressed with Amee's answers. He tosses his arm around her shoulders and whispers in her ear, "Let's go get a tofu burger with sprouts for lunch at Collis." And off they go on their matching mountain bikes 'til another test time.

The End

APPENDIX S

SCORING RUBRIC FOR OCEAN PRESENTATIONS

Scoring rubric for OCEAN presentations

Topic presented:______________________________

Group Presenting:______________________________

Scored by:______________________________

	poor				excel
Speakers can be heard by everyone in the audience		1	2	3	4
Speakers show enthusiasm and interest in topic		1	2	3	4
Introduction is clear and catchy	1	2	3	4	
It is clear speakers know topic		1	2	3	4
Support and details are given to main ideas		1	2	3	4

What were the main ideas? ______________________________

____

____

Poster(s) are creative, attractive, can be seen by all	1	2	3	4
Speakers make eye contact throughout presentation	1	2	3	4
Everyone speaks and participates	1	2	3	4
Presentation is organized and well-planned, smooth	1	2	3	4
Presentation is creative, interesting and humorous	1	2	3	4
There is a concluding statement/ summary	1	2	3	4
Presentation stays within time limit (15 - 45 minutes)				
Demonstration/ activity increases understanding of topic	1	2	3	4
Quality of handout or notes	1	2	3	4
Quality of other visual aids______________	1	2	3	4

Is there a Homework assignment ? yes / no

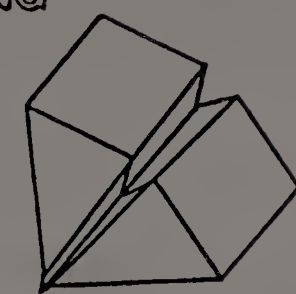
Praise

Comments/ recommendations

APPENDIX T

EXPERIMENT 1: MOVING ALONG
EXPERIMENT 2: SPIN STABILITY

EXPERIMENT 1: MOVING ALONG



Make a standard airplane. Fly it forward. Fly it backward. Is there a difference? Make a runway for your plane. Is it hard to land the plane accurately? Try to make a plane that spins and one that does loops. Discover how wing flaps make a plane turn.

1. Will a standard paper airplane soar as well as it does on earth?

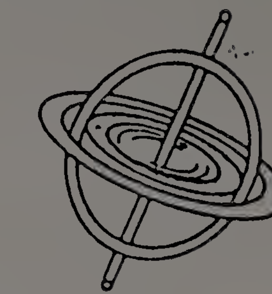
2. Can a paper airplane be flown as well backward as forward?

3. How will a paper airplane behave when released with no push?

4. What will happen to a paper airplane when it reaches a wall?

5. Can a paper airplane be thrown so that it makes a loop?

EXPERIMENT 2: SPIN STABILITY



Start a gyroscope or top spinning. Try to tilt its spin axis. What happens? Push a spinning gyroscope or top with a string. How does it move? Try balancing a gyroscope on your finger, on a string, or on another spinning gyroscope. What happens? Watch a top or gyroscope slow down. What happens to the spin axis?

1. Will a spinning gyroscope or top spin faster or longer?

2. Will a spinning object wobble as it slows down?

3. Will a spinning object move along a string?

4. If a spinning gyroscope is swing around in circles by an attached string, how will its axis orient?

5. Will it be possible to start a push knob top?

APPENDIX U

PLANET TRAVEL BROCHURE OR ALIEN OR WEATHER REPORT

Planet Travel Brochure or Alien or Weather Report
*Your Planet:*________________________________

First research your planet using your worksheet to record and organize your information. Now get ready to write your travel brochure OR weather report OR Alien model/ sketch. Look at the previous student samples to get your imagination moving.

To write a travel brochure:
What is the most important feature of your planet? Could it be something a traveler would want to see or experience? For example: Where in the solar system could you get a tan? [Mercury, of course].

To write or record a weather report:
What information could you include in your weather report? Read the weather section of the newspaper for ideas. Watch the weather forecast on the TV. An example of a brief report is: Forecast for Venus today will be windy with scattered acid rain. Temperatures will be in the low 900's.

To sketch or build an Alien:
Be sure to adapt your creature to the conditions of your planet's special conditions so that other students and me can identify which planet it inhabits. Be sure to look at samples of student work.

Your planet Information Worksheet

Use this worksheet to organize your information on your planet to prepare to make a travel brochure, weather report or alien.

My planet is ______________________
Surface conditions:

Weather: Temperatures:
Extremes(day and night)

Humidity(any water?)

Precipitation:

Barometric reading:

Wind speed:

Special Conditions:

Surface water in any form(ice, steam, liquid):

Atmoshpere: Gasses:
Oxygen:
Special Conditions:

Gravity Equivalent(How much would you weigh? See the <u>Magic School Bus tours the Solar System</u> for this information):

Other Features: (canals, volcanoes, canyons, clouds):

Anything else of importance?

APPENDIX V

LOST ON THE MOON SCORING

LOST ON THE MOON SCORING

Answers

15 Box of matches
4 Food concentrate
6 50 ft. nylon rope
8 Parachute silk
13 Portable heater unit
11 Two .45 cal. pistols
12 One case dehydr. milk
1 Two 100 lb. tanks oxygen
3 Stellar map (Moon version)
9 Life raft
14 Magnetic compass
2 Five gallons of water
10 Signal flares
7 First-aid kit with needles

Rank Order of Items

1 Two 100-lb, tank of oxygen
2 Five gallons of water
3 Stellar map
4 Food concentrate
5 Solar-powered FM transceiver
6 Fifty feet of nylon rope
7 First-aid kit with injection needles
8 Parachute silk
9 Life raft
10 Signal flares
11 Two .45 caliber pistols
12 One case dehydrated Pet Milk
13 Portable heating unit
14 Magnetic Compass
15 Box of matches

Scoring

Subtract your ranking number for each item from NASA's ranking number. Add these differences. Also do this for the ranking list and compare individual prediction with the group prediction.

Example:

	Your Ranking	NASA's	Difference
Box of matches	8	15	7
Signal Flares	14	10	4

Explanation

These are the answers supplied by the NASA scientists. The answers are split into groups--physical survival and traveling to the rendezvous.

The first two items are air and water without which you cannot survive at all. After that comes the map for locating position and figuring out how to get to the rendezvous. Food comes next for strength on the trip. It is not as necessary for survival as air and water.

The FM transceiver is for keeping in touch with earth. In a vacuum, without the ionosphere, radio transmission travels only in line of sight and would be limited on the moon to destination of approximately ten miles. On earth powerful receivers could pick up messages which would then be relayed to the mother ship. The next item would be the rope for lunar mountain climbing and traversing crevasses on the trip. The next item would be first aid for injuries. Parachute silk would offer excellent protection from sunlight and heat buildup.

The life raft is a carry all for supplies, (the moon's gravity permits heavy loads to be carried), as a shelter, and a possible stretcher for the injured. It also offers protection from micro-meterite showers.

Flares cannot burn in a vacuum but they, as well as the pistols, can be shot. Flares and guns would therefore be excellent propulsive devices for flying over obstructions. The milk is heavy and relatively less valuable.

On the moon overheating is a problem and not cold. Thus the heating unit is useless.

The magnetic compass is useless without a map of the moon's field.

The box of matches is the most useless item.

APPENDIX W

COOPERATION EVALUATION

COOPERATION EVALUATION

SELF	Strongly agree 5	4	3	2	1
1. I worked hard toward our goal	5	4	3	2	1
2. I stayed on task	5	4	3	2	1
3. I made decisions based both on my thoughts and those of my partner.	5	4	3	2	1
4. I expressed my opinions	5	4	3	2	1
5. I listened to my partner	5	4	3	2	1
6. I helped my partner	5	4	3	2	1
7. I respected my partner	5	4	3	2	1

PARTNER

1. Worked hard	5	4	3	2	1
2. Stayed on task	5	4	3	2	1
3. Expressed opinions	5	4	3	2	1
4. Listened to me	5	4	3	2	1
5. Helped me	5	4	3	2	1
6. Respected me	5	4	3	2	1

DIFFERENCES IN OPINION:

SUGGESTIONS FOR THE FUTURE:

APPENDIX X

CHECKLIST FOR PLANET TRAVEL BROCHURE OR PROJECT

NAME: Shauna PLANET: Venus)

Checklist for Planet travel brochure or project:

Have you included the following information?

__Surface conditions - What covers the surface? Water? Craters? Red soils, etc

__Atmosphere - does it have one? What gasses are in the atmosphere?

__Temperature - Highs? Lows?

__Surface Water - Is there any? Ice? Steam? Liquid?

__ Gravity Equivalent - What would you weigh on your planet? (Use Ms. Friz)

__Moons? How many?

__Distance from earth?

__Rotation (day)

__Revolution (year)

__Special features? Rings? Spots? Canals? Volcanoes? Tilt? Double planet?Rings?

__Do you have visuals of your planet?List them.

__Is it colorful?

✓Is it clever, creative and has wordplay?

Clever - name VENUS! + adjectives

APPENDIX Y

PHYSICS BASICS

PHYSICS BASICS

0. **GRAVITY:** On the earth's surface, all objects experience a downward force caused by the gravitational attraction between the object and the earth. THE BEHAVIOR OF ANY TOY ON EARTH IS AFFECTED TO SOME EXTENT BY GRAVITY'S PULL.

1. **MICROGRAVITY:** The earth's GRAVITY keeps satellites and their contents in orbit. The satellites travel so quickly that they do not fall toward the earth. Astronauts inside feel as if they are falling freely like a diver jumping off a diving board. This experience is also called "weightlessness" or "zero gravity". Microgravity is the official term because there are small forces still felt in the Space Shuttle when the spacecraft maneuvers in orbit. THE TOYS ON SHUTTLE FLOAT THROUGH THE CABIN WITHOUT EXPERIENCING ANY DOWNWARD FORCE RELATIVE TO THE SPACECRAFT.

2. **ENERGY CONSERVATION:** When an object moves, it has Kinetic Energy. AN ASTRONAUT TRYING TO MOVE A TOY MUST FIND A SOURCE FOR THE ENERGY NEEDED BY THE TOY.

3. **MOMENTUM CONSERVATION:** Objects in motion have momentum. More massive faster moving objects have more momentum. In a collision, momentum is conserved. When one object loses momentum, another object must gain momentum. This momentum conservation is also described as a REACTION FORCE produced by an object for every ACTION FORCE acting on the object. THE RESULTS OF MANY TOY COLLISIONS ARE DETERMINED BY THIS CONSERVATION LAW.

4. **INERTIA:** Objects in motion tend to stay in motion. Objects at rest tend to stay at rest. An astronaut must exert a force to cause a toy to change its motion. It requires more force to move an object with more mass. If an astronaut tries to make a toy turn or move in a circle, the inward action force exerted on the toy is called a CENTRIPETAL FORCE. The outward reaction force produced by the toy is called the CENTRIFUGAL FORCE. GRAVITY PROVIDES THE CENTRIPETAL FORCE THAT KEEPS THE SPACE SHUTTLE IN ORBIT.

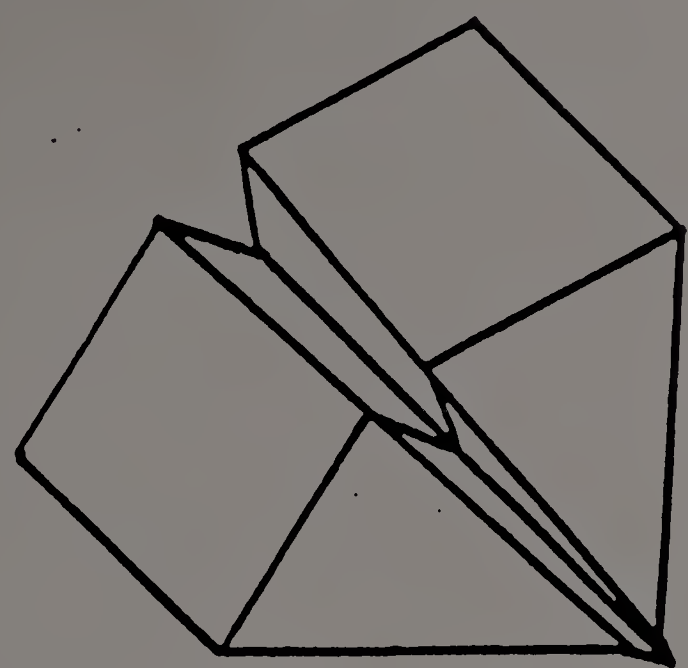
5. **ANGULAR MOMENTUM CONSERVATION:** Spinning objects have angular momentum. More massive, more spread-out, and more rapidly spinning objects have more angular momentum. Angular momentum must be conserved. A SPINNING TOY WILL CONTINUE SPINNING WITH THE SAME AXIS TILT UNTIL IT TRANSFERS SOME OF ITS ANGULAR MOMENTUM TO ANOTHER OBJECT - SUCH AS A SUPPORTING TABLE.

APPENDIX Z

THE SPACE PLANE/
THE GYROSCOPE AND TOP IN SPACE

THE SPACE PLANE:

In space a paper airplane will soar farther than on earth. The airplane's shape is important. It must be aerodynamic. It will fly forward, but will NOT fly backward. When the airplane is released with no push, the airplane will drift in the air currents. When an airplane hits the wall, it will bounce off and float backward. In space, an astronaut can blow on a paper airplane to make it fly. A paper airplane should loop in space although no looping airplane was tried on Mission 51D.

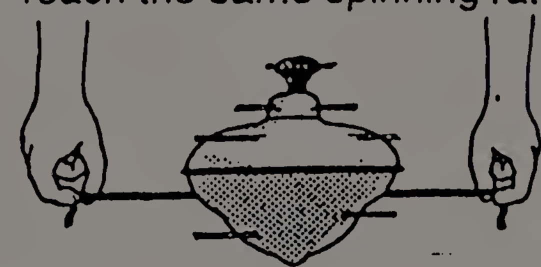


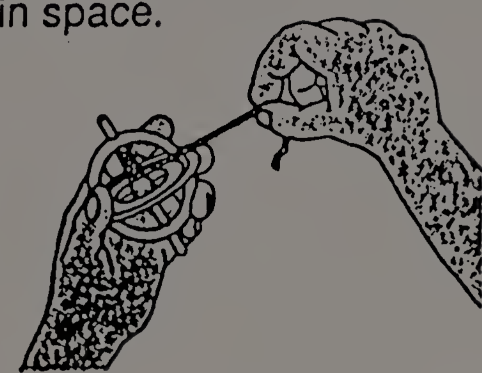
If a standard paper airplane is released with a sideways push, the airplane will twist to the right or left as it soars forward.

THE GYROSCOPE AND TOP IN SPACE:

In space a spinning gyroscope can reach about the same spinning speed as it does on earth. Its spinning will cause its support cage to spin. Because there is no friction with a support surface, the gyroscope will spin much longer. Only air resistance gradually slows down the spinning space gyroscope. Gravity causes the wobble in a gyroscope or top. This wobble (officially called Precession) increases as the gyroscope slows down on earth. In space there is no force to cause a wobbling motion. When touched by a string, a spinning space gyroscope reacts by floating away. When attached to a string and swung around in circles, a spinning gyroscope will orient its axis to be perpendicular to the string.

In space a push-top comes back up when the astronaut pulls up on the knob. To start the top, one hand must push downward on the top while the other pumps the knob up and down. For this reason, the top cannot reach the same spinning rate in space.





Commander Bobko demonstrated the value of gyroscopes by starting his gyroscope spinning and then circling around it. As he moved around, the gyroscope kept its orientation. There are gyroscopes inside the Shuttle's computer instrumentation that tell the Commander about the orientation of the Shuttle as it [illegible]

APPENDIX AA

WORLD WAR II ESSAYS

Ms. [redacted] / Mr. [redacted]
Ms. [redacted]/ Mr. [redacted]

Name 1994-1995
Date ____________

Tolerance, the Holocaust and Individual Responsibility
World War II Essay Topics

Tolerance is the ability to recognize and respect
beliefs and practices different from your own.
(Webster's New World Dictionary)

The Overview

For the past three and a half weeks you have used literature, film and history to explore the themes of tolerance, the Holocaust and individual responsibility. Together we have watched and discussed <u>All Summer in a Day</u>, <u>Swing Kids</u>, and <u>The Hiding Place</u>, and we have read books on the Holocaust. You have learned about the social and political climate during the twenties, thirties and forties and about Hitler's rise to power.

Now it's time for reflection. Mr. W , Ms. , Mr. and I would like you to focus on the themes of tolerance, the Holocaust and individual responsibility and write an essay that helps you better understand something which really caught your attention or puzzled you during this exploration. Read through the essay questions that follow and focus on the one that sparks your mind the most. Think of the topic you select as a puzzle to solve. The essay you write is the process of fitting the puzzle pieces together on paper.

Remember, **writing is thinking**, and this essay is an opportunity for you to think your way through the intellectually and emotionally challenging material we have been exploring for almost a month.

The Due Dates:

The **first draft** is **due** __________. We will be working on the format of the essay in class this week in Language Arts. Both Mr. Williams and I will be available for help with questions you discover about your topic as you begin to tackle it. Before writing a second draft, please read it to another person.

The **second draft** is **due** __________. After you have carefully edited your second draft, read it again to someone else. Pleas hand the essays in on time so one of us can edit it and hand it back on Monday, May 8, so you can have a full week to write the final.

The **final draft** is **due** __________. We will fill out self-evaluations in class together and I guarantee that the essays will be graded promptly.

The Essay Topics

1. How did the brutality of war, life in the death camps, and the sinister triumph of Nazis affect individuals and their families? How did Jewish and non-Jewish families survive? What did they go through? How were their loyalties eroded or strengthened by their experiences? What choices did they make? How did their choices affect each other? Use the books we read and Swing Kids as touchstones.

2. What difficult situations did the teenagers in Swing Kids face? What specific choices did the characters make and how did their choices affect them, their families and their friends? What characters were most alike or most different? What traits did the characters share? What did you learn about the power of "belonging" to a special group through the different characters' responses to the temptation of being considered "special"?

3. Throughout Hitler's rise to power, the Nazis were committed to creating a country free of Jews, cripples, misfits, and homosexuals. The Nazis believed they were members of a superior race of people and felt they had to humiliate and otherwise dehumanlize their prisoners or anyone opposed to the Third Reich. From the books you have read or movies you have watched, give at least three detailed examples of how the Nazis tormented and humiliated their foes.

4. How does the peer pressure you feel in school every day to be "cool" or part of the group affect your behavior towards others? Where do you fall in the spectrum of these behaviors: from being the victimizer - to being the one who watches - to being the victim (remember "All Summer in a Day")? Think about these quotes from The Wave (We didn't watch this as a class, but I will show it to students who want to stay after; let me know if you are interested).

> "The popular thing is not always the right thing." -Laurie's mom, from The Wave
>
> "We are all responsible for our own actions. You must question what you do rather than blindly following a leader. Never allow a group's will to usurp your individual rights." -Mr. Ross, from The Wave

5. Think and write about this quote, "Fascism isn't something those other people did. Fascism is right here, in all of us." Use what we have read and the movies we watched to help you sort this out. Or, explore what you notice happening around you every day which proves Mr. Ross's point. Consider the AIDS epidemic; consider homophobia; consider whatever strikes you as intolerance of people who have different beliefs and practices. Write about it.

6. Think and write about how a person can successfully balance being part of a group and maintain her/his individuality. Think about some of the more disturbing events in the books you read. Think about yourself. How does an individual learn

to cooperate with others in a group and still maintain her/his individuality. What leads some individuals to stand up for others, even at personal risk to themselves? Try to weave into your discussion events and lessons from the Holocaust as well as your personal beliefs.

7. Think and write about an individual's responsibility to know and act in a moral and just way. Why do some people give up their individuality and do things in groups that they would not do as individuals? What is individual responsibility? What does it mean to be moral? to be just? Think about these quotes.

> "How could the Germans sit back and say they didn't know about it? How could they do that? How could they say that?" -Laurie in "The Wave"
>
> "I wouldn't let a couple of Nazis scare me into pretending I didn't see or hear anything." Eric in "The Wave"
>
> "Unjust laws exist: shall we be content to obey them or shall we endeavor to amend them, and obey them until we have succeeded, or shall we disobey them at once?"
>
> "The day we become silent about the things that matter is the day that our lives cease to be important." -Dr. Martin Luther King

8. Can we learn from history? By studying the horrors of the Holocaust, are we better prepared to prevent similar events from happening again or are we destined to repeat the same mistakes? Think about the quotes below.

> "Anyone who closes his eyes to the past is blind to the present. Whoever refuses to remember .. is prone to new risks of infection... We must erect a memorial to thought and feelings in our own hearts." -Elie Wiesel
>
> "Many thousands (Nazis) we know nothing about - if they are alive or dead or living under false names. There are a number of big shots, criminals. We are looking for them....I don't want people to forget this. And I want the new generation to learn from the past." -Simon Wiesenthal (famous hunter of Nazi war criminals)

> "Our recent history is a catalog of crime,
> The besotted and the powerful - the architects of time,
> Mother of invention - oppression of the mild,
> The constant fear of scarcity - aggression as its child.
>
> History will teach us nothing
> Sooner or later, just like the world's first day,
> Sooner or later, we'll learn to throw the past away,
> History will teach us nothing..." -from Sting's "History Will Teach Us Nothing"

9. YOUR IDEA!!! This is the hardest one of all, folks. You develop the topic as it relates to the themes covered above and in class. You MUST outline, plan, or brainstorm your topic in some way and clear it with me before you begin to write.

APPENDIX BB

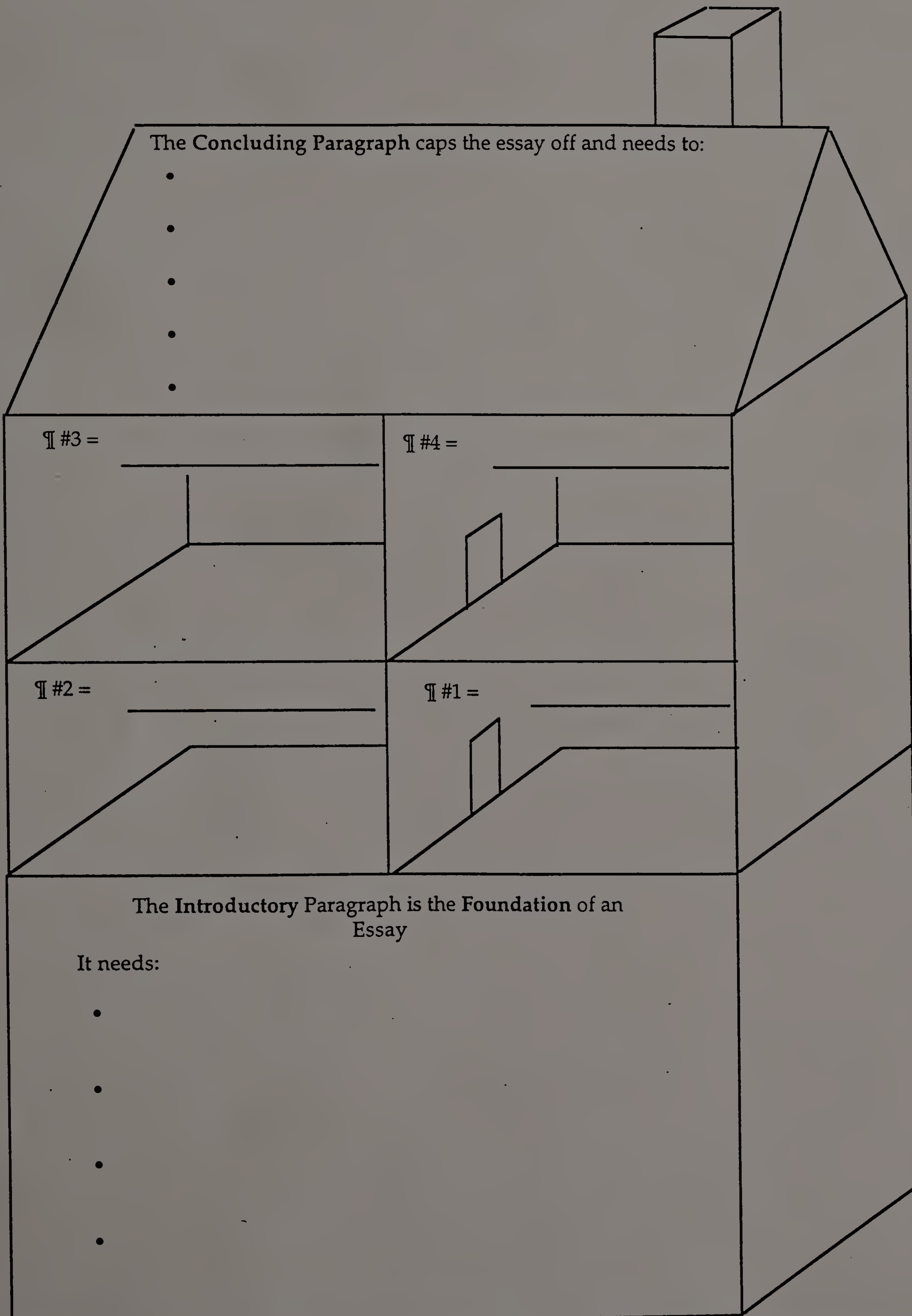
WRITING AN ESSAY IS LIKE BUILDING A HOUSE

Version 4

Name 1994-1995

Date ________

Writing an Essay is Like Building a House
A Metaphor for Writing



The Body

Pd. # ____

Name ____________________
Date __________

Tolerance, the Holocaust and Individual Responsibility
World War II Essay Topics

Pick one of the essay topics from the handout that appeals to you and about which you have strong opinions, thoughts or feelings. Your essay should be between **7 - 10** paragraphs in length (in certain cases I will accept a minimum of five).

Remember - Writing an Essay is Like Building a House

Paragraph #1 - **Introductory Paragraph** (The **Foundation** of the Essay)
Length = 4-5 Sentences
Begins with a catchy lead sentence
Clearly explains the topic or question you intend to address
A transition sentence into the body of the essay

Paragraph #2 - The first paragraph of the **body** of the essay
Length = 4-5 Sentences
Begins with your first point (a.k.a. **The Topic Sentence**)
Explains or describes your the first point in detail
Backs up your ideas with examples from the books or movies, etc.
(Using brief quotes is a good idea)
Has a closing sentence that links to the next paragraph

Paragraph #3 - Length = **4-5 Sentences**
Begins with your second point (a.k.a. **The Topic Sentence**)
Explains or describes your the second point in detail
Backs up your ideas with examples from the books or movies, etc.
(Using brief quotes is a good idea)
Has a closing sentence that links to the next paragraph

Paragraphs#4 - 7 - **More paragraphs in the body of the essay**
Length = **4-5 Sentences**
Begins with your third (4th, 5th, etc) point
Explains or describes your the third point in detail
Backs up your ideas with examples from the books or movies, etc.
(Using brief quotes is a good idea)
Has a closing sentence that links to the next paragraph

Last Paragraph - **Concluding Paragraph**
Length = **4-5 sentences**
Draws conclusions
Makes predictions
Suggests alternatives
Answers the original question
Reemphasizes key points

Please, carefully self-edit each draft.

APPENDIX CC

WRITING EVALUATION

World War II & Intolerance Essays
Writing Evaluation

Name ______________________ date __________

Title of Piece ______________________________

____/____ 1. Process grade
- Did you go through a process of:
  - brainstorming?
  - first draft/ conferencing / revision?
  - second draft/ conferencing / revision?
  - self-editing draft to hand in?
  - teacher-editing?
  - and then a final draft?
- Did you meet due dates?

____/____ 2. Content grade - based on our class discussions & my mini lessons
- Does your piece have a catchy lead?
- Do you state the point of your essay clearly in the opening ¶?
- Have you organized your piece so that the flow of your ideas & info moves is clear and easy to follow?
- Do you make smooth transitions between paragraphs?
- Does your piece make sense?
- Do you use descriptive, specific words and powerful language to help make your point?
- Does your essay end gracefully so that the reader feels satisfied at the end?

____/____ 3. **Mechanics grade** - Have you done your best to polish your writing for the reader by checking for :
- capitalization? (ex. Jew(ish), Nazi, German...)
- punctuation -
  (external= periods, exclamation points, question marks, quotes?)
  (internal= commas, semicolons, colons, dashes, apostrophes, hyphens?)
- spelling?
- sentences (avoiding unintentional fragments and run-ons?)
- paragraphing?
- standard use of the language?

Comments (Please make at least one detailed comment that tells me something special or important about your piece I might not have otherwise known.)

<u>**Spelling**</u>

APPENDIX DD

WORLD WAR II BOOK PRESENTATIONS

1994-1995

WORLD WAR II BOOK PRESENTATIONS

Group members ____

____ (25 pts) everyone had a role in the presentation

____ (25 pts) the presentation provided a clear plot summary

- the setting
- the characters
- the conflict
- three to five surprising rising action elements
- the climax
- the conclusion
- themes that emerged

_____ (25 pts) a visual aid (which included the book's title and author)

_____ (25 pts) an enthusiastic delivery!

_____ TOTAL POINTS = _______ (letter grade)

Comments-

APPENDIX EE

SAMPLE STUDENT LOG ENTRY

Date: 2-23-95
Tittle: Friedrich
Author: Hans Peter Richter
Pg: 1-15

The Characters in my book are Herr Johann Resch. Herr is a Land Lord that ownes a Small Apartment building. Herr doesn't like Jew's. Herr seems like an old grump most of the time.

Friedrich is a young Jewish boy, who lives in One of the apartments that Herr ownes. Friedrich is a good Kid, that doesn't get in trouble. I think Friedrich is a good Kid who doesn't understand why most people hate people like him. Excellent observation.

Friedrich's mother's name is Frau Schneider. She's a small women with dark hair. She seems like a very happy lady, and she smiles at everyone. She seems like a very Kind and gentle lady, who loves her son very much.

The narrator is a young

boy, who also lives in Herrs' apartment building. The Narrator is good friends with Friedrich. Even though The Narrator is a christian. The narrator Sometimes get jealos of Friedrich, because Friedrich's mother took Friedrich outside when it was Snowing, and The narrator kept bugging his mother to take him outside. I think the narrator is a good kid, but is kind of spoiled.

The narrator's mother, I think wants to give her son everything, but she doesn't have the money. She doesn't mind that her son and a Jew are friends either. She sounds like a thin, middle aged women.

The narrator's father is often away on buisness trips, but he sounds like a man who never makes decisions for himself. Because when Grandpa comes Grandpa tells him to do a bunch of stuff with his life and he Said he would do it.

Grandpa is a very picky old man. He makes sure that the bottom of his grandsons shoes are polished, and his hands are very clean. Then he inspects every room in the house, to see if they're clean. Then when he finds out that his grandson is friends with a Jew he gets very upset. Grandpa IS Kind of like Herr. An old grump. *

K

P.S. I'm realley enjoying this book. YAY!!

K. – I am positively thrilled to hear this... I am so impressed with your careful reading and intelligent observations about the characters... You have clearly connected with the novel and I'm psyched!

AF

APPENDIX FF

ASKING & WRITING INTERPRETIVE QUESTIONS

Ms. /Mr.
Pd. # 5

Name Jeff Benbaug
Date 3-27-95

Asking & Writing Interpretive Questions

Asking interpretive questions is the key to unlocking your understanding of the meaning of literature (and life in general). Please take notes below on how to generate and write interpretive questions.

An interpretive question is A question that has more than one answer, that can be supported with evidence from the story (open-ended).

Step # 1 - "Taking Note"

As you read, take the time to:

1) note anything that you do not understan or anything that puzzles you
2) note anything you think is especially important or anything that grabs your attention
3) note anything about which you feel strongly and ask yourself what troubles me or what inspires me, what do I agree and/or disagree with

Step # 2 - "Writing Questions"

After you have "taken note," transform your notes/thoughts into questions by focusing on:

1) questions you have about the characters and how they act or speak.
2) questions you have about unusual uses of language. (The way the author writes)
3) questions you have about details that stand out or grab your attention.

4) words, phrases and sentences which can be under-stood. There is more than one wa

5) connections between sections of the story, characters, or erents in the story.

Consider beginning your questions with words and phrases like:

- why
- why does the author.......
- what is the connection betwee
- What does the character mean when he/she says/does.......

APPENDIX GG

KEY QUESTIONS

KEY QUESTIONS

1. What gives some groups power over others?

2. Why is fitting in sometimes more important than doing the right thing?

3. Why do people sometimes do things in groups which they would not do as individuals?

4. How do victimizers dehumanize their victims and how does that dehumanization affect both groups?

5. What leads some individuals to stand up for others, even at personal risk to themselves?

APPENDIX HH

"ALL SUMMER IN A DAY"
LITERATURE LOG ASSIGNMENT

"All Summer in a Day" Ray Bradbury
Lit Log Assignment

Name ___ ___ ___

Please respond with complete sentences & details to the following questions.

1. Reflect on the story for a few minutes. What do you think the author wanted you, as a reader, to think about after reading this story? What theme(s) emerged?

2. Why do the others dislike Margot? Give as many reasons as you can.

3. Why do the other children allow William to be so cruel to her - especially when he locks her in the closet?

4. Write about an experience you have had where you either observed something like this, were the "William," or were the "Margot" in the situation. Describe the situation by focusing on how it felt.

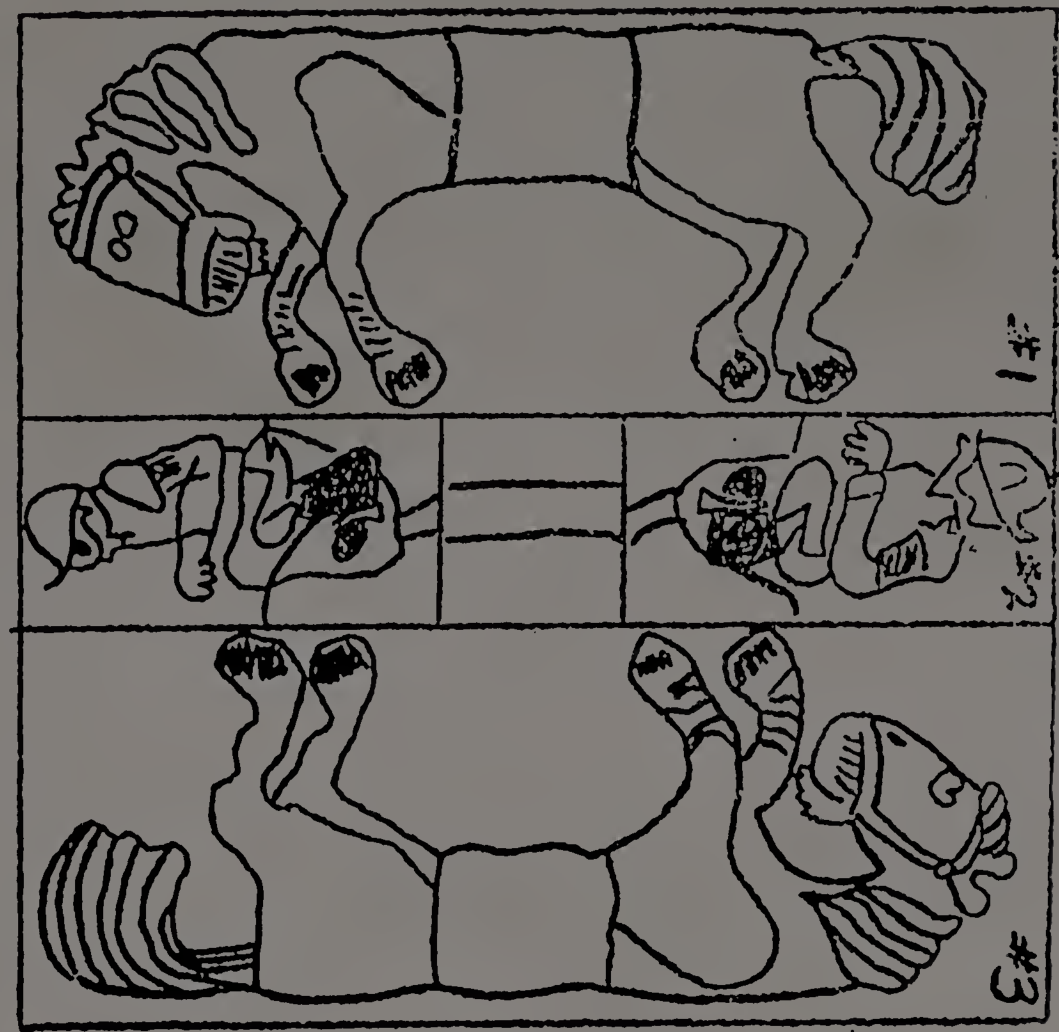
5. a) What qualities make a person a leader?
   b) What qualities make a person a follower?
   c) What qualities make a person who can withstand negative peer pressure?
   d) What kind of a person are you?

APPENDIX II

HORSES AND RIDERS

BET'CHA CAN'T DO IT!

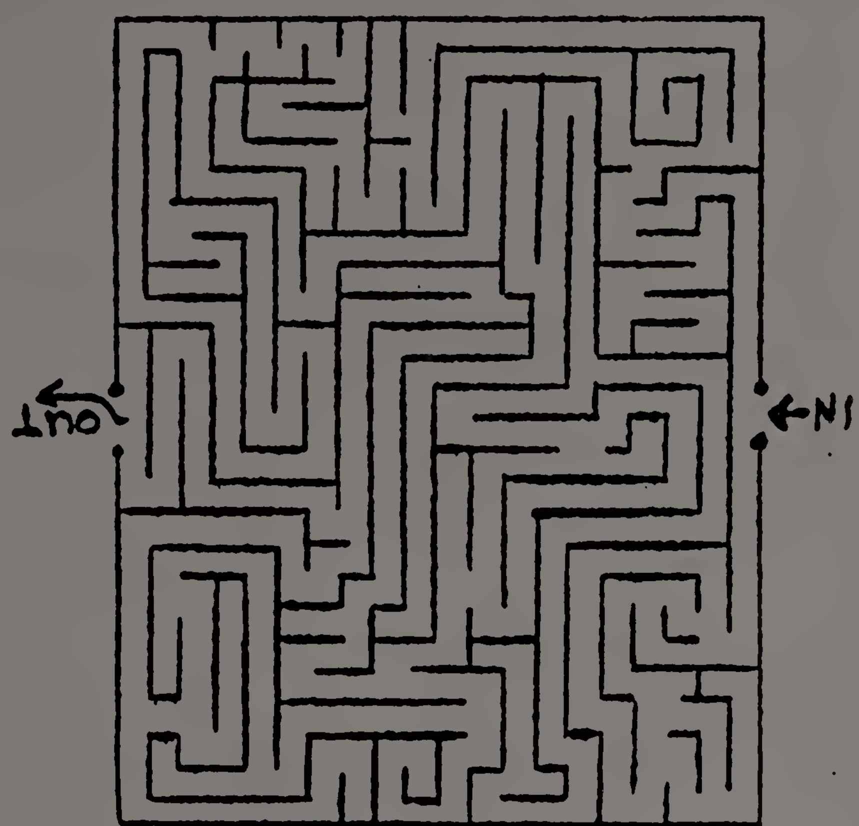
CUT ON THE LINES CAREFULLY!



DIRECTIONS: Cut out the three sections. Arrange them so that each horse has a rider <u>and</u> so that each horse is in full gallop. You may not fold, mutilate, or cut any of the sections - or Mr. Hussey when you can't do this simple, simple, simple task.

CAN YOU THREAD THE MAZE?

If you are using a pen, try to trace your solution with your finger 'til you see how to go.



THERE ARE VERY FEW EXTRAS

APPENDIX JJ

REBUSES

looking

1. 1111

2. TRI

3. struggle

4. VICTORY

5. LEWON

6. 25¢25¢

7. S H E E T S

8. sidestoryside sidestoryside sidestoryside
sidestoryside sidestoryside sidestoryside
sidestoryside sidestoryside sidestoryside
sidestoryside sidestoryside sidestoryside

9. estdawn

10. poc 3
k
e
t

11. hen

12. TtUiLpItPoSe

Noodle-Doodles

Try to solve the Noodle-Doodles before using the clues on page 8.

Readers are invited to submit Noodle-Doodles for publication in AHA! Readers whose entries are used will receive a Creative License.

APPENDIX KK

STREET SCENE


BOOKS
LAUNDRY

APPENDIX LL

LENSES AND LEVELS THROUGH WHICH TO APPROACH *MARY HAD A LITTLE LAMB*

Lenses and Levels Through Which to Approach *Mary Had A Little Lamb*

Mary had a little lamb/ Its fleece was white as snow/ And everywhere that Mary went / The lamb was sure to go./ It followed her to school one day,/ Which was against the rules./ It made the children laugh and play/ To see a lamb at school...

Lens	Epistemological Levels*		
	Dualistic/Received	**Multiplistic/Subjective**	**Relativistic/Separate Procedural**
Marxist	What is Mary's social class?	What is the best setting in which to educate the young: The classroom or the farm?	Whose interests are being served by excluding lambs from school?
Feminist	What type of relationship does Mary have w/ her lamb?	If you were Mary, would you break the rules to be with your lamb? What impact might your decision have on your relationships w/ your teacher? Your classmates?	How should we decide whether lambs belong in school?
Psychoanalytic	Explain how the lamb is symbolic of Mary's ID.	What do you think the lamb symbolizes?	Is the lamb more symbolic of Mary's rebellion against authority figures or her innocence?
Cultural Transmission (Classical)	What simile does the writer use in the first stanza?	What other songs do you know of with a similar theme?	Is this song an example of excellent art? Explain linking examples from the text w/ a theory of aesthetics.
Multicultural	From what cultural tradition does this song derive?	Do you think lambs should be allowed in school? Why or why not?	Select a cultural community and identify the standards by which the appropriateness of lambs in school would be decided.
Teacher Education	What disciplinary procedures best suit this infraction?	Why do you think the writer sets the song in school and not some other social institution like church?	Based on three educational theories of your choice, compare & constrast how the lamb's presence would be viewed.

* Based on epistemological positions in the theories of Perry (1981) and Belenky, Clinchy, Goldberger and Tarule (1986).

APPENDIX MM

SAMPLE PAGES FROM DISSERTATION LOGS

Wednesday July 12, 1995

1. Backed up dissertation disc

2. Called Personnel Connection w/ go ahead on
   a. Purchasing dictaphone $250.00
   b. Beginning transcription of first interview.

3. Made changes to Chap. 7 (on computer)

Think piece:
PCK for conceptual understanding seems to miss the focus of some very effective constructivist teachers who are interested in process learning, affective outcomes .... ??

External reps. reflect mental ones, but mental reps. may not always be reflected externally, as w/ Cifarelli's levels of problem-solving capability

NOTE

To DO: → Definitely follow up on Raheima's study.

S.S. talks alot @ concept formation but few studies (Burlbaw, L.M. (1994) Applying Generalizations in Middle School Geography Classes. Social Studies 85(3), 110-13.

8 4th/5th gr study

Wade, R. C. (1994). C.A. in class: A case. Theory + Research in Social Ed. 22(1), 74-95

→ Concept attainment feels decontextualized

[redacted]

garden - shopping

write up last obs.

fish cup.

E-mail Dick + Charlie

Tuesday, May 28, 1996

1. Need to integrate the science article from Eric - the AERJ materials, also one from ED Researcher on teachers' stories.
Then I need to pull together this section & finish. Will need to work in early AMS Wed + Thurs + Fri. (get up at 4:30)
Then rewrite Ch. 3 + go observe ~~classes~~!
Then begin the

✓ Rec. 1 Importance of $\boxed{\text{epist. beliefs}}$ in ~~supporting~~ predict^s C∆ learning EJ 509339

✓ Rec. 4 Graph^g + $\boxed{\text{microcomputers}}$ (& obj. in motion) helped ~~stu~~ change stn. concept. u of kinematic concepts.

✓ (Rec. 10) Bonnie Shapiro - valuing students' $\boxed{\text{constructions}}$ as a way to suggest instructional approaches. EJ 501940

pg. 7

Rec. 22 Social interaction can facilitate knowledge construction when
① Horizontal info. is present
② Comparable domain k. is present
③ Cognitive tools are present.

allow confront of diff. perspect. & foster meta-cognitive awareness of one's own concept.

✓ Rec. 39 concept. fit^g + everyday life
✓ Rec. 75 conc. exp. alone not enough to foster CH.
✓ Rec. 76 " conflict (Solution in chem.)
✓ R. 80 C∆ theory omits motiv. (4 wade)
✓ R81 Computer sim. molecules
✓ R95 " " mustivalu. RK.

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