THE GOOD STUDENT

WHAT DOES IT MEAN AND WHAT DOES IT TAKE TO BE SUCCESSFUL IN HIGH SCHOOL CHEMISTRY?

-OR-

"WILL THIS STUFF BE ON THE TEST?"

By

Charles Jay Rop

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree
of

DOCTOR OF PHILOSOPHY

Department of Teacher Education

1996

ABSTRACT

THE GOOD STUDENT
WHAT DOES IT MEAN AND WHAT DOES IT TAKE TO BE SUCCESSFUL IN HIGH SCHOOL CHEMISTRY?
-OR-
"WILL THIS STUFF BE ON THE TEST?"

By

Charles J. Rop

This study attends to the voices of college-bound students in the context of high school chemistry. I used participant observation to understand students' views of success in two Midwestern public high school chemistry classes. Field notes, interviews and informal conversations with focus groups of students and teachers were considered primary data sources. Audio-tape transcriptions and written artifacts served as secondary sources.

Listening to the media, everyday conversations and public perceptions of American education tempts us to think schools are filled with lazy students, negative peer pressure and ineffective teachers. Instead, I found intelligent young men and women doing their school work willingly, benefiting from positive peer pressure and learning from teachers who know their chemistry well and teach it effectively. These students not only take pride in their accomplishments and reputations, they also make rational, intelligent decisions about schoolwork that make perfect sense to them in context. However, the school chemistry which they successfully learn and which is well supported by the social structure around them is a surrogate for real chemistry. Rather than deep understanding of chemical

processes, students describe traditional strategies and task performances that become a rite of passage. The evidence of success is a good grade on one's transcript.

Students demonstrated limited but real awareness of events in the natural world. They described a higher calling--deeper understandings of the substantive content and process in the academic discipline. Some students described real molecules and atoms in real objects and events as "something awesome." They spoke sometimes indirectly, sometimes explicitly, occasionally with passion, of a desire to learn real chemistry and have it count for success. However, they acknowledged that real chemistry learning in school could be viable only if the incentives, expectancies and norms of the cultural milieu supported it. The same socio-cultural system which so effectively supports students in efforts and investments in school chemistry has the potential for supporting real chemistry equally well. This potentiality challenges us to find ways to support and encourage the teaching and learning of real chemistry in American high schools.

ACKNOWLEDGMENTS

I would like to acknowledge all the participants, especially the students and teachers, who willingly and enthusiastically supported me in this research. Your honesty, trust, support, guidance, and willingness to take risks made this study possible.

I would also like to thank my family who gave their unconditional love, support and encouragement throughout my doctoral program. Without your faith in me and your help, my success would not have been possible. I am especially grateful to Sheri, my wife, for her love, patience, and her emotional and intellectual support. Thank you for putting up with my preoccupation and lack of attention while I was away from home, obsessed by data, and glued to my computer screen. Thank you for your wisdom, support and editorial help throughout my entire career.

Throughout my graduate program, I have received invaluable support and guidance from my doctoral committee and friends. I wish to thank Dr. Joanne Simmons, Dr. Christopher Clark, and Dr. Kathy Roth for all their help above and beyond the call of duty. I especially want to thank Dr. James Gallagher, a true mentor and friend. Without your patience, wisdom, and support, this dissertation would not have been written.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

The Evolution of a Research Problem

> Then Bilbo sat down on a seat by his door, crossed his legs, and blew out a beautiful gray ring of smoke that sailed up into the air without breaking and floated away over the hill. "Very pretty!" said Gandalf. "But I have no time to blow smoke-rings this morning. I am looking for someone to share an adventure that I am arranging, and its very difficult to find anyone."
>
> "I think so-- in these parts! We are plain quiet folk and have no use for adventures, nasty, disturbing, uncomfortable things! Make you late for dinner! I can't think what anybody sees in them," said our Mr. Baggins, and stuck one thumb behind his braces, and blew out another even bigger smoke ring.
>
> *The Hobbit* (J.R.R. Tolkien, 1966, p.18)

Adventures are costly--taxing the individual and the group. Adventures involve pushing off into the unknown and the difficult. Those who are faced with adventures naturally weigh the necessary physical, emotional, and intellectual costs against perceived gains and then make decisions whether to embark or not. Real learning is an adventure. I have found that learning is most often difficult and filled with uncertainty. It is understandable that many, in plotting a course for school learning, seek level ground and an easier, less costly, and more familiar path. Many would agree with Mr. Baggins about adventures-- they are "nasty, disturbing, uncomfortable things."

Bruner (1966) describes two factors which effect a person's intellectual life--coping and defending. "Coping respects the requirements of problems we encounter while still respecting our integrity." And "defending is a strategy whose objective is avoiding and escaping from problems for which we believe there is no solution that does not violate our integrity of functioning" (p.129). He defines integrity of functioning as self-consistency or style in solving problems in ways consonant with personal values. He found that children "could not cope with demands of schoolwork unless they first were able to defend themselves against the panic of impulse and anxiety that the demands of schoolwork set off in them" (p.132). When I taught high school science, my students brought their defending strategies with them to class and found it difficult to cope with the situation in ways that resulted in positive problem solving and subject-matter learning. Like most of us in many situations, they seemed to measure their investment of time, energy, and tolerance for anxiety against perceived rewards. Especially in chemistry classes, the student-perceived end didn't necessarily justify the means.

In schools, it is quite common that students wager limited investments, attitudes and effort against perceived gains. The odds of the wager can be manipulated, the gains and potential losses negotiated through a process of bargaining. This bargaining is common in American high schools, often implicit and usually expensive. I agree with Sedlak (1986) that it is un-affordable because a result of the bargaining process is a form of surrogate learning--learning characterized by an avoidance of the anxieties, stresses, and effort involved in learning difficult things. The bargain is a "complex, tacit conspiracy to avoid sustained rigorous academic inquiry" (p.1). Successful bargains often reduce the value of the credential received upon completion of chemistry as well as the high school diploma. A devaluated credential is purchased with a minimal investment as students learn negotiation skills and how to play the system instead of focusing on the academic. As a science teacher, I have found the bargain especially common, and especially disturbing, in high school chemistry classes where college-bound students, perhaps for the first time, find academic "success" (as they know it) uncertain and unpredictable. The nature of chemistry subject matter, if taught for understanding, exposes the student to a level of analytical thinking and an integration of mathematics and science that might potentially upset or redefine the bargain. When a course is taught to engage students in doing, applying and critiquing the discipline, the teacher presents academic obstacles. Getting students to think hard and struggle with ideas in any subject is a challenge.

I found this especially in chemistry. There is a general consensus among chemistry teachers that the nature of chemistry as a discipline presents students with academic obstacles to overcome. Exactly what makes these obstacles so difficult for students to overcome is not very clear but perhaps it is the uncertainty and initial confusion that results from confronting new skills, new concepts, and new conceptual frameworks that are so difficult. Chemistry is a quantitative, analytical science that involves abstract ideas, unseen things, new problems and other conceptual challenges. Perhaps the students' personal academic history has failed to prepare them for this difficult learning they now face in chemistry.

On the other hand, perhaps it is uncertainty and an inability to see procedural tasks clearly that sometimes confuses and causes anxiety. Chemistry students are often used to good grades and maintain high grade-point averages. Academic work has not been difficult for them. Therefore, as Dweck (1986) has explained, they often come to chemistry classes with either a history of personally easy academic tasks or difficult tasks within a performance framework. By the time these students reach high school chemistry, they have gotten used to manipulating formulas, looking up answers, and applying algorithmic procedures in problem-solving tasks. One of the reasons, is that their academic success in past science classes has often been measured by adequate performance in these tasks. Therefore, if chemistry is task-oriented or performance-oriented, it actually seems quite familiar to these students and they find school chemistry quite easy.

The chemistry I taught seemed to present a new framework, and students perceived it as a difficult subject. Students were faced with a choice to rise to the challenges associated with the academic rigor and conceptual difficulties of chemistry or to resist them. Unfortunately, many resisted. They may have resisted the particular challenges associated with the chemistry presented them. On the other hand, their resistance might have been to the academic rigor I required regardless of the discipline. Perhaps their resistance was due to a combination of these things. Whatever the cause, I found student resistance the most significant impediment to "teaching for understanding" and improvements in my teaching. It is possible that this student conspiracy to avoid sustained academic rigor stands as one of the most significant roadblocks in the way of educational improvement in general.

This research is about the nature of student decision making regarding academic coursework and the cultural context in which the process occurs. It was designed to hear the voices and stories of college-bound young people about their experiences and understandings concerning their high school chemistry education. It examines participant perspectives of what it takes to be a good student and what it means to know and understand introductory chemistry. I began my study with four main research questions in mind:

I. What does it mean to be successful in high school chemistry?

II. What is required for a good student to be successful?

III. What is the nature of the cultural influence experienced by students of chemistry?

IV. How do these cultural influences affect student decisions regarding academic work?

A Personal and Historical Context

When I look back to my science teaching career, the most formidable roadblock I faced was student resistance to the unfamiliar and difficult. I found this resistance most profound in high school chemistry classes where college-bound students, perhaps for the first time, confronted an academic situation characterized by uncertainty. These "good students" came to me with carefully nurtured and highly valued grade-point averages. They were, of course, very familiar with schooling and what it normally takes to succeed in the school system. Many of my students were used to school learning that took little effort. Chemistry was elective, but students knew colleges expected it on their high-school transcript--counselors, teachers, and their friends had told them this; their parents expected it. They also believed that college entrance would not require subject matter understanding.

Traditional learning was familiar and safe and usually not a threat to these students' grade-point averages. But I presented a constructivist approach to chemistry that was radically different from the norm. It involved conceptual challenges regarding science knowledge as well as what it meant to succeed in school. I was asking students to make fundamental changes in attitudes and thinking while familiar constructs of schooling and learning gave way to strange, uncertain and difficult things. For example, students wrote essays and research papers, long lab reports, designed experiments and learned mathematics in science classes. As a result, students suddenly found themselves facing a dilemma--they needed to maintain their grade-point averages as efficiently as possible but they did not know how to negotiate this new and messy terrain. In a more traditional chemistry class, these students may never have faced this dilemma. Now, they could no longer depend on their old ways of learning, knowing, and reporting what they knew. They were challenged to examine themselves as students metacognitively, and they began a process of personal introspection about what it means to be successful, what it means to understand, and what it means to be a good student.

The associated dissonance led to a variety of responses and results. A few students adapted positively and tenuously embraced this new situation. Many more students tried a variety of traditional defense strategies (Bruner, 1960; Sedlak, et al., 1986), but my methods even seemed to frustrate those. Looking back, I realize I was upsetting the traditional bargains and perhaps making new ones. A few parents became concerned and involved as they wondered why chemistry should suddenly require a disproportionate amount of stress and anxiety-- disproportionate to other academic courses and science courses of the past. "If my son (daughter) did so well in biology and does to well in geometry and English, why is chemistry so difficult and frustrating?" Some parents also remembered their own chemistry classes and although they didn't necessarily like chemistry (in fact many said they hated it), they often did not find getting a good grade in chemistry very difficult. It seemed most logical to these parents that the problem rested in the way chemistry was now being taught. Some parents complained, threatened, and went to the principal in efforts to alleviate their children's anxiety. I was asking them to make paradigmatic changes in conceptions of schooling and learning. Students could no longer count on their old ways of learning, knowing, and reporting what they knew. Life in science class became unpredictable and complicated. I found that paradigmatic change in teaching is often risky and uncertain (Gallagher, 1989). A student complained:

"Mr. Rop, all you want to do is make us think."

Upsetting old constructs and building new ones in their place is a difficult and emotionally upsetting thing. One result is that familiar authority structures and assessments begin to erode and change. Students came to me thinking that authority rested in textbooks, but they soon discovered that the text gave few "correct" and easy answers. Many students believed the information they needed was in the teacher's head, and that he should just give them that information and the answers to problems. He should also tell them what procedures to practice and exactly what to memorize for the next test. They were used to teachers who were knowers and information givers. They soon realized that this teacher, instead of just giving information and providing answers, more often acted as guide and active participant in inquiry. They expected evaluation on the factual, memorization level but they soon not only struggled with evaluations based on their knowledge of the concepts, but also evaluations of their ability to sort through major ideas well enough to apply them to new situations. Students continually complained: "You never covered this in class."

I have found that less than enthusiastic reactions to academic rigor are rather traditional student responses. Educators often react by trying to force or coerce their students to work hard in school. And historically, according to some, few students have ever been devoted to academic learning (Doyle, 1980; Sedlak, 1986). Sedlak (1986) made the claim that the problem has been getting progressively worse during the 20th century-- especially worse in the last generation. Traditional incentives have collapsed as the culture and the school's role have evolved to a market view of education. A dissonance exists between the value of the high school diploma and the value of knowledge acquisition. Having a diploma still has value, but its value is decreasing because of its universality and its failure to hold educational, personal, or economic meaning. Sedlak wisely points out that the diploma perhaps never validated the possession of academic knowledge or skills, but it was at least relatively exclusive. Now, its universality has caused its loss of meritocratic value.

Although chemistry students' diplomas were almost never in question, the perceived stakes were very high. Students felt very strongly that they needed a good grade in chemistry. Some expected scholarships and most felt that an excellent grade was necessary to gain college admission. It seemed as though a good grade in chemistry was the only thing of importance and although understanding chemistry might be nice, it was not necessary. Theirs was a very practical, meritocratic and capitalistic view of education. Chemistry was a hurdle to cross on the way to getting ahead. It was practical therefore to cross the hurdle as smoothly and effortlessly as possible. Changing the nature of the race or creating a new path caused anxiety and stress in the minds of college-bound students. There was a tendency in school to try to release any tension or anxiety and resist any disorder in school life.

The Pilot Study

As explained above, this research project is rooted in my intellectual and educational history. My teaching career was plagued with questions and problems concerning the difficulties associated with my form of adventurous teaching. The questions evolved as I learned, developed and changed. But the most intriguing were linked to student attitudes, values, and beliefs which seemed to hold hostage my efforts to change and improve my teaching. Although I knew the importance of understanding student attitudes better, for many reasons I found it difficult to study them objectively while intimately connected to the situation. Therefore, once out of the classroom, I took the opportunity to go back as a researcher to examine the insider perspective.

I went into this pilot study hoping to find out more about anxiety and stress in high-expectation students. I soon realized that students had developed often elaborate mechanisms, "games," to eliminate anxiety and stress, and thus effectively avoid challenges associated with learning difficult concepts. I found a socially constructed ethos (Grant, 1988) that seems to make sense to students and teachers within the context of the classroom and school. Students wager limited investments against perceived gains. Teachers participated in the games sometimes explicitly, more often implicitly, and often unconsciously or unknowingly. But I was left with many questions as to why these mechanisms exist, who authored them, how they are maintained, and how students learn them.

The realization that teachers participated in their construction and maintenance suggested that these mechanisms are culturally connected. My focus is on students' own perception of their own situation. In their perception, what school community and cultural factors agree, conflict with, influence and support these phenomena? Implicit in this question is the assumption that there is a degree of congruence of goals at least three institutions: family, school science education, and friendships which provide a context for attitudes and decisions regarding school learning. The most obvious discrepant cases involved families and friendships in which goals are not congruent. In these cases, the question followed: Why and how do student decisions make sense to them even though parents' and friends' goals and students' decisions do not match?

The following four cases are taken from the pilot study and used here to introduce the student perceptions of being a good student of chemistry. They are listed in order of the conceptual development of the pilot assertions. Although I went into the pilot study looking for anxiety and stress as students struggled to learn difficult things, I didn't find much. Christine was one of the first participants to clearly articulate the gamesmanship involved in school chemistry. She also led me to deeper appreciation of the complexity of the cultural context in which these students lived and made decisions. Sam provided specific details of how getting a good enough grade in chemistry involves a complex, traditional and co-constructed bargaining system. In his perspective, this is just the way things are in school. Kristie added deeper dimensions and further complexity to the context of school chemistry when she described her dilemma. In her perspective, there are very different "understandings" involved in learning chemistry. One might even stand in the way of the other. Jaime helped me see that for her, traditional task-oriented understandings, though they earn her success, are not very satisfying because she has visions of something much deeper and better--"something awesome out there."

1) Christine: "It's all a game"

It was the beginning of lunch time when I walked toward the back of the chemistry room. In the back half of the room there were lab tables with stools where students occasionally sat eating and talking. This time only one person, Christine, sat at a table with a chemistry textbook and papers spread around her. She had a spiral notebook open, a closed chemistry book laying off to her right side, and a pencil in her hand. One of the papers that was in front of her was a chemistry lab sheet from a lab experiment her class had done the day before. The lab was about molarity and the students had worked in groups as usual. For this particular lab, each person was “volunteered” by the group members for a particular task and thereby given their share of the reporting responsibilities. The lab report would then be handed in later as a composite of the individual tasks. Each member of the group received the same grade for their efforts and therefore, the entire lab group would depend somewhat on the quality of Christine's work.

Christine was staring at the door and tapping a pencil on the notebook in front of her. It appeared that she was deep in thought. I did not know her from any of the classes I had been observing so I introduced myself. She responded: "Oh, so you are the one everyone has been talking about." Evidently the word was out in the school that I was the one from the university who was talking to students about chemistry. I said that I hope everything said had been good. She smiled. Right at this time, two other students, whom I did recognize, came into the door and began a conversation with Christine and me. Christine kept doodling on her paper while she participated in the conversation so, except that her tools for chemistry were laying there on her table, it was not very evident that she was actually doing a chemistry assignment. The other students noticed these chemistry tools and asked her what she was doing. They all had done the experiment on the day before and they started to joke about it. I listened.

It appeared as if she was trying to carry on a conversation with the other students and yet maintain at least a limited involvement with the graph she was making. As she began to page through the chemistry textbook she laughed. She started to explain to all of us that "somehow" she had gotten "railroaded" into making the graph for the group data generated in the lab and didn't know what she was doing. Her laugh suggested that she found humor in not knowing what she was doing in the graphing task, in what she saw or failed to see in the textbook, or in some connection between the book and her being "railroaded." I asked her if the textbook helped.

She said: "Yea, if I would read it ever."

I asked her: "You mean you never have?"

She said: "Well, not really--chemistry is not really my thing--besides, you don't have to--it has no function."

I looked for a response from the other students but there was none apparent. They left the room and as they went, said something about some other place to go or people to see. I was thinking about what Christine was saying and what could have been the source of her humor so I asked her who her Chemistry teacher was and if she felt successful. She said that she was in Mr. S's class in the afternoon and that "I get good grades but that does not mean I know anything." She then went on and surprised me by saying that "its all a game--telling the teacher what he wants to hear." I began to think that it was in this "game" that she found humor and that the graphing task in some way reminded her of the game. I asked her to go on, she thought for a minute, and then she began to explain what a student must do to do well.

> bullshit--you know--like there was a question on the last test that asked about saturated and supersaturated solutions. (pause) I wrote about making candy and then about world problems--and Mr. S. (her chemistry teacher) loved it. He asked if he could read it in front of class.

The emphasis in this last statement was on the "bullshit" and the "world problems." I received the impression from her inflection and the way she smiled at me when she said it, that she thought it especially descriptive of the "game" to "bullshit" about world problems on a chemistry test. Many questions came up in my mind about the game, about "bullshit", and about how "world problems" could supply fuel for or a vehicle for a process of deception. "World problems", in adolescent vernacular probably refers to current events or newsworthy topics which potentially start discussion, preferably off the teacher's agenda, in chemistry class. It is not uncommon for students to try to change the subject from what they don't know to irrelevant topics in order to waste time or to cover their lack of knowledge. Christine's point was that this subject had little to do with chemistry or the test question and yet she received credit for it. She wanted me to know that her subversion was effective. She also was making a specific point by saying that "Mr. S. loved it" and asked to share her answer with the class. She acted as if she was taking pride in deception--giving the impression of knowing what she was talking about when that may not have actually been the case. At first, it seemed that at least in her perception, "World problems" discussed were something she just thought up instead of relying on her rich chemical knowledge in order to receive credit for an essay question. However, she evidently received more than mere credit; she explained that her answer was considered exemplary. Her apparent pride seemed linked to her ability as a game player and not as a wise student of chemistry subject matter.

2) Sam: Co-constructed bargaining system

Sam explained that limited investment was possible because the system has been constructed in such a way that encourages and rewards it. Chemistry is "something you do" in high school--a right of passage to college.

Since chemistry subject matter has no apparent value to Sam, only the grade is important--a B would be adequate for what he wants. Sam told me that "if you understand 90% without much effort, they (other students) are going to take that instead of working a whole lot because there is a big gap between a B and an A... an A takes a whole lot more work than a B." If we believe Sam, a B is easy to attain without much investment because his B in the course came without any homework time and no study outside of school time. He said that he just had to listen in class and "get enough to do well." Assuming that an A would take just a little more effort, I asked Sam if he wouldn't rather work a little harder and earn a better grade. He realized my assumption, smiled and explained how I was wrong. He explained that an A takes a disproportionate amount of work and the extra 10% (his figure) of subject-matter knowledge or understanding needed to attain an A is not worth the effort. He believes that more work is involved because the understanding needed to go from a B to an A is somehow more sophisticated or at least more difficult to attain. "The first 90% comes easily for me but the last 10% would be much more work and isn't worth it." Sam was not interested in investment of work any more work than is necessary for the B.

There might be other reasons he told me this story, but Sam at least seemed to be measuring personal investment against gains. He has apparently developed a method of knowing just how much work is needed to get the grade he wants. He appeared proud and confident as he said: "If I tried, I could get an A--no problem." But he also said "I just sort of go for the ride, you know?." Ignoring any pretense for now, a good grade holds value because it makes a difference for the future. However, the student has little or no interest in the subject matter or understandings apart from their limited role in making the grade possible. Sam explains that chemistry is set up by the teachers so that the B is easy and does not require much investment of effort. He believes that is just the way it is. The teacher himself confirmed Sam's system and explained that he intentionally arranges this to alleviate student anxiety while gaining student cooperation.

It is not that Sam and other students fail to see that chemistry could be interesting or could have intrinsic value. Several of them explained that the search for understanding would not be worth the effort or compromises they would have to make. For them, success is quite painlessly achieved by a rather rote, mundane "doing the work" and "getting good grades on tests." They said this is just the way it is, not necessarily the way they want it to be.

3) Kristie: A dilemma.

Kristie feels that deep understandings of chemistry are better than just doing the work because there is a future in those understandings. Understandings will help her later in college much more than mere memorization would. She spoke of a difference between "going for understanding" and "going for a grade." It was very interesting to hear her talk of the differences even though it is not clear exactly what she meant by understanding. She contrasts understanding with memorization.

> I remember the first couple weeks I was in here, I went to Mr. S. for help and he said that I was doing too much memorizing so I kinda backed away from the memorizing stuff and tried a little bit more to understand the concepts and I think that, that made me. The actual grade was not as good but I understood what I was doing instead of just memorizing stuff-- you know? You know what I mean? So I think you have to understand what you are doing to come in here to get the kind of grade you can feel confident that you have earned... I have a cousin-- she gets straight A's and she just memorizes everything. I'm more of a B student and you know, I feel better about it if I understand it and get B's instead of memorize it and get A's.

Kristie thus found herself caught in a dilemma. She said that although she began the school year in search of understandings of real things, she soon found herself spending all of her study time with rather dull assignments, flash cards, lists of terms and formulas. She explained that good grades were actually quite easily attained because tests were based mainly on recall of information and demonstrations of simple performances. On the other hand, she knew that if she were to "go for understanding," (a right-brained, rather messy process of sitting back in thought and inquiry) it would take her a disproportional amount of time and energy. And of course because of play practice, an active social life, and so many other extracurricular commitments, time is in limited supply. Thus she explained that although the traditional path to a good grade (and success) is far less satisfying, intellectually rewarding and less practical for the long term, it is far more straightforward, efficient and immediately practical. She knew that although she would be considered successful if she made the grade her goal, she would also necessarily sacrifice the messing about in the less efficient world of real-world things and applications. She decided to "go for understanding"--a difficult decision, but wise: "the actual grade was not as good, but I understood what I was doing instead of just memorizing stuff..." And to help me understand the wisdom but also some of the frustration of her decision, she compared herself to her cousin, a student in the same class, who enjoyed a better good-student reputation. Her cousin gets "all A's by just memorizing," a policy that will come back to haunt her later in life.

> What would happen if you go on to college? I mean if I memorize something, about two weeks down the line I'm sure, at the most, I'll forget most of it. Don't you think that if you just memorize things they just go out of your brain after a while? You can just memorize so much. Her head (her cousin's) must be made of just mindless facts you

> know? And--what's she going to do when she gets into college and she has to write a paper that requires a thought process?

4) Jaime: "Something awesome out there."

Listen to Jaime as she enthusiastically described her version of "the game" she plays in chemistry.

> I didn't understand any of it (chemistry)though--like I said, I survived. I feel like I played her game. I memorized what she wanted me to memorize--I got my way through it--but I couldn't tell you a thing about chemistry. I, I mean maybe it's because I've been in high school for two years and I have learned how to beat the system. What--I can figure out what a teacher is asking and write it down but I couldn't explain to you what I just wrote down. I could explain what I memorized from a book. But if I don't understand it, if all else fails, I'll just memorize it and say: 'well, there, if this is what you want, I don't understand it'--and I have such a hard time taking a course even if I get a good grade if I didn't learn anything. It's--I mean I'd rather have a grade that represents what I learned about this so that someone would pay attention to me, tell me I need some help or take the class over again. But if I can come up and never learn anything and it's just a grade, you know at that point it doesn't mean anything--even if it gets me to a different physics course next year, it doesn't mean I know anything about chemistry.

I then asked if she felt powerless in this situation. She said:

> Incredibly (laughs and throws up her hands) I just feel like--Whatever--I don't understand it but I'll do it!

Like many of her classmates, Jaime describes herself as being involved in playing a "game." She described it as a memorization game that, in her perspective, was supported or perhaps even established by her teacher. Jaime gave evidence of this when she called the game "her (the teacher's) game." Jaime seems to feel that the game existed so that students like her can learn it and play it. The game involved "beating the system," and this involved giving what the teacher wanted to hear. There is a certain fatalism in Jaime's description. She seemed trapped by her circumstances, and by her game, and actually described something better--deeper understanding--as something to grasp or try to attain. She even seemed forced into choices which compromise her understanding.

Jaime's (and other students') "telling the teacher what she wants to hear" is out of choice, not because they feel they are not intellectually capable to understand chemistry, but because the system seems established or arranged for making limited investment of intellectual energy. This limited investment seems to be a common theme in school chemistry. Students go just so far in investing intellectual effort, study time, and energy into their chemistry course. Jaime seemed to limit her investments, and her teacher offered corresponding rewards.

The way Jaime describes her school work, she is not really required to understand molecules, atoms and the ways things work in the real world. But after Jaime described her mundane "doing the work," she paused, looked up, and then dramatically raised her hands and said: "... but there must be something awesome out there." There *must* be something of the imagination "out there" somewhere beyond the constant plodding-on in daily life in chemistry class. Something in a different world of moving, acting electrons and atoms--things unseen but wonderful--things that could help her begin to understand how real things behave and how they work.

Chapter Summary

Teaching for me is like offering an adventure in learning for anyone willing to push off into the unknown and the difficult. In schools, it is not often easy to convince students to see learning difficult subject matter as an adventure. Students learn to cope and defend themselves from difficult learning as the educational system in many ways seems to encourage limited investments. In the context of school, student attitudes and decisions about academic learning seem to depend heavily on social and cultural influences around them. One area of strongest influence is peer relationships in day-to-day life in school and in chemistry class. Understandably, students form personal meaning and learn to act in the context of these peer relationships. Other strong cultural influences include the teacher and other adults

The pilot study showed that the stage for gamesmanship as well as learning is set by these cultural influences. Students seem to make sense of their world through the filters of these influences. Teachers and other adults hold power over grades and credentials. Students often become willing or unwilling partners in bargains acted out between them and teachers in order to facilitate success. However, reflecting on these stories and the preliminary assertions concerning limited investments and games people play seemed too simple and perhaps too cynical. It seemed that the pilot study, as it should, raised more questions than it answered.

While listening to students like Jaime, Sam, Kristie, and Christine, I was impressed by their rational approach to making decisions concerning effort in school work but also by their use of the word "understanding" in explaining what is necessary for success in chemistry class. As Jaime and a few others spoke, I was struck by the contrast and potential conflict between the matter-or-fact, traditional understandings necessary for doing school work and the much deeper conceptual understandings identified by some of them. There seemed to be differences between school chemistry and another chemistry of the imagination, of the mind, and yet connected to real things and processes. The pilot confirmed and informed my methodology, my interest, and my need to explore these issues farther. Since it was found that students were extremely open, willing to hold conversations with me and to tell their stories, and able to describe their situation in the context of their culture, I decided to continue research in the same spirit and style. The questions generated in the pilot lived on, evolved, and informed this dissertation study.

CHAPTER 2

Success in School is a Cultural Construct: The Cultural Spheres of Influence Model

> [Ethnography] is defined by anthropologists as an analytic description of an intact cultural scene delineating the shared beliefs, practices, artifacts, folk knowledge, and behaviors of some group of people. Its objective is the holistic reconstruction of the culture or phenomena investigated (Goetz, 1984, p. 244).

While teaching introductory chemistry for twenty years and more recently as a participant observer in other teachers' classrooms, I have continuously been interested in how students make sense of, cope with, or resist intellectual challenges in chemistry. Students arrive from Biology which they found more relevant, and clearly defined. Most of them enjoyed learning about bugs, plants, the environment and themselves. One student explained that she could see and understand what a human organ is and does because it is so close to home. But it is almost impossible for her to imagine atoms and other little moving things in tables and chairs. Like her, many students talk of molecules, atoms and other invisible things as mysterious and difficult to imagine. Chemistry seems more abstract and potentially pushes them to different dimensions of conceptual uncertainty. This is not surprising since several researchers also point to the abstract nature of chemistry concepts (Abraham, 1994; Barrow, 1991) and suggest that there is a link between understanding chemistry and Piaget's higher stages of reasoning ability. Although this seems to be a consensus among researchers, they do not necessarily agree on why chemistry presents such problems for students.

One suggested reason is that students now need to deal with atomic and molecular models which fail to help students link experiential observations with of chemical phenomena in laboratory exercises with recognized chemistry constructs (Abraham, 1994, p. 163). They find conceptions of invisible, three-dimensional working things difficult to imagine. Another reason chemistry seems difficult to them is that chemistry is often the first time college-bound students experience a quantitative science (Reif, 1983). Students find this mixing of mathematical principles and quantitative problems difficult to deal with. Others say that while biology appeals to students' propensity for left-brained thought and action, chemistry requires a right-brained aesthetic approach (Barrow, 1991; Edwards, 1979). The latter seems foreign and strange to them so that they do not know how to act.

Although chemistry is officially an elective course, it is also very clear to these college-bound students that a good grade in chemistry is expected on the high school transcript. In fact, the good grade and a high grade-point average is often a driving force in these student's academic lives. For some, this presents a dilemma as they struggle with a desire to receive a good grade as efficiently as possible on the one hand, and a desire to learn chemistry, a much more challenging and uncertain endeavor, on the other. Because of all this, students who take chemistry are a rather special group. They have many reasons to try to be good students. They want to please their parents, culture their reputation in school, as well as facilitate future plans that include acceptance in the college of their choice. Educators and other adults, in turn, hold great hope for their success because these students are known as academically successful and are often held out as examples of the effectiveness of our public school educational system. It follows that educators need to understand them, how they make sense of their situation, and how they make meaning in the context of school culture. I have designed a model to help us understand the social/cultural influences on student attitudes and decisions.

Success: New Visions of Chemistry for the 21st Century

There have been many recent reports in the Journal of Chemical Education which make the point that chemistry education must be more than passing on lifeless, externally held information or knowledge. Herron (1983) quotes Richard Feyman and Henri Poincare: "science is *the process* of extracting meaning from the environment" (p.947). The knowledge that is the product of this process is undoubtedly important and often is present in chemistry classrooms in one form or another. The process, however, is often left out of American classrooms and therefore, competence in the process is often unnecessary for student success in science classes. As Herron explains, a theory of knowledge that is limited to the transmission of existing facts and concepts from these sources to students misses a better and more powerful understanding of the nature of science.

This limited theory of scientific knowledge as facts and concepts is evidently quite commonly held in American chemistry classrooms. Perhaps one of the important reasons is that high school teachers, thinking they know what college professors expect of their students, believe this form of chemistry knowledge best prepares them. In a survey of high school teachers' beliefs and practices in Minnesota, Lin (1992) found that teachers ranked "learning basic science concepts," as the first priority. They found this emphasis even though the chemistry teachers in their survey seemed "aware of and are implementing the recommended types of science teaching such as hands-on and process-based inquiry teaching" (p.906). It seems to high school chemistry teachers that the more content knowledge a student owns, the better.

Although high school chemistry teachers try to anticipate what college professors expect of them and their students, they often base their conclusions in myths (Yager, 1986). The result is that students are not often well prepared for their introductory college chemistry courses. Instead of content knowledge, introductory chemistry professors, according to Shumba (1994) especially value specific science process skills, scientific attitudes, and higher-level thinking skills as well as mathematics understanding. In fact, a significant number of college professors in this survey valued mathematics ability; "math through spherical trig and elementary calculus and application of those skills through word problems" (p.389) is more important than chemistry content knowledge. This study found that chemistry professors value thinking and mathematical ability as they relate to working chemistry problems in the discipline rather than problems that relate chemistry to societal issues (as high school chemistry teachers believe). Most professors want "intelligent, curious students, students with good study habits, students who want to study a particular discipline, and students with mathematical skills and knowledge" (p.389). The consensus seems to be that thinking skills, attitudes, and mathematics knowledge are vital while more abstract chemistry content knowledge can come later. Many college professors said that in high school, there should be more concern for making chemistry more fun and less scary. When asked about the content knowledge high school teachers valued, college professors generally felt that only the introductory, basic chemical concepts were most important.

It is, therefore, quite clear that there are differences of opinion or discrepancies in what should actually be taught in high school introductory chemistry classes. Barrow (1991) states that the chemistry education enterprise should get back to "real chemistry" that has longer-lasting, practical value for students. He states that too many teachers hold their students back in rote, often meaningless, concrete fundamentals because they feel students are not developmentally ready for higher-order thinking processes. Instead, in his perspective, educators should be very careful not to sell students intellectually short. They are capable of some of the higher-level thinking skills necessary for an honest study of chemistry if they are nurtured.

> We need not wait for some mysterious general mental development or change to happen in our students. ...Then the formal reasoning, the active construction. or the synthesizing right-brain activity that is necessary for any honest study of chemistry can be nurtured (Barrow, 1991, p.4).

According to Barrow, a key to improving chemistry education is bringing students into mental contact with the substance of the discipline, not all at once, but with a few basic concepts at a time in greater depth.

> The principle goal is to make a few actual substances and reactions part of that body of experience that can be drawn on automatically, when higher level thoughts are processed (Barrow, 1991, p.5).

He uses a metaphor of a teacher leading students to intellectual "base camps" from which they together venture out on other related learning adventures. He thus suggests "some small pieces of the chemical world and fostering the intellectual development and appreciation of chemistry that can grow around such base camps" (Barrow, 1991, p.6). The process of discovery and the intellectual venture is more important to him than the choice of which fundamental concepts or principles to cover. Barrow's "base camps" would force teachers to pick and choose between basic concepts, concentrate in depth instead of breadth and thus avoid the temptation to "cover the book."

In striving for chemistry literacy, the teacher would need to make positive efforts to not only be aware of students' reasoning abilities, but also challenge their development. He calls for a constructivist approach which would support these ideas and goals (Ausubel, 1978) and "right-brained activities" which focus attention on attitudes and values such as curiosity, wonder, and delight in learning new scientific things. The goal is to produce students who are chemistry literate. He therefore stresses three things necessary for really becoming chemistry literate: a Piagetian formal reasoning, an active construction of knowledge, and a synthesizing right-brained activity.

According to the American Association for the Advancement of Science (AAAS, 1989), the scientifically literate people are able to make meaningful connections to the real world of substances and their transformations. Project 2061's *Science For All Americans*, is a rally call for science literacy for *all* Americans. The authors, instead of traditionally asking for more and more content, focus on the philosophical substance of science (including chemistry) and how to teach it more effectively. Literacy, in this vision, is a set of understandings and scientific habits of mind. Those involved in science find it a process and set out through inquiry to discover patterns and knowledge of the natural world. Emphasis is on the use of evidence, the use of hypothesis and theory, logic, and imagination. Science explains and predicts while avoiding bias. According to AAAS, the scientific enterprise is a cooperative human and endeavor which is socially constructed with individual, social, and institutional dimensions. The knowledge that is produced in this process is tentative but also durable. Although there certainly are fundamental concepts, and there is a science language in which the literate person should be able to converse, there are no agreed upon lists of terms and no checklist of facts. It is also a goal that all humans should participate in the pleasure of coming to know the universe better. Therefore, the focus of Project 2061 is on ideas, ways of finding out and knowing, not on disconnected, on-paper vocabulary and the memorization of facts.

> *Science for All Americans* is based on the belief that the scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both the diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (p.4).

Knowledge of the physical sciences including chemistry is, of course, an important component of scientific literacy. All the AAAS and NRC (1996) standards for and characteristics of science, the knowing and doing of science applies to chemistry. Chemical knowledge is tentative, durable and socially constructed with individual, social, and institutional dimensions. So in high school chemistry, it should be a fundamental goal that all participants should actively partake in the pleasure of coming to know the chemical universe better. They should also know how chemistry dovetails and integrates with practical knowledge, technology, and other disciplines. Therefore, the focus chemistry for the 21st century should also be on ideas, ways of finding out and knowing, not on disconnected, on-paper vocabulary and the memorization of lifeless facts. The successful learner of the discipline should be one who continually improves his/her state of scientific literacy.

Success: Personal Meaning is Formed in Context

> Each man is given a scientific heritage plus a continuing barrage of sensory stimulation; and the considerations which guide him in

> warping his scientific heritage to fit his continuing sensory promptings are, where rational, pragmatic (Quine, 1953).

Conceptions of culture have a long history in ethnographic anthropology. E.B. Tylor, as early as 1871 explained, "Culture or civilization, taken in its widest ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, laws, customs, and any other capabilities and habits acquired by man as a member of society" (Mehan, 1980, p.131) Much later, Goodenough (1964) placed some constraints on this older conception of culture when he wrote:

> As I see it, a society's culture consists of whatever one has to know or believe in order to operate in a manner acceptable to its members, and to do so in any role that they may accept for themselves" (Mehan, 1980, p.131).

There are standards of knowing, believing and acting which an individual needs to gain competence in order to establish membership in any culture. Self concept is often based on what a person decides is acceptable for self in relationship to these cultural standards. These things are learned as the person negotiates a viable path through culture. At the same time, people learn their role in culture by interaction with the competent members of culture, who themselves can look back on past success in culture. For example, a high school student can look up to the teacher as a competent member of the culture of the discipline taught. Or, less successful students can look to more culturally competent peers. This learning process is important and necessary for anyone to be able to live comfortably and successfully in culture. Once the appropriate behavior is learned, the appropriate behavior needs to be effectively demonstrated if one is to be considered successful. In other words, the person needs to transfer what is known into acceptable behavior and a viable role.

These behaviors and demonstrations are material manifestations that give evidence of knowing and doing what it takes. Goodenough calls these material artifacts.

> [W]e shall reserve the term culture for what is learned, for the things one needs to know in order to meet the standards of others. And, we shall refer to the material manifestations of what is learned as cultural artifacts" (Goodenough, 1981, p.50).

Culture is learned and the physical evidence of cultural competence or membership are the material artifacts. "What they learn are the necessary precepts, concepts, recipes, and skills--the things they need to know in order to make things that will meet the standards of their fellows" (p.50). So culture exists in the mind and actions of people. It is one's representation of and participation in the world. For the researcher, material things are evidence of culture and help us understand culture.

The interplay between standards set both externally and internally is as complex as it is interesting. For Goodenough, culture is essentially an individual construct--it exists in the mind of the individual--the things one needs to know in order to successfully live in culture. There are artifacts of course, but Goodenough's focus is on the criteria, the personal judgment and individual meaning assigned to those artifacts. Personal representations of the artifacts are more important than the objects themselves. In order to help us understand his position, he explains that his conception of culture is quite different from Geertz's conception of culture.

> He (Geertz) focuses on the artifacts--exposure to artifacts is what people share--and states that these artifacts as public symbols and the public meaning they have acquired in social exchanges constitute culture. We

> take the position that culture consists of criteria people use to discern the artifacts as having distinctive forms and the criteria people use to attribute meaning to them. We address the problem of how these criteria, which are individually learned in social exchanges, can be said to be public at all, a problem Geertz does not address. (Goodenough, 1981, p.59).

Geertz writes that human behavior must be viewed as "symbolic action" and that culture is in the public, social mind instead of the individual mind. "Culture is public because meaning is" (Goodenough, 1981, p.12). His focus is on the product or the artifacts themselves which are symbolic--the things *are* culture. Tables, chairs, lab reports, textbooks have meaning in context and are culture set before the observer's eyes.

In his description of a "Balinese Cockfight," Geertz also describes culture as an "assemblage of texts" (Geertz, 1973b, p.448). "Text" is beyond written material and beyond verbal--it is metaphorical. Cultural forms or artifacts can be treated as texts--"imaginary works built out of social materials" (p.449). Because of this, and perhaps in a way of gaining some form of understanding of our world, we come to know our world in terms of metaphors (Lakoff, 1980). In other words, we construct our own ideas of local knowledge, our own constructs of our place in culture. As ideas are formed, we learn culturally appropriate, or purposeful behavior, what Geertz calls "minded action."

In Interpretations of Culture, Geertz (1973a) argues that "minded action" originates and evolves in culture and that mind cannot exist without culture. The word "action" refers to behavior that has personal and cultural meaning. A person acts according to how he/she has learned to act in the context of culture. Therefore, a person's action is directly related to, and flows from the thought and sense making of the individual. Action always has meaning associated with it. That meaning, mind, is culturally derived and exists in the brain of the individual.

Here, Geertz's position is similar to Vygotsky. According to Vygotsky, mind emerges from culture (Wertsch, 1985). Although mind is not restricted to interactions, it is through interaction with others that mind develops in the individual. Mind is therefore a social/cultural construction as a person learns to master the conventions of the culture. According to Vygotsky, individual meaning is socially constructed. The term "social" has reference to group communicative processes and social institutional processes (Wertsch, 1985, p.209ff). He explained that although biological and neurological factors certainly have a role in the making of constructs, they must be understood within social context. Therefore it would be an oversimplification and a mistake to reduce a person's ability to make sense of his world to biological processes. Avoiding this reduction requires a change of focus. Specifically, in Vygotsky's view, social factors operate within biological frameworks and are compatible with them, but they can't be reduced to them (p.21). In the complexity of the human mind, no single explanation is adequate in explaining the process of making meaning. Biological processes work hand-in-hand with sociological processes in the immediate sense and cultural processes in the broader sense.

It is therefore quite clear that students in chemistry class construct meaning in terms of their surroundings, in light of social, institutional phenomena. For example, as the child communicates and interacts with the adult, internalization occurs and the child learns. The social therefore creates the conditions, the context, in which the mind is formed and therefore self concept is constructed. By "mind," I mean the set of personal constructs one develops as he/she grows up in society and culture.

> "Mind" is a term denoting a class of skills, propensities, capacities, tendencies, habits; it refers in Dewey's phrase to an "active and eager background which lies in wait and engages whatever comes its way." And, as such, it is neither an action nor a thing, but an organized system of dispositions which finds its manifestation in some actions and some things (Geertz, 1973b, p.59).

The mind is a system of dispositions that is manifested in meaningful actions and things; mind is dependent on culture as it also forms culture. It is not only manifest in action, but also in things or cultural artifacts. Language, scientific descriptions or theories, technological objects or tools are cultural products of minds that also go on to influence the evolution of minds. Geertz goes on to say that not only is one's mind made up of thinking and acting, but also of how people feel about things. Thus, mind, which forms and is formed by culture, includes thinking, acting, and also feeling. Therefore, Ethnographers not only try to understand what a person knows and to understand meaning in behavior, but ethnographers also ask about how participants feel about things if they are to learn about what is in participants' minds. All of these things are part of and reflective of culture and help us understand students making sense of their world under social, cultural influences.

Geertz considers society built on emotions and individuals put together (p. 449). There is a cultural ethos that is shared and personal; both public and private. "The culture of a people is an ensemble of texts, themselves ensembles, which the anthropologist strains to read over the shoulders of those to whom they properly belong" (p. 452). Therefore, in culture, all people have standard of logic and also empirical standards for assessing the validity of propositions. Customs are behaviors with purpose and viability in the context of common sense and public meaning.

As Singer (1988) explains, Goodenough's theory "ignores such broader aspects of culture as traditions, existential axioms, root metaphors, beliefs, attitudes, world view, and values" (p.3). It seems that membership in a culture includes much more than demonstrating competent action and assuming a viable role. For example, there are also necessarily material manifestations of a person's ability to successfully assume a viable role.

Individuals cannot be separated from their cultural context, and epistemological access to high school subjects depends on socially-developed constructs and the filters of cultural influences. More specifically, the newness of chemistry in many ways conforms to, but also runs up against traditional constructs of schooling and school learning. Through communication with others and interaction with institutional processes, students develop personal constructs of meaning. These are socially derived meanings and therefore, the analysis model places the individual student in the center of concentric cultural spheres. Each sphere represents a cultural influence through which the individual student views her world and how the world works. Because the subject of study is chemistry, the larger context in which this cultural influences exists is the world of chemistry disciplinary knowledge. Ideally, chemistry class and chemistry learning provide a student with epistemic access, the ability to know and understand this world (Danziger, 1990). Although there may be many beneficial, tangential things learned, epistemic access is, of course, the central expressed purpose of chemistry courses. However, this access is limited by a veiling or filtering process of the cultural influences of peers, family, popular culture, teachers and institutions.

According to Goodenough (1976) to find out how things work in culture, a competent ethnographer enters a culture, interacts with the people conversant and competent there, and learns to understand them. The researcher attributes concepts, beliefs, and principles of action and organization.

> The culture of any society is made up of the concepts, beliefs, and principles of action and organization that an ethnographer has found he could attribute successfully to the members of society in the context of his dealings with them. ... His competence is indicated by his ability to interact effectively in its terms with others who are already competent (p.3).

In Goodenaugh's perspective, public meaning is still significant and should be the subject of study. Goodenough goes farther than Geertz to explain cognitive and emotional factors which make it possible for the novel event to be meaningful. If culture is in the individual mind, students can experience novel events and make them meaningful. Under Geertz, we have a hard time accounting for these. Students in schools meet novel events in chemistry and perhaps, as stated before, these are what make chemistry problematic and uncertain. But students do make meaning and learn culturally appropriate attitudes, feelings and behaviors. They learn how to be culturally successful. Along with Goodenough, I take a perspective in my model that culture centered in the mind of the individual and the individual makes sense of his life in cultural context. Therefore, self is in the conceptual center of the concentric cultural spheres of influence.

It is not that these spheres of influence are the same in every cultural situation or in every school. School life varies from place to place, from school to school and from classroom to classroom. Each setting has its own cultural constructs for action and beliefs. And in schools, culture is learned and practiced in context of the watchful, evaluative eyes of administrators and teachers. The teacher establishes, often through negotiation with stakeholders, the standards for appropriateness and also measures a students' success in attaining these standards. At the same time this process is evaluative, it sets incentives for leaning culture. This process is multifaceted, complex and not necessarily easy to learn. Some of which needs to be learned and demonstrated is straightforward, and other things are hidden, implicit or written between the lines of interaction. As Singer (1988) explains, cultural differences require very basic, situation-specific standards for behavior.

> There are indeed considerable differences between cultures as to how one appropriately conducts oneself in interacting and communicating with other people: How one gets the floor in conversation, how one shows attention or respect, how one makes a point or indicates concurrence or disagreement, how one asserts oneself or defers to others, how one indicates approval or disapproval--all of these very basic aspects of classroom life vary from culture to culture" (Singer, 1988, p.4)

Human behavior is purposeful and people learn from consequences of past actions. They place value on things and things learned, depending on their goals and purposes, and this effects the decisions they make regarding future actions. Thus, acting together, people establish customs and customary behavior. Students in chemistry develop standards of logic and learn to assess the validity of that logic in interaction with others. Student behavior, as it gains associated meaning and relates to success in chemistry thus becomes part of customary practice.

Thus, in examining the content of culture we must take into account the entire range of phenomena that is part of the chemistry student's experience and that become the subject matter of learning in chemistry but also the culture of school chemistry. There is no solid precedent set for this in educational research. In fact, there are relatively few studies of the content of secondary school culture from the insiders' perspective (Cusick, 1973; McNeil, 1986; Peshkin, 1978; Solomon, 1992; Willis, 1977). There are fewer studies of student perspectives and the culture of secondary school science.

Personal Meaning in School is Socially Constructed

> Culture, then, consists of standards for deciding what is, standards for deciding what can be, standards for deciding how one feels about it, standards for deciding what to do about it, and standards for deciding how to go about doing it (Goodenough, 1963, p. 258).

High schools each have their own culture or standards for meaningful action that enable a person to be successful in that culture. Competence in school chemistry is a construct; it is defined, learned and must be understood culturally. Standards for competence are often set by or at least passed on to others by persons already competent in a particular culture. The novice entering a culture learns these standards from these experts. Teachers could be considered competent in school chemistry, and their students are novices. Primarily, teachers set personal competence standards for their own classroom and also for the study in their discipline. The successful student learns what is needed to become competent according to these set standards. Learned competence is more or less accurately measured and evaluated by this already-competent teacher. Peers, parents, and other representatives of the institution also make significant contributions in terms of cultural influence, but the teacher is the local expert. The culture of a science classroom, and a person's ability to become culturally competent (successful) depends on these interrelationships between experts, novices, and other cultural influences.

The cultural influences working in schools have been largely ignored in educational research, especially the multilevel meanings students form in the most ordinary taken-for-granted events. This omission leaves us searching for common sense meanings associated with daily life in schools and descriptions of schooling.

Okey (1990) and Fine (1986) studied dropouts, their families, and cultural meaning in action. Okey came to the realization that rural students and their families made decisions regarding schooling and academic work in the context of symbolic interaction. Students often adopted their parents' conceptions of school and school learning because they worked for them. Dropping out made perfect sense within this environment of cultural influence. Fine's research involved a very different student population but came to similar conclusions about student decisions. She describes their dropping out through their eyes and meaning is revealed in their words. They also made decisions that made perfect sense to them in the context of their environment. In both of these studies, many economic, social factors and structural features of schools contribute to the sense making and self concepts of adolescents. It is clear that students live and make meaning in the context of cultural influences.

Coleman and Hoffer's Public and Private High Schools: The Impact of Communities (Coleman, 1987) was an important and controversial study that compares public, parochial, and private sectors of American education. They conclude that family influence is the most important factor in determining a student's propensity for success in school. Factors like SES, minority status, as well as absence of one or more parent, parental attitudes toward education, and whether or not parents work all play significant roles in determining whether or not a student will get along well in school or rate highly in academic achievement. In another study, Rappoport (1977) also found that family influences are significant in student decisions regarding school work.

His focus was on the characteristics of family such as career aspirations, and family relationships with the life of work. Delgado-Gaitan (1988) did an interesting study of Chicano families and found that for those who were successful in school, a strong home support system that values education was vital. In a study of poor black children, Clark (1983) concluded that it is the overall quality of the family's life style, instead of other measurable factors (number of parents in the home, parents' marital status, status, etc.) that determines whether or not a child succeeds in school. According to Clark, the overall quality of family life is determined by the family members' beliefs, activities, and overall cultural style (p.1-2). According to Clark, the family's ability or desire to support a student in school depends on the family socio-cultural history and expectancies. "A family's ability to provide a home environment that prepares its children for future success, including success in school, develops out of past experiences with cultural tasks and social rewards" (p.x).

Other studies were more general ethnographies of the lives of students of high schools as institutions. Many years ago, Philip Cusick walked the halls of an urban high school and found that students' behavior has personal and social meaning. Cusick's focus was on how their action makes sense to them and to the observer in the context of schools as institutions (Cusick, 1973). More recently, in The Educational System, (Cusick, 1992) he refines his conceptions of these institutions by saying that the educational system is composed of a set of "overlapping collectivities" where social reality meets social ideals. The purposes that schools are assigned often fly in the face of social reality. Because of the conflict between collectivities, the school system's purpose is reduced to control.

> The first collectivity is society with all of its differences that it sends into school with its children and that show up in the way children behave. The next collectivity is the students and teachers, the former exhibiting their diversity, the latter charged with channeling the diversity into more narrow lines (p.68).

According to Cusick, the school system is actually established and maintained to control students. Because of this, control is the central problem in American public schools. He came to this conclusion by observing and listening to students and their parents, and reviewing other studies which focus on students' lives in the socio-cultural context of schools and schooling.

There are other important studies of schools as institutions and the cultural influences in and around them. Several of these studies focus on student perceptions and socially constructed meaning in context. Willis' (1977) "Lads" found schooling counterproductive to social goals and they understandably resisted. In his schools, socialization and compliance seem to be the curriculum. McNeil (1986) also comes to the conclusion that student experience in schooling is shaped by the tensions between the school goals for education and the persistent, institutional need to control students. These and many other studies give special attention to discrepant behavior and personal action that sets the student up for failure or perhaps even voluntary and involuntary removal.

An especially helpful and wonderful book about life and learning in schools, Lives on the Boundary (Rose, 1989), is a personal commentary about literacy and those who struggle in the American educational system. Rose tells the stories of class and cultural barriers.

> ...language and human connection, literacy and culture, and it focuses on those who have trouble reading and writing in the schools and the

> workplace. It is a story of abilities hidden by class and cultural barriers (p. xi).

In schools, we test, grade, and measure students and then we group and label them. Rose focuses on those who live in the "educational underclass." He calls his book a "vignette and a commentary, reflection and analysis" (p.xii) of lives in schools and in American education. As he tells stories of himself and other people struggling with literacy, class and culture boundaries are established between people and between people and their potential. If we are to break down these boundaries, Rose asserts that we will need to reform education:

> To have a prayer of success, we'll need many conceptual blessings: A philosophy of language and literacy that affirms the diverse sources of linguistic competence and deepens our understanding of the ways class and culture blind us to the richness of those sources. A perspective on failure that lays open the logic of error. ... Finally, we'll need a revised store of images of educational excellence, ones closer to egalitarian ideals-- ones that embody the reward and turmoil of education in a democracy, that celebrate the plural, messy human reality of it (p.238).

One set of rather recent ethnographies done by Peshkin focus on participant perspectives and institutional tensions. For example, Peshkin (1986) studied the students' views of structural and social factors at work in a private Fundamentalist Christian school. His school presented a context for rather intense cultural influences across people and institutions. He described school rituals and related understandings as well as conflicts between constituents and their school. The school was set up to meet individual and community needs. In a complementary way, individuals made sense of their situation in terms of what was going on around them.

Peshkin's work has been instrumental in my thinking about focus and research questions. In <u>Growing Up American: Schooling and the Survival of</u>

Community. Peshkin (1978) tells the story of how he entered Mansfield High School, a school at the center of small-town America, to study student life in American high school education. The high school is a "top notch school for this community" because it fits cultural expectations and society goals. His focus is on those who hold positive views of school and schooling in their community. He went there to study the relationship between school and community. Although there may be many questions about the quality of the education, he found an ethos that mutually benefited the school with its participants and society in Mansfield.

> Mansfield's ethos, the guiding belief... the spirit that motivates the ideas...or practices of people has been formed partly in response to the realities of small-town rural life and partly in reaction to the predominance of urban society (p.193).

Mansfield High School is a school that belongs in Mansfield. It is successful because a majority of its students feel successful. But as Peshkin explains, success in Mansfield only has meaning in social and cultural context. A school's success and the success of its students depends on how well the culture of the school dovetails with the culture of its constituency. In Cusick's words, the problem schools face is for students "to mesh their class and cultures with the school" (Cusick, 1992, p.69)-- not necessarily an easy or often rewarding task.

By talking to seniors in reflection about their high school careers, Peshkin learned something about their conceptions of success.

> It seems that the school experience often provides more than those who do not intend to go to college want, but no more than the college-bound wish to work for. Somewhere between these modest points Mansfield's teachers pitch their tents, accommodating themselves to a level of success with which most participants learn to be comfortable (p.180).

This negotiation happens in American schools as students construct meaning in relation to their social and cultural situation. Their action, choices and conceptions of schooling make sense to them in context. To be successful then, the student must understand social norms and social constructs. "[S]ocieties, like lives, contain their own interpretations. One has only to learn how to gain access to them" (Harre, 1994). Access to societal norms can often be gained by learning to negotiate common experience. Because fellow students share common experiences and a shared social unit or structure, these processes and constructs of schooling have common- sense character. Or, in other words, they share a folk psychology-- according to Bruner, an ethnopsychology.

Bruner (1990), explains that "Folk psychology... is a culture's account of what makes human beings tick...I should call it 'ethnopsychology'" (p.15). In fact, he claims that institutions like schools *enforce* folk psychology and that "culture shapes human beings to its requirements" (p.15). In trying to understand how common sense or folk psychology works in high schools, it is significant that culture *enforces* and therefore shapes folk psychology. A student brings his own constructs or meanings to the situation but the situation, in turn, interactively influences the making of meaning.

> [Folk psychology is a] reflection of culture, it partakes in the culture's way of valuing as well as its way of knowing. In fact, it *must* be so, for the culture's normatively oriented institutions--its laws, its educational institutions, its family structures-- serve to enforce folk psychology. Indeed, folk psychology in its turn serves to justify such enforcement (Bruner, 1990, p.14).

What students value and know in relation to subject matter, their common sense of it, is directly related to and in fact, dependent on cultural norms. These norms are established outside of the individual with the individual's cooperation if not support. The shaping is done interactively "in situ" as a student enters an historically developed and established culture and further shapes it through personal influence. Thus the student both adopts a common sense and contributes to it. The student cannot be apart from this cultural process and still be part of his class.

Common sense or folk psychology historically is a product of the cognitive revolution. Harre (1994) even gives Kant much of the credit for the beginnings of the cognitive revolution. The cognitive revolution helped us shift our focus to the human mind:

> The philosopher par excellence of this move in psychology. ... He [Kant] went beyond Hume and the early empiricists to emphasize the need to take seriously the rational structure of the mind and the way that the mind synthesized or ordered experiences on the basis of its cognitive capacities (p. 16).

It's not that Kant used present paradigm terminology, of course, but he used similar rules of understanding. In Kantian philosophy, the human mind uses rules of understanding to negotiate the cultural domain. Much later, according to Harre (1994, p.13), rule following came to the center of attention again during Bruner and Miller's first cognitive revolution. Rule following implies uniform, orderly, mechanistic forms of behavior. More recently in the cognitive revolution, the emphasis has been more on meaning than mechanistic rule following. A person attributes meaning on events and thus develops personal constructs through which he comes to know his world. This is still in the context of normative accountability.

> Instead of roles and rules, which are rigid concepts, we substitute the notion of "position of speaker" for "role." Instead of citing rules to account for the structure of a discursive interaction--say, a conversation-- we use the idea of narrative conventions. ... A narrative

> convention is simply an expression of the ways in which we tell stories in our culture (Harre, 1994, p. 34).

Students do not merely learn the rules of their culture or the norms of schooling for success. They also learn certain attitudes, practices or performances that make common sense, or work in practical ways and hold personal rewards. And some practices and attitudes do not. This places students in control of, but also under the control of right and wrong performances. To be deemed successful, one needs to have the common sense but also needs to be able to perform or act in certain culturally appropriate ways. In other words, a student must know what behaviors and performances are appropriate--what rights and duties necessary--for success in culture and then act accordingly. At the same time, students are agents in forming these norms and appropriate actions because the construct formation is an interactive process. Rights and duties are on-going, somewhat flexible, and negotiated in social context.

A recent interpretive study of the culture of school physics and student perspectives of knowing, learning and cultural appropriateness was conducted by Roth and associates (1994). The researchers found that students "pieced together" their conceptions of appropriate action from classroom experiences and cultural cues. They called the classroom a "dynamic cultural ecology that involves the various social and cultural forces that students and teachers exemplify" (p.6). Student conceptions and views of their situation are thought to have a significant effect on student learning. It is vital therefore that the cultural ecology of the classroom is most conducive to learning. Educators have traditionally not understood or paid enough attention to this complex cultural ecology of schools. In response, the researchers call for a new epistemology of school culture and a re-conceptualization of the ecology of learning. Prerequisite to this is the understanding of student views.

> Before we can expect significant shifts in the epistemology of school culture, we must understand all the three components of classroom culture: students, teachers and the context of learning. Once the myths, metaphors, and conceptual framework of all of these components are known, they can serve as a powerful foundation of meaningful learning in a re- conceptualized ecology of teaching and learning (Roth, 1994, p.7).

According to Roth, culture plays crucial roles in determining student views of appropriate behavior and views of the nature of knowledge. When the author and assistants attempted to elicit student views on the nature of scientific knowledge, they found that students generally use an objectivist conduit metaphor (Roth, 1994, p.26) of science knowledge in which information is sent from the transmitters of knowledge, teachers and textbooks, to the receiver, the student's brain. Under this conception, communication amounts to the teacher feeding and filling hungry and mainly empty student heads. Laboratory exercises are "cookbooks" and have little relation to scientific discovery or inquiry. Teaching from a constructivist epistemology is therefore risky because it does not fit student conceptions of knowledge and of doing school. Although this study is a start in understanding the culture of school science, the authors admit it is very limited. One of the most disturbing limitations is related to the fact that the study was conducted in an all-male school. Therefore, the findings lack the character and complexity of a more typical, co-ed high school classroom setting. It also is a study of a rather non-traditional "open-inquiry" framework for physics education.

> [S]tudents were free to decide which phenomena to investigate (within topics prescribed by the (Canadian) ministry of education), which

> research questions to frame, how to design the set-up, and how to collect the data" (Roth, 1994, p.8).

It is quite clear to Roth that physics students' perspectives and meaning are socio-culturally derived. The author, in a derived model or "grounded theory," describe student-held physics knowledge has having two major aspects, cultural and individual. In the cultural aspect, and from the student's point of view, mathematical and conceptual frameworks are culturally mediated and presented to them by teachers and texts [usually in textbooks] in the form of lectures, notes, and additional readings (Roth, 1994, p.24-26). Although directional arrows represent how these factors relate, their model seems to place individuals, peer groups, and teachers outside and aside from culture. The authors are not very clear about what they actually mean by culture. Therefore, what "cultural cues" are and how these can influence a person's physics knowledge or conceptions of schooling is also not clear. Perhaps this uncertainty about cultural influence is due to the nature of the research design. The data was collected through questionnaires and student written responses to questions. Some interviews of students were attempted, but after a total of 11 student interviews were conducted, the process was cut short because the researchers felt the "additional information was largely redundant" (Roth, 1994, p.10).

Personal Meaning in the Context of Chemistry Class

If we adopt Forgas' (1981) definition of cognition in the "broader sense", student sense making, or the formation of meaning, is "intrinsically, inevitably and profoundly social" (p.2). Therefore, knowing chemistry, or gaining epistemic access, is socially structured and develops continually through a person's educational life. In other words, constructs regarding schooling and chemistry develop socially and culturally as the student grows, relates and becomes more educated. By the first day of high school chemistry class, a student has built strongly-held conceptions of chemistry and attitudes about chemistry. Of course, as the school year in chemistry class progresses, "knowledge is socially structured and transmitted" (p.2) even farther.

This is a socially interactive process where student and other cultural influences negotiate meaning in context. This interactive negotiation process in Chemistry class, in relation to chemistry itself, is not individualistic but social and collective. As Danziger (1990) explains, a student of any discipline will not develop disciplinary knowledge only through an individual, lone interaction with nature. Instead, epistemic access, the beginnings of developing knowledge of the discipline, is social in nature and must be mediated by social conditions.

> If , however, we think of reality as a domain that exists independently of empirical constructions, then the question of access to such a domain cannot be decided on the level of a particular empirical investigation. That would imply an epistemic individualism according to which knowledge is the product of an interaction between an individual investigator and nature. But epistemic access to the world is collective--it is always mediated by the social conditions under which groups of investigators work" (Danziger, 1990, p. 195).

Danziger is discussing the discipline of psychology, but his position also clearly applies to any discipline including chemistry. The "however" in the quote above, follows his thoughts about the "cult of empiricism" and its Humean view or reality taking control of the discipline of psychology. He points out that the limits of access to psychological reality are often decided on a technical level. However, there *is* an ontological reality, and a personal access to it cannot depend alone on personal, empirical investigation. This is contrary to the positivist view that would limit reality to the observable, to empirical evidence and to individualistic, personal reality as we come to know and understand the world.

But to say that epistemic access is collective suggests something different than that evidence is assigned collectively. Evidence is a social construct when a scientist is involved in disciplinary discourse. Scientists usually do not work alone and if they do, they need to also partake in disciplinary discourse. Scientists need others to criticize, confirm, relate to and react to what they think they see in data. Since epistemic access to this world of science is collective, the only way a student can come to know in the discipline is through social means--through socially constructed meaning. In the case of this research, the investigator is not only trying to understand chemistry knowledge, but also trying to investigate personal constructs concerning rights, duties, performances, and attitudes in culture that can contribute to success.

In one Kuhnian and optimistic sense, students are socially constructing knowledge of the discipline. Thus the chemistry discipline is the outermost context for this model. But as the student voices were heard in this research, it became quite clear that their understandings of chemistry are more often about knowing how to perform the tasks and performances required in school. Therefore, the chemistry the student comes to understand, and the epistemology gained, is not necessarily congruent with what a chemist or expert in the discipline would know. Cognition is not necessarily about chemistry as if students were the "little scientists." Understanding chemistry in the epistemological sense often seems far removed from daily norms and routines. In students words, chemistry often remains "out there somewhere" and out of conceptual reach.

Success: Earned Through Conventional School Performances

Introductory Chemistry teachers often proceed as if there were a consensus as to what to teach and how to teach it. According to Steven Hawkes (1992) and others, a common cliché survives that students must learn the "fundamentals" so that they can be equipped for bigger and better things in later science classes. Too often, a list of fundamental principles are presented to students with hope that some, as they get smarter, will be able to make real-world connections. The hope is that later, when they are up to the task, their knowledge will become relevant and meaningful. However, Hawkes proposes that in reality "[N]obody knows what aspects of introductory chemistry are actually valuable to students or which of many 'fundamental' concepts they will find most useful" (p. 178). Not only is there no consensus of which fundamentals, it appears that "we have chosen to teach fundamentals that are of little value to the student while neglecting fundamentals of greater value" (p. 179). He points out that instructors and researchers should carefully examine areas of student interest and world applications to discover content with relevance and therefore greater value. Because this is not often done, many students respond with dislike or contempt for the chemistry they encounter. He laments the fact that even in his own introductory chemistry classes, he "wasted millions of student-hours" (p.181).

In traditional chemistry classes, instead of focusing on "real chemistry" (Barrow, 1991), instruction and learning is actually focused on paper, where symbols become the reality and traditional performances provide a path toward students' success. Barrow states persuasively that this chemistry is not chemistry at all. What is being passed off as chemistry in introductory chemistry classes, he says, is a "fraud and a sham" (p. 449). Typically, on-paper chemistry does not meet the needs of students and contributes little to scientific literacy. He states that although most students manage to do what is required to be successful, few know what chemistry is all about. They are thus not only left unprepared for further study in science, they also most often lack an enjoyment and satisfaction of basic understandings, inquiry and discovery in the discipline. For example, problems are too often solved with the factor-label method and the periodic table is a display of information rather than an organizational tool. Barrow laments the fact that traditionally, "principles of chemistry" or "problem-solving" alternatives to chemistry are presented in American classrooms instead of real chemistry. The result is that few students in introductory courses even experience chemistry as science and few see any practical value or applications for what they learn. Certainly then, few graduates of the typical high school chemistry classes are chemistry literate.

> Substances and their transformations, the proper subject matter of chemistry are in no part of the students' background and are not part of the experience provided by the course. Students memorize what the teacher and the textbook tell them and base the answers they give on what they have been told. They do calculations according to accepted rituals. Very little of the course material is based on or even related to, anything students have seen or experienced (p.451).

Gallagher and his students provide further evidence that science is not what it should be in high school classes (Gallagher, 1991). Between 1984 and 1987 Gallagher' team conducted an ethnographic study of 27 secondary science teachers and found that teachers virtually made "no reference to the scientific method and the objective character of science or to the means by which knowledge being studied was formulated" (p. 125) They found that there was virtually no time devoted to the nature of science, how scientific knowledge develops or how scientists validate knowledge. Instead, the major focus was on what the teachers know best--on the body of facts and information to cover in their course. Although they know the facts and concepts of chemistry, most teachers have little knowledge of the history, philosophy, sociology or even the processes of science. For the typical science teacher, symbols are the reality and their focus is often directly on paper. Gallagher suggests that this is understandable because too often, teachers' academic preparation does not include these perspectives and they are never challenged to develop a deeper relationship with their discipline.

> None had experienced an advanced course in science, such as a senior seminar, to aid in integrating the knowledge learned in twenty or more separate discipline-based courses that compromise the undergraduate major in science (p. 126).

It is not surprising that teachers regularly miss opportunities to lift their eyes and minds off paper and make their subject apply to their students' real lives and world. The teacher is an authoritative presenter of facts and rituals to memorize and learn to repeat on examinations because that is the only science teachers know themselves. Teachers will tend to replicate the science they learned themselves in their own academic preparation to teach. Therefore, there seems to be a discrepancy between some of the rhetoric and the practice of teaching in college-level chemistry courses. College-level professors often complain about quality and the understandings of the students who enter their introductory chemistry classes, but they seem to forget that the high school students learn from teachers who learned science in college chemistry courses (see Ch. 6).

It is not that these high school teachers teach poorly. Instead, if student success is a measure of good teaching, the chemistry that teachers know and require of their students seems to be taught very well. Since chemistry teachers have very limited backgrounds in real chemistry and fail to really comprehend many of the chemical events in the natural world, the consequence is often inaccurate and inappropriate chemistry taught quite well (Gallagher, 1991, p. 132). According to Gallagher and his colleagues, teachers often present science from a positivist viewpoint, have little knowledge about integration and applications to real life and seldom portray science as a process of formulating and validating knowledge. "Failure to characterize scientific knowledge as tentative, and scientific work as creative, are two important inaccuracies in science teachers' work" (Gallagher, 1991, p.132).

Gallagher identified only two science teachers from their sample who had a significant depth of understanding about the nature of science and the historical development of knowledge. However, both teachers were only able to provide a limited and "sketchy" understanding of the philosophy of science. Although both see science as tentative, creative and developmental as new questions are asked and new information is collected, "neither clearly articulated an understanding of the processes by which scientists formulate new knowledge, or the controversies among philosophers of science about those processes" (p.127). Consequently, their students do not have any idea of how scientific knowledge is generated or validated and few experience attitudes that help form the ethos of science. It is not very surprising that even in these classes, teaching and learning is limited to an on-paper collection of facts, concepts and procedures that are presented, memorized, and repeated on examinations. This is an epistemological issue and there is little appreciation or understanding of the origin and development of ideas and knowledge about the natural world.

I

se
sh
p
th
tr
it
re
ca
ot
or

liv
sc
st
th
fir
in
gr
gc
hc
w
sc
th
an
rep

<u>The Cultural Spheres of Influence Model: Its Birth and Evolution</u>

As I observed them in their chemistry classes, in their daily lives in school, and engaged them in conversations, I began to realize that most students face certain pressures regarding academic success. They experience pressures to succeed and other pressures that operate against success. Most of this positive and negative pressure seems to be related to grades. This rings true for me because as I stated before, during my teaching experience, I found it very difficult to engage students in learning for its own sake. Now, from a researcher's perspective, I understand in different ways that students are caught in a dilemma of grade consciousness on the one hand and on the other hand, the nagging realization that success would be sweeter if one could only understand chemistry.

As I heard student conversations and observed them in their daily lives, I needed a model that would provide a framework that would help me sort out and conceptualize the things I saw and heard. I began to think that students were trying to live in two parallel, coexisting, linear dimensions. I therefore developed a parallel dimension model as an analysis plan. In the first dimension of this model, the grade is the goal, the prize won. Students, in very practical ways, find a formula for doing what it takes to get good grades and go about the business of getting them. Doing what it takes to get good grades seems to have little to do with real chemistry or comprehending how things work in the natural world. Instead, it is more about doing the work, coming to class and cooperating with the teacher. Day-to-day life in school often seems quite full and preoccupied with getting good grades and the associated, rather mundane behavior. It is hard enough to find the time and energy in busy lives to do homework, study for tests, and write lab reports. Since the grade is the goal, this sometimes cultures a spirit of gamesmanship in doing what it takes to succeed in the least amount of effort and emotional expense.

The second linear dimension of the parallel dimension model involves a more epistemological approach to chemistry. Students sometimes talk about knowing and understanding chemistry as something different from and quite unrelated to getting good grades in Chemistry class. They often find it difficult to describe what they mean by understanding chemistry but most of them know that success would be sweeter and more personally rewarding if some sort of understandings could be gained. They would like to know how what they are learning relates to the real world and to their futures. Often, when the conversations included what it means and what it takes to understand chemistry, it became difficult for students to articulate their feelings and difficult for this researcher to know what they meant. They talked of understanding chemical substances and transformations almost simultaneously with "understanding" in ways that resulted in good grades on tests. In the former, they seemed to be talking about real atoms and molecules and understanding chemical concepts and ideas. In the latter use of "understanding" they seemed to be describing what they need to know in order to be a good test taker. In other words, "understanding" is merely anticipating and knowing whatever will be on the next test--"I understand what I need to know or memorize for the next test."

This parallel-dimension model required students to live in two dimensions and it would seem that student life would be filled with contradictions and conflict. Perhaps on the other hand, some students would be able to live in one dimension and when practical, switch to the other for a time. I increasingly became uncomfortable with this model because in talk and behavior, students seemed to inhabit these dimensions simultaneously, interrelating them and co-occupying them more than this model could represent.

As is usually the case, discussion with others sheds different light on any situation. I presented this model to several fellow educators and researchers. As Dr. James Gallagher and I discussed it, I began to see that perhaps these two worlds, life according to each dimension, were not parallel and linear at all. Perhaps the student's attitudes, values, beliefs, and corresponding behavior could be understood better in terms of concentric cultural/social spheres of influence instead of parallel, coexisting dimensions. In this new model, instead of struggling and waffling between two different, parallel dimensions of success, students look out at their world through concentric spheres of influence. They thus make sense of their situation in Chemistry class (and schooling) and act accordingly. I'll call this new model the "Cultural Spheres of Influence Model."

The Conceptual Model

As I heard participant voices, it increasingly became clear that students were making sense of their situation within different but interrelated socio-cultural influences. As the research progressed and the analysis unfolded, the Cultural Spheres of Influence Model evolved as a conceptual device to help me understand how students described and perceived their situation. It represents the ways in which the individual high school student makes sense of his/her life and world in school--specifically of high school chemistry. These are American middle-class, college-bound students but this model could apply to many adolescent high school learners in a majority of suburban schools. This model uses vision as a metaphor to represent how students make sense of their life in high school chemistry in terms of the social and cultural influences surrounding them. Using this visual metaphor, perceptions depend on the light traveling to the eye. The light is affected by the nature of the medium through which it passes. In an effort to understand this model, the reader should place himself or herself metaphorically in the center, in the place of the student, and look out through the different concentric, spatial spheres at the chemistry discipline as it appears from that vantage point. Concentric, shaded spheres represent interdependent, dynamic, and cultural influences that taken together, construct the cultural milieu.

Fred Erickson (1982) provides a conceptual model to represent the categories of data that a person requires and relationships among them as the learner makes sense of his/her situation (See Figure #1). In his model, "the lines between the individual, the immediate environment, and the wider socio-cultural context are left broken to show the reflexive nature of the relationships between these three levels of organization and functioning" (p.159). The individual's thought and action helps to constitute the immediate environment in which action is taken and the environment both influences and is influenced by wider socio-cultural contexts.

Erickson's emphasis is not only on the playing out of "learned cultural expectations" (p.158) or "frames" but on the creation of frames and expectations within social interaction. "Learning is viewed theoretically as interaction between the individual and the environment in real time" (p.158). He states that any written description of what is going on should:

1. Account for the actions of the individual learner.

2. Account for relevant features of the environment (including the intentions of the teacher...).

3. Show specific change in the individual-environment interaction across time, from before learning, through during learning, and after having learned (p.159).

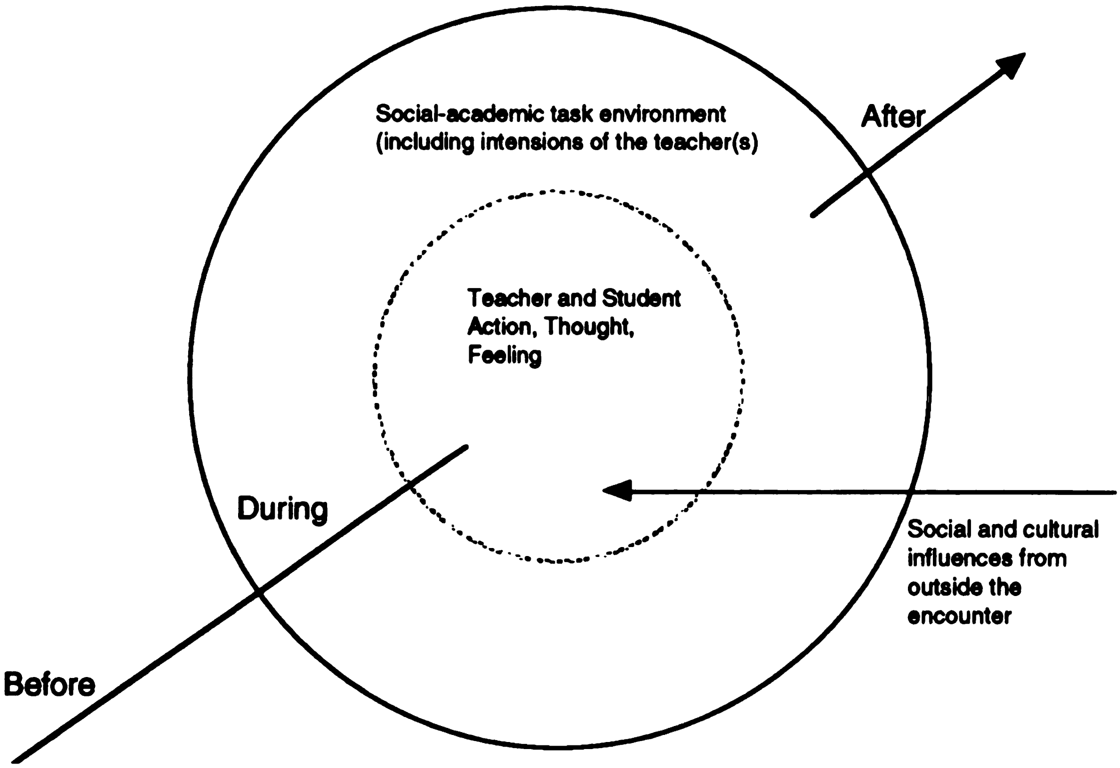


Figure #1 Erickson's model.
(Erickson, 1982, p. 159)

It is significant that Erickson puts the individual in the center of the cultural milieu as the individual responds to and creates his/her own sense of the world. It is crucial that the narrative account (For an example, he uses a narrative account of Helen Keller's learning as reported by Sullivan) gives evidence of the state of the learner's mental life before the learner encounters a new learning experience. Next, any interventions (such as a teacher's) must, according to Erickson, help the reader understand the change in the learner's thinking through time as one reacts with the environment. Finally, the account should describe the learner's action in interaction with the environment after the new learning occurs. All this points to the conclusion that the immediate environment of learning is vital in trying to understand the learner's thought and action. In accepting Vygotsky's perspective on the face-to-face encounters between the individual and the environment, , Erickson explains that we can:

> [U]nite the analysis of the study of socio-cultural patterns in the world beyond the encounter together with the study of (1) individual thought and action and of (2) the acquisition across time by the individual of new and more complex capacities for thought and action" (p.166). This is an ecological theory of the individual-environment interface as a pedagogical encounter. As in other kinds of ecological theory, the unit of analysis is the individual organism in transaction with its immediate surround, not the individual organism or the surround considered separate from each other (p. 166).

Each cultural sphere colors, shapes, and influences the individual student's perception of the other spheres as well as perceptions of self. The first cultural sphere, the one closest to the student, has the most direct, immediate and profound influence. This is because adolescent high school students are usually, in daily life, most keenly aware of and most concerned with the influence of peers. Peer-related social factors take priority over factors further removed. The classroom sphere is not shaded because it represents the space and time, the context, into which students bring these social constructs and conceptions of self. The teacher's sphere is metaphorically between the classroom and the chemistry subject matter because of the nature of the teacher's influence. The teachers are vital components of this model as they brings their own personal chemistry and expectancies to the classroom context.

The boundaries between these spheres are dynamic and flex with different priorities and events. The order of the spheres may be different for individuals depending on socio-cultural influences. For example, when parents linked a student's driving privileges to the grade on the next test, parental influence was certainly, at least temporarily given priority over the other spheres. Different dimensions of experience can and do exist simultaneously, overlap and continuously interact. Therefore, it is not realistic to isolate a student's perceptions and behavior in relation to only one or another cultural influence. In reality, the person's perceptions of the world around him or her depend on interaction of all the concentric, cultural spheres together.

The Inner-most Sphere

The inner-most sphere represents the individual student. At the core of this study is the individual who perceives and makes personal sense of what it means to be a good student in high school chemistry. We will look at the cultural and social world around the student through his or her eyes and attempt to hear individual voices. It is from this vantage point that we seek to understand the cultural and social factors which influence a student's sense making, perceptions and decisions regarding chemistry and academic work.

The First Cultural Sphere: Peer Culture

The first cultural sphere of influence represents the most pressing and powerful social influence in the high school student's daily sense making and behavior. This influence is very complex and comes in many forms. Peers form culture together and most of them learn to think and act appropriately in this context. Individuals consider their reputations among peers vitally important. Peer groups have their own micro-social orders, rights of passage and norms for behavior. Peer influence occurs in classrooms, in school hallways, at social events and extracurricular activities in daily life in and out of school. Students usually watch the same television shows, read the same things and respond to popular culture together. Students deal with societal influences such as perceptions of science, scientists, chemistry, and school success. For example, reformists struggle against the societal messages that chemistry is not very important for females and that science is for unpopular students. Students struggle to agree or disagree with these influences. They come to chemistry class together, sit together, do their homework together. The nature of influence of the other cultural spheres is therefore partially determined, at least somewhat dependent on how this first sphere colors one's vision and perspectives. It is the first and most significant sphere of influence the individual considers when making sense of his situation. It is primary in the social construction of meaning and the resultant constructs of schooling which a student or group of students bring to chemistry class.

The Second Cultural Sphere: Family Influence

This sphere represents the cultural influence of parents and other adult family members. Parents were not the most common topic in conversations but when they were, the story was usually consistent among participants. Parents of college preparatory students expect their children to do well and there are usually consequences if they do not. Therefore, parents are perhaps the most significant members of this second cultural sphere. Most chemistry students' parents took chemistry when they were young and assume that their children should also. For example, two student participants in this study, Jeff and Paul, both belong to families of engineers. They both feel very specific pressure and family expectations to both go on to a career in engineering, but also to succeed in chemistry as "one step along the way."

The Third Cultural Sphere: Institutional Influence

This sphere of influence represents schools as institutions and the associated adults [other than the teacher] that affect a student's perceptions and decisions. The school as institution exerts pressure on college-bound students explicitly through academic counselors and through subtle expectations. For example, although there are no official policies requiring chemistry in the college-bound track, it is made clear to these students that success in chemistry is definitely expected of them. Participants speak of institutional pressures both at the high school and college levels and these pressures effect a student's perspectives and action.

The Fourth Cultural Sphere: Teacher's Cultural Influence

> whether the scene of learning is inside or outside of school, what the teacher knows is part of the learning environment for the learner, including the teacher's implicit and explicit knowledge and beliefs about what learning is, how it should take place, and how the particular learner at hand is getting along in learning what the teacher intends to be learned (Erickson, 1982, p.173).

The teacher's cultural influence is related to the other adult and institutional influences. The teacher not only represents the educational system, but also represents chemistry as a discipline. It is almost impossible for most of these students to think about chemistry apart from their teacher's influence. This gives chemistry teachers such significant power that they require their own cultural sphere, separate from the institution in which they work. The teacher's influence exists at least on two levels. First, the teacher is ultimately in control of the requirements and expectations necessary for attaining a grade. Secondly, the teacher essentially controls the information and processes presented and available to students in chemistry class. Success in chemistry depends on the cooperative efforts of students and teachers who jointly determine the character of the chemistry learned and understood in the classroom.

The Fifth Cultural Sphere: Chemistry Subject Matter

This sphere of influence represents chemistry as knowledge and action within the discipline before it is acted upon or filtered by teachers or the other cultural influences. As I will explain (see Arrow #2 below) some students make attempts to bridge or transcend the teacher and the other cultural influences in order to develop a personal relationship with chemistry. This is quite rare and seems to exist in fleeting moments of student epistemological awareness and interest. More typically, the teacher interprets or translates the students' exposure to and experiences with chemistry subject matter.

Chapter Summary: Knowing Chemistry and Knowing Success

This research model places the individual high school college-bound chemistry student and individual cognition in context of cultural influences which effect what cultural products are formed and operational in chemistry classrooms. Cultural influences were identified in student conversation and narrative. These conversations not only informed this research but also, in the process, helped the participants assign meaning to action and thus understand their own situation better. The cultural products of most concern are the construct "success" and the nature and methods of epistemic access. As the research model demonstrates, the relationship a student is able to develop with chemistry is influenced and determined by cultural spheres of influence. The next chapters of this dissertation examine student perspectives and the influence of the cultural milieu.

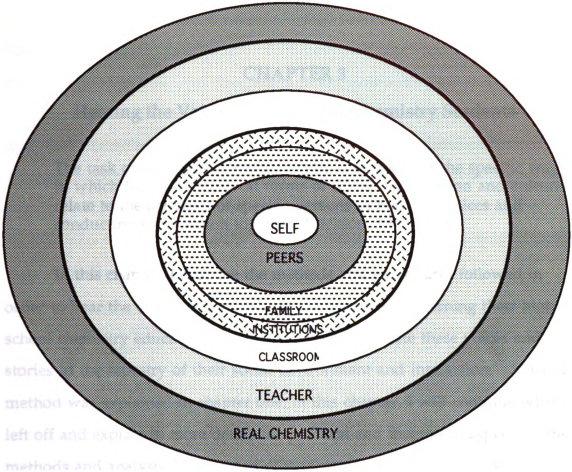


Figure 2. Cultural Spheres of Influence Model (American College-Bound High School Students)

CHAPTER 3

Hearing the Voices of Successful Chemistry Students

> The task of interpretive research then, is to discover the specific ways in which local and nonlocal forms of social organization and culture relate to the activities of specific persons in making choices and conducting social action together (Erickson, 1990, p.106)

In this chapter, I describe the methods and procedures followed in order to hear the voices and stories of young people concerning their high school chemistry education as it is experienced. I locate these voices and stories in the tapestry of their social environment and interactions. Since the method was explained in chapter one, in this chapter, I will continue where I left off and explain in more detail, the practical and theoretical aspects of field methods and analysis. The record of student voices are very limited in educational literature. Yet as Hawkins (1974) and others have explained, the "I, thou, and it" play together to construct the warp and woof of social structures and educational experiences. This has always concerned me because students, their families, teachers and peers play vital roles in the success or failures of educational efforts. Student perspectives of peer and other social influences will not only open windows on present events and meanings, but also will be useful in constructing the historical picture of social, cultural structures. For example, I assume the parents' attitudes toward science and learning were products of their schooling experiences and in turn, were passed on in some form to their children. Generational experiences place personal lives in the context of historical and social worlds.

Theoretical Framework

It is imperative that the research design be best fit for the purposes and aims of the research. Ethnographic fieldwork provided the framework to enter the world of chemistry students as participant observer and participant in conversation. The purpose was to go into secondary schools to find out what students believe and how they make sense of their situation both individually and as members of a social structure. As Cusick (1983) suggests, field study enables the researcher to study a particular event or cultural situation and thus make valuable contributions to others attempting to make sense of similar situations.

> A field study, after all, is only an individual's attempt to unravel and explain a human event giving particular attention to the collective understandings of those who created the event. If the event is significant, and that account is intelligible and plausible, then the result can be of value to those interested and involved in similar events (Cusick, 1983, p. 135).

More specifically, the purpose of this research is to answer questions concerning student perspectives on what it means and takes to succeed in high school chemistry. The perspectives of the participants are the object of study. A perspective is a mental relation of individuals to one another and to the social structure in which they live and breathe. They respond and relate to the objects, events, people and structures around them. They make sense of their world in their own individual, social and cultural ways. They then make decisions regarding school and school work in relationship to these developed perspectives. It behooves me to consider the angle of observation of all the primary actors in the situation. I consciously add the angle of view of teachers, administrators and parents as other forms of triangulation on the situation. Thus, in this research, perspective is a many-faceted thing but primary focus is from the students' particular point of view.

Throughout this research, I choose the word participant instead of informant for a specific, deliberate reason. The school is a social system and the classroom is a micro-social component or subsystem (Parsons, 1963, pp. 9-11) As explained in Chapter 2, students are insiders in their own world, make personal sense of their world and act accordingly. They are both individuals and conformists as members of a group of peers with similar goals and beliefs. In contrast, informants give information or supply personal analyses of situations as if this information is personal information and didactically given, not constructed in social interaction. The word, informants, also has a negative connotation in our culture in part because mass media treats informants as those who reveal the secrets of their friends and turn on their peers.

As researcher, I am an actor in the situation and therefore essentially add another way of looking at the world. The researcher's perspective, according to Schatzman and Strauss (1973) is an "angle of observation" (p.53) in the study of individuals and their interactions with others. I bring my own history, attitudes and beliefs, my own bias to the situation. However, because I enter the situation as participant observer, I attempt to look at the situation from the participants' angle, taking on their perspective as much as possible. The goal is to understand their world through their eyes--their understandings of their world as they understand it.

> A central element in the method is the researcher's gradual taking on of the perspective of the participants, the sharing in their lives in those places to understand their world as they understand it, the adoption of the interpretations they use to make sense of events around them and construct their lives accordingly. To the degree one is successful in that, so he can describe the event and account for it just as would the

> participants where they to collectively explain their world. That is the goal of the participant observation as a research method (Cusick, 1983, p. 133).

Because the system itself is a participative venture, participant observation is generally recognized as appropriate in studies of social systems and subsystems. Systems are "created and sustained by the members as they pursue their endeavors" (Cusick, 1983, p.132). At the same time I recorded fieldnotes, recorded observations and kept records of interactions, I also participated in the making of the system by just being there. The result is not just objective observation, but rich description and on-going analyses and interpretations of the events from participants' points of view.

In addition to participant observation, informal interviews and group conversations are central to this research. Although participant observation places the researcher into the situation in search of shared meaning, conversation adds the opportunity for participants to explain themselves and their situations collectively. I also participated while audio recording these conversations, recording fieldnotes, and paying particular attention to social interactions and non-auditory forms of communication.

There are other background or supplementary sources of data that helped me understand this social situation in all its complexity. Cultural products and artifacts are physical manifestations of culture and therefore help reveal the nature of the situation. According to Geertz (1983), they are part of culture itself. For example, in the examination of student writing, there are clues to assessments, expectations. In this study, student writing, textbooks, student tests, the physical setting and any other products or artifacts were considered important sources of data.

Table 1. Data Collection-Question Matrix & Guiding Questions

Question	Participant Observation	Interviews & Conversations Phase 1	Teacher	Phase 2	Written Artifacts
1		X	X	X	X
2		X	X	X	
3	X	X	X	X	
4		X	X	X	X
5		X	X	X	
6	X	X	X	X	
7	X	X	X	X	X
8	X	X	X	X	X
9	X	X	X	X	
10	X	X	X	X	
11	X	X	X	X	X
12	X	X	X	X	X

The following are questions which informally guided interviews and conversations. Each should be considered from the students' perspective. When science education or academics are mentioned, they refer to a person's history of science education in general and chemistry in particular.

1. What academic choices are there concerning science education?

2. How do family members define their roles in relationship to science education in the school? When and under what conditions will parents intervene? What form would the intervention take?

3. How do peers contribute to academic decisions?

4. What are the academic goals of the student? How do these compare to parental goals for the student?

5. What is the family history of science education in this school?

6. What ethnic or cultural values, values and beliefs affect attitudes toward chemistry?

7. How, when and why do teachers contribute to students coping with or learning to defend themselves against academic challenges?

8. What is the teacher's role in science education? The Textbook? The school as institution?

9. How do social lives and lives in sports contribute to academic success?

10. What attitudes are displayed about gender roles and science education?

11. How is success measured in chemistry education?

12. What is difficult about chemistry learning? How are these difficulties related to the value of what is learned in chemistry?

Table 2. Data Collection Time Table

Participant Observation	4 days each week, September-January. 8 days, February--April. Average of 3-4 days each week in May.
Phase 1 Field Procedures	Schedule corresponded to participant observation schedule.
Phase 2 Field Procedures, conversations and Interviews	Each focus student was interviewed 3 times during the first semester and once during the second semester. Students frequently engaged in conversations with the researcher.
Teacher Interviews	Frequent, informal interviews between classes and after school according to participant observation schedule. Scheduled, formal interviews and conversations twice during the first semester and twice during the second semester.

Field Procedures for Data Collection

The situation was quite familiar because I have a long personal history in chemistry classrooms and in schools which are similar to these research sites. As the field research progressed, the assumed perspective soon made the familiar strange. This research put me literally and metaphorically at the opposite end of the classroom. It also was new and strange to sit in the back of the classroom or amongst the students as teaching was going on. Not unexpectedly, I discovered that the social/cultural situation looked very different from this perspective. It also afforded the opening of the perspectives of others. It is very significant, as I made very clear to the participants, that I, as researcher did not intend to criticize, grade or assume any authority over anyone in any way. Discussions and interviews were at the participants' convenience and explicitly voluntary. I never taught, avoided any teacher-like roles, and throughout the process, avoided donning authority's hat. For example, during laboratory exercises, although I participated in conversations and asked students questions, I deferred any questions of procedure or questions about "right answers" to the teacher. It is important to note that my role was rehearsed in other research and in the pilot study. In past research of my own teaching, I always felt that because I was in authority and I was grading students' performance, they felt a need to perform or "give me what I wanted to hear." In this research, all such implied coercion and its associated baggage was actively avoided. The participants seemed to feel relatively safe and trusted that I would not reveal any secrets to authorities. Although there was obviously a generation gap, the students seemed very free to talk openly and honestly.

The inquiry progressed and evolved as it gained a life of its own. In the rest of this section, I will describe this evolution of method, describe the research procedures and discuss their practical and theoretical fit to the research questions. This chapter concludes with a brief description of procedures employed in the analysis of the data.

Field Procedures--Phase One: The Choice of Setting and Gaining Access

Based on what was learned in the pilot study, there were two main criteria for deciding on the best setting for the major study. First, I looked for college-bound chemistry students who had a history of academic success and now, at least in the beginning, expected to succeed in chemistry class. In the ideal setting, students should be interested in getting a good preparation for college, the administration should take pride in the quality of education, and parents should be somewhat involved and care about the quality of education their children receive. The second criterion for the setting choice was a teacher who enjoys a reputation in his/her school and community for good, effective teaching and takes pride in teaching for understanding. Ideally, this teacher would understand, relate to, and be able to talk about the fundamental constructs underpinning my research questions.

I was successful in satisfying each of these criteria. (The settings are described in greater detail in chapter four.) In the beginning of my search for a research setting, I found myself also concerned about the basic and practical matters. For example, it was important that the school or schools were nearby and accessible so that I could concentrate appropriately while not letting my other work suffer. Realistically, this is one of the first concerns of most university researchers with busy schedules. These practical concerns did not compromise the work and neither did they mean the choice of settings was less than ideal. In fact, in my efforts to survey all the high schools within driving distance, I quickly narrowed the list to two schools, both of which would be excellent settings for this study.

The search procedures were quite simple. I first made a quick survey of the neighborhood and a visual inspection of the school. After getting official permission from the school district offices and school administrations, I entered the schools, walked the halls and observed. I was trying to get a feel for the place and physical, neighborhood context of the school. Many schools in this state draw their students from the neighborhoods in the school district and I made the assumption that the setting, the neighborhoods and the social structures found there would contribute to the ambiance and ethos of the school. During this first visit to the high school, I talked to individuals in the halls or in this school office in order to get a first impression of the social setting. Because high schools are familiar places to me, a first reconnaissance seemed useful at least for the first part of the selection process. It gave preliminary indications of the mixture of students, whether or not the school is a pleasant and friendly place, and if students generally take their school work seriously. I looked for physical clues like cleanliness, the nature of the pictures on the hallway walls and bulletin boards. I wanted to know what the physical appearance of the place could tell me about the atmosphere and priorities there. The trophy case, its location as well as its contents can tell its own story about student life. Physical objects are culture and cultural products and can reveal much about a place and its people (Geertz, 1992). There would be evidence for assertions about what is important to the people who spend their time there. I tried to characterize the school spirit in terms of sports, academics, the arts and the social lives of the people who reside there. I felt it important that the people seemed happy, pleasant, friendly to a stranger who walked the halls between classes. These are important factors since this is a study of culture and cultural influence in participants' lives.

Two schools in different school districts survived the first cull and reached the next stage in the selection process. The next step was to visit the office, informally interview the principal, and all preliminary things considered, begin the process of gaining access. It was important to have friendly, supportive and helpful academic counselors and other office personnel as well as legal access privileges. I found principals who were very interested in my subject, who wanted to learn with me and offered their services and office support. In both of these schools, the principals boasted about the quality of their educational system in general and specifically about their chemistry teaching staff. At one of the schools, a chemistry teacher enjoyed an especially good reputation within her district and also in the larger educational community. At the other school, the principal and other science teachers strongly recommended their own General Chemistry teacher. They said he was an excellent teacher, his students were very well prepared for Advanced Placement Chemistry, and "the kids love him." In this way, the selection process gained its own momentum and a life of its own. It was almost as if the site selection process was taking care of itself through interest in the topic and the reputations of the teachers. Although I anticipated difficulty in gaining access, I soon found myself enthusiastically welcomed at each location.

To gain more information and to confirm these preliminary choices, I went to the school district offices to collect demographic data (see Chapter 4) and to get official access privileges. In this state, the school district office is the gatekeeper for legal access. A written, formal request is required. Once legal access was gained, I met with school counselors to discuss the character of the student population. I also arranged to meet the recommended teachers and to visit their classes. In one school, the principal introduced me to the teacher and together we discussed my project and research questions. In the other school, I made my own preliminary contact and introductions. Both teachers, after an initial conversation responded positively and gave me their consent. The stories they told about their students and concerned parents demonstrated their understanding of my questions and their concern for the issues. In other words, the proposed research rang so true to their experiences and their serious concerns that they actually described my study for me as if they already had read my research proposal. They both expressed a desire to participate in this study. I then knew that both teachers, although very different from each other, closely fit my criteria in different ways and would be extremely valuable participants in this research.

Because I originally wanted the sample to include only one school and one teacher, I not only needed to choose between these two schools, but also needed to be sure that the final choice of teacher and class was ideal. The only way to make an informed decision was to immerse myself in each situation and spend considerable time in each school. The plan was to visit all the chemistry classes in both schools taught by these and other teachers for a trial period of 3-4 weeks. While doing this and through sharing my preliminary observations with others, another choice soon presented itself. Both of these schools offered Advanced Placement Chemistry classes. Since the pilot study was done in introductory chemistry classes, I wanted to be sure this was the best choice in the context of these two schools. To answer this question, I also became a participant observer in A.P. Chemistry classes to find out what life was like there. I also wanted to develop relationships with the students and teachers in A.P. classes because even if I decided to stay with introductory chemistry, these students were veterans of the program, had been students of these same teachers and were therefore potentially valuable participants. I soon found that most A.P. students' conceptions of success was mostly and explicitly preoccupied with the Advanced Placement Test held in the spring. They were already the most successful veterans of introductory chemistry so that now, they were rather entrenched in this pursuit and were not necessarily struggling with the same issues as students experiencing high school chemistry for the first time. Although this is a very interesting arena for future study, it was not the study I wanted. Because General Chemistry offers students their first experiences with high school chemistry, it fit my objectives much more closely.

Most importantly in the selection process, because this study is about student perspectives, I searched for the best social combination of chemistry students. To make this decision, I had to know more about them. I informally talked to many students in classes, in the halls and in the school cafeterias. After several weeks of reconnaissance and observations, several interviews and conversations with teachers, students and other school personnel, I decided to concentrate on one General Chemistry class in each school. Although I intended to study only one school, both of these schools seemed ideal and both teachers were very willing and able to contribute to this research. I did not want to choose between them so I decided to include both. There were of course positive and negative effects of this decision. This decision increased the size of the study and more than doubled the amount of data available. And, although these two settings were very similar, each was unique. For example, the teacher is one of the most influential cultural factors and each teacher had very different educational backgrounds and experiences in education. Another important difference was that one teacher was male and the other female. Two settings instead of one thus encouraged comparative analyses of two very different cultural situations as it enriched and informed this study.

The next task was to narrow the study to one focus chemistry class of participants in each school. My criterion for this choice at first seems deceptively simple: the students should be interesting. In reality, the choice would also be determined by a combination of this criterion and more practical concerns. Of course "interesting" is a personal construct and it is difficult to explain. The concept has meaning in terms of my personal history and also in light of the pilot study. Interesting students are especially willing and able to participate in this research because they would be very thoughtful, quite articulate, very willing to talk to an adult and with each other about their lives in chemistry. To add another facet, they should also be interested in the topic of my research. In one school, the focus teacher taught only one introductory chemistry class so there was in effect, no choice. This was not a problem because the students were very interesting. In the other school, one teacher taught several sections of introductory chemistry so the selection was more difficult. Since I had to be in the other school in the afternoon, the list of classes was narrowed to morning sections. The students and the ethos that was developing in the third-period session seemed most interesting and better tuned to my needs. They were very vocal in class, regularly asked questions in class, and seemed willing to engage the subject matter. The teacher also suggested third-period chemistry because he felt these students would be the best choice for my research. He explained that of all his classes, third period students seemed responsive to his teaching, interested in the subject while several were struggling with whether or not the rewards were worth the personal investment of time and energy. I also received the warmest welcome in this class session and from the first day I arrived, several of them expressed an interest in being participants.

The next step was to narrow my list of students to a focus group of students within each of these classes through a process of observation and interview. During classroom observations and informal interviews, I made a list of students who seemed interesting. I also talked to their teachers to get their input and advice about my choice. The teachers suggested individuals who, in their opinion, were getting good grades and yet struggled with chemistry in varying ways and were uncertain about what it means to be a good student. From this preliminary list, I began to schedule informal interviews with groups of two or three students each. The scheduling process itself eliminated several students in each class. These meetings were strictly optional and since a few students seemed somewhat reluctant, they were first to be eliminated from my list. They knew that interviews would happen during their lunch time or after school and some students were not able or willing to invest their time. Others simply did not return their parental consent forms (A legal university requirement when working with human subjects) and thereby eliminated themselves. A couple students expressed concerns about being far too busy in school to be involved in such a project. The remaining students on the preliminary list became my focus group. This choice was interactive and these individuals chose themselves almost as much as I chose them. Several asked me if they could be involved and several, after preliminary and very informal interviews asked if they could "do this again sometime." These focus students were therefore the most available but also the most willing to take part in the conversations which were to follow. They also had taken a personal interest in this project and were willing to invest their time and energy. In other words, when the culling process was complete, I was left with the most willing, interested and able students. All of these focus students continued to participate for the duration of this project.

It was very important that the students and teachers in this study were willing, even excited about participating in this research. They willingly brought me into their world, into their school and essentially co-constructed the research experience. Several of them explained that this was an opportunity to talk about their world, to learn from each other, from me, and the experience. It was common for students to write notes to share with me, engage me in conversations, and to thank me for my interest in them. One student explained that "adults just don't talk to us about our lives." They seemed to value and appreciate the interest I had in them as well as feeling they were being served by the research.

Once the settings were chosen, access gained, and as the focus students were selected, I continued to position myself in the research. Positioning self, a very important concern for any fieldwork, the researcher develops a relationship with those being studied that is conducive to the objectives of the study.

> The relationship...entails a delicate act of fence-straddling that is the responsibility of the participant-observer. The fieldworker as participant observer is required to maintain a distance of the critical observer as well as the intimacy of the insider participant. The formula for working out the distance-intimacy quotient is based upon the way fieldworkers conceptualize the relationship between the self and the other and how that relationship is consummated (Camitta, 1990)

Any researcher has a physical and psychological presence and will effect the situation simply by being there. The participant observer walks a delicate line between too much involvement and not enough. The task was to participate but not to interfere, to be a part of conversations but not to manipulate or evaluate, to lead conversations but not to overpower, to be useful and sensitive to participants' needs while not taking control. To develop relationships it was necessary that I gain the trust of the students, teachers, and other school people. I needed to affiliate with participants in order to learn with them and from them about their situation, their beliefs and meaning of action. Yet at the same time, the researcher must remain at a distance to afford a critical stance. The process is quite deliberate, constant and it evolves temporally. Especially at the beginning, I physically positioned myself in the back of the room. Physical placements have psychological meaning and purpose. In this case, it at least gave me a new and different perspective. As a veteran teacher, I am very familiar with a front-of-the room, teacher's perspective. For this research, it was necessary that I seek the opposite perspective. Later in the study, after my position was better established and understood, I frequently took the vacant seat of any absent student in order to gain a slightly different perspective. During more formal class sessions, I rarely participated in the conversations. During laboratory exercises, and in the halls and other locations, I was free to walk around and engage students and teachers in brief conversations about what they were doing. On several occasions, informal conversations occurred over lunch both in the schools and at a local fast-food restaurant that students would frequent. I resisted the urge to teach, to be an answer giver, or to assume an air of authority because these roles would have changed my identity and altered my position negatively. At the beginning of class sessions, students regularly acknowledged my presence. If I missed a class session, they usually asked me about it the following day. They seemed to ignore my presence during class sessions. I always made it a point to arrive during between-class breaks and stay for a short time after class. Students and/or teachers as they filed into class, would engage me in conversations. Students often told me that they enjoyed talking to an adult who demonstrated respect for their opinions, listened to their stories, and who was generally very interested in them.

To summarize Phase One field procedures, I spent a lot of time choosing the best setting, identifying participants for research, positioning myself and continually, interactively collecting data. After I chose the research sites and gained access in two classrooms in two different schools, I intentionally positioned myself and took on the role of participant observer. I recorded field notes, conducted informal interviews and engaged participants in conversations. I recorded daily, expanded fieldnotes in a research journal. My objectives for this phase included access, positioning self and getting to know the situation, the students, and their lives in science education. I also began the process of identifying a focus group of students in each school for participation in the Phase Two research. As it did in the pilot, Phase One continued throughout the entire academic year of study. Consistent with theoretical sampling techniques (Glaser, 1970), observations were continually made and assertions evolved. Although these phases of research evolved concurrently, Phase One informed Phase Two research.

Field Procedures--Phase Two Interviews

Phase One research continually and concurrently informed the subjects, content, and objectives of the interviews of Phase Two. Phase Two research consisted of conversations and interviews with participants. First, each focus group afforded a manageable and greater reliance on recorded interviews and conversations. Very informal conversations and interviews occurred between classes, in hallways, cafeterias, and even in restaurants after chance meetings. For more formal conversations, private conference rooms with comfortable chairs and a table were reserved. It was important that the conversations could be private, neutral and away from science classrooms. Conference rooms provided a place to meet and It seemed to make the students feel special. There was no evaluation here, no performances for a grade, and every effort made for confidentiality. Students usually considered it a privilege to talk to the "university guy" about what was important to them. Students, on several occasions expressed their appreciation of the role they were given as participants in this research as well as an appreciation for "sitting down and talking about these things." They seemed to want to talk about their lives in school. They occasionally canceled or failed to appear, which I took as evidence that they understood the voluntary character of their participation.

During the pilot study, I had found students were more open and willing to talk when they were interviewed in small mixed-gender groups of 2-3 students than if interviewed individually. Meeting in small groups encouraged relaxed conversation as students interrelated with each other and the researcher. On the other hand, when interviewed individually, students would tend to answer questions very briefly and then act as if there was nothing more to say. Therefore, individual interviews seemed too restricted, too formal and often regressed into question and short-answer sessions. Conversations were more relaxed and more subjective than more formal interview protocols. Students understood my research objectives and often took control of the conversations. Participants were quite free to reveal their judgments, feelings, and evaluations of their situations. They felt a membership in a group and articulated a satisfaction, ownership or sense of honor in being actual participants in this research. Group conversations are also important for social construction of meaning. Small-group conversations were much more collaborative, encouraged group sense making and also solicited stories (see Chapter 2). Sense making is social construction so small group conversations were expedient and ideal for this type of research. Also, in the same way, the researcher's understanding is socially constructed.

Of course there were also negative aspects of mixed-gender groups. For example, during one conversation, it was clear that Brad's stories were being flavored by the fact that he was talking with Amy, a student he apparently wanted to impress. Although he certainly colored the truth for his own purposes, he was also very reluctant to talk when I attempted to interview him alone. However, in fieldwork, if care is taken in the analysis, this negative effect can be turned to good. In the analysis of this conversation, it is probably more significant to understand why a story is told or a personal position taken than what actually was said (Bruner, 1990) . Both for the pilot and for the major study, I decided that the positive effects of mixed groups far outweighed the negative. Students were able to tell each other stories, ask each other questions as well as confront one another. In a sense, the presence of peers kept students more honest as well as providing different perspectives in conversation (Belenky, 1986; Tannen, 1990). Group conversations also allowed the researcher to maintain his position by more or less fading into the background, entering only to ask questions, carefully guiding the sessions toward research objectives or to seek clarification.

Focus groups provided a subset or smaller group of "special respondents" (Gordon, 1987) with which the researcher was able to develop a special relationship. It was not possible to develop these closer relationships with the entire classes. A focus group also allowed a continuity to the interviews and because of limited time and resources, a manageable limit to the necessary number of interviews. Because interview tapes were transcribed, coded, and partially analyzed between interview sessions, the conversations gained a continuity and a continuance as questions evolved and assertions were formed and tested (Ives, 1974). Successive interviews also seemed to be more relaxed and students seemed less intimidated by the process. Therefore, interviewing a select group several times was more beneficial than interviewing more people less often.

All scheduled interviews or extended conversations were tape recorded, face-to-face interactions in order to bring the reader in personal contact with the participants.

> The best results are obtained when a good informant and a good interviewer get together and the narrative is the product of the conscious or unconscious collaboration of the two. Or when the interviewer succeeds in eliminating himself entirely and the reader is brought face to face with the informant. (Kirshenblatt-Gimblett, 1989)

Because of this, the conversations themselves were considered primary data sources while my fieldnotes and transcriptions were secondary sources (Gordon, 1987; Ives, 1974). During coding and further analyses, the transcriptions were read and coded while the tapes were played back. This playing back of the interview tape brought the event back to the present while allowing consideration of voice, inflection and other important observations not evident in the transcriptions alone. The journal and other written artifacts also helped triangulate the data and bring the events back to life in the analysis. For example, it was helpful to have a copy of a student's lab report on the table during analysis while the played-back conversation dealt with that laboratory exercise.

The stories elicited in conversations were considered the author's version of reality and a personal version of their situation (Bruner, 1986). Stories give the researcher understanding as they gain a life of their own. The researcher must be cognizant "of what is involved in the telling and understanding great stories and how it is that stories create a reality of their own" (p.43). Of course, this is the central objective; to understand their perspectives, the nature of the teller as well as the reality in which the teller lives (Erickson, 1986). It is important that the atmosphere created in repeated conversation sessions was conducive to narrative. Stories in conversation are powerful research tools because they provide pictures of real people in real cultural situations, struggling with real-life problems (Noddings, 1991). Once told, as Ives suggests, stories are "set pieces" and "fixed in their structure and detail" (Ives, 1974, p.68). Yet they are not static and necessarily set for the record out of context. "Personal experience stories live in the telling" (Allen, 1978, p.6). Thus, they live in the analysis and help us construct meaning as they helped the participants construct meaning in situ. And their meaning is dependent on the situation in which the teller lives and breathes. Stories are social forms of sense making in which personal perspectives reside. Therefore, research sessions that stimulate or provide a forum for narrative are powerful tools in understanding people and are invaluable methodologies for this research.

> Meaning, thinking, memory, knowledge, and belief are not the names of mental entities residing privately in people's heads. They are rather, the names of socio-mental practices that extend beyond the skin to include the world and society. In regard to human cognition, the proper unit of study is not, I believe, the individual mind/brain, but people engaged in social forms of life our in the world" (Gee, 1992, p.1).

It is imperative that the researcher is situated, immersed in participant observation and in context in order for the personal and group narratives to reveal their meaning. In other words, "you had to have been there." Extensive use of quotations and the participants' own words will help bring the narrative home to the reader but lifeless transcriptions are inadequate for the reader to gain understanding. The account of the narrative given in the analysis (Chapter 4) is written by someone who was there, present at the telling. The analysis is of course once-removed from the telling because it is a personal revisiting or sense-making effort. It is therefore twice-removed for the reader, but the next-best thing to being there.

One way of looking at this research is by characterizing it as an examination of the common sense or folk psychology of high school chemistry. I came to know what meaning students form in relation to their social situation and what meanings are viable. I came to know and understand these meanings through conversations and narrative. As The Cultural Spheres Model suggests, students construct meaning and gain epistemological access to chemistry interactively in social and cultural context. Narrative is both a window into that meaning and a way meaning is socially constructed by the participants. Even though, in the scientific community, "[w]e have been taught to treat such 'said' accounts as untrustworthy, even in some odd philosophical way as untrue" (Bruner, 1990, p.16), we can and should use conversations and narrative for searching for meaning. Not that we should take what students say at face value, but we should think about context, why they said it, and what meaning is beyond or underneath the saying. Bruner calls an individual's action "situated action" (p.19), the intentionally-based counterpart to behavior. Through discourse we can learn about why and how a person makes sense of his situation, negotiates his way and makes choices. Again, it is an interactive process because meaning is both made and understood in the telling.

> Our culturally adapted way of life depends upon shared meanings and shared concepts and depends as well upon shared modes of discourse for negotiating differences in meaning and interpretation... the child does not enter the life of his or her group as a private and autistic sport

> of primary processes, but rather as a participant in a larger public process in which public meanings are negotiated. And in this process, meanings are not to his own advantage unless he can get them shared by others (Bruner, 1990, p.13)

The word "negotiated" is especially interesting here. It suggests that students, teachers and others participate in the formation of public meanings. If success in high school chemistry is the prize to be won, success is also something to be negotiated socially and must be assigned public, or social meaning. In schools, like other institutions, and in chemistry classes in particular, establishing certain rules, rights, and responsibilities--"Local moral orders" (Harre, 1994)-- are part of common sense psychology. In order for the adoption of a public meaning of success to be an advantage to the individual, or viable, it must be a product of social agreement-- a common ground or understanding. Because conversation and stories both help us construct meaning and reveal meaning, narrative is a window to socially influenced and determined meanings. These are common-sense meanings or folklore.

> [F]olklorists are concerned with briefer, more loosely organized accounts of personal experience. These stories are often embedded in conversation and may be conceptualized and conveyed by their tellers as "information" rather than "art."
>
> These kinds of stories often depend heavily upon the social context of interaction for their sense and meaning. They are rarely monologues but are rather constructed in and around conversational exchange. When removed from that immediate context they may prove pointless and eminently forgettable ...these stories can work to define, maintain, enhance or transform a social situation. Stories, generally... are formed up for just the audience and just the occasion for their occurrence." (p.6)

Other Sources of Data

Other sources of data also informed this research. As Geertz teaches (Geertz, 1992), a culture can be observed and analyzed in its products. The culture of school and of chemistry class is also evidenced in written documents and artifacts. Assessments, classroom and school policy statements and expectations, and other artifacts were collected and analyzed for clues to informants' thinking and practice. Assessments were especially important because they are usually the major, sometimes only source of student grades. Grades are very important to college-bound students and are the object of the bargaining process. The methods of assessment and grading were often specific referents during student conversations.

It was also important to analyze these documents and artifacts for ways in which they were used to facilitate or frustrate student coping and defending strategies. For example, chemistry problems are often written and graded in such a way that an algorithmic approach to "getting the correct answer" is provided. This form of "problem solving" would tend to support students in the avoidance of challenges in otherwise difficult problems.

School policy statements and expectations were also considered important in framing student decisions. For example, even though chemistry often is officially an elective, the counselors and administrators of these schools strongly recommend it for college-bound students. In fact, for many of these students, chemistry was the first "elective" college-bound students took. Some felt coerced, all felt pressured into taking chemistry for different reasons and from different fronts, but there was always a nagging option of dropping out of chemistry. This option is significant because it was always there, haunting them as if it were a ghost of failure. It also became a bargaining chip (Sedlak, et al., 1986). Teachers are vested in their desire to keep students satisfied if not happy, and in class. They did not want students to fail and they did not want too many people dropping out of their classes. In addition, students might feel chemistry is important on their transcripts but they might not feel that understanding chemistry is important or necessary. Several described their struggle to decide whether or not the effort and emotional stress involved in chemistry was worth the grade on their transcript. It is interesting that few actually chose to drop out. A couple students at Suburban High changed their schedule at semester break in order to "get an easier teacher." All of these factors certainly contributed to the culture of these settings and influenced students' lives dramatically.

Theoretical Sampling and the Formation of the Model

> Theoretical sampling is done in order to discover categories and their properties and to suggest their interrelationships into a theory. ...The researcher who generates theory need not combine random sampling when setting forth relationships among categories and properties. These relationships are suggested as hypotheses pertinent to direction of relationships, not tested as description of both direction and magnitude" (Glaser & Strauss 1970, p.106).

The selection of schools and participants was certainly not random and no effort was made to make them random. Theoretical sampling techniques are a closer fit to the research objectives. As explained above, it was not my objective to make these site-specific situations explicitly generalizable to a larger sample or population. In theoretical sampling, it is only necessary that the phenomena be evidenced at the sites (Cusick, 1992, p.134). Because this study is based in my professional experience and because it was informed by a pilot study, I began with a conception of what I was looking for and held plausible reasons to assume the research questions would apply to the situation at these two schools. I developed assertions and these evolved in research in an ongoing analysis. I began to develop a model in order to help me understand the cultural context and the influences under which students made sense of their world. (see Chapter 2)

The development of the research model helped in understanding the meaning of these events and interaction. The model has its own developmental history and evolution as does any substantive theory (Glaser & Strauss, 1965). I frequently communicated with fellow educational researchers and anthropologists who were interested in this work.

Data Analysis Procedures

Once I chose the sites and identified the participants, data collection through participant observation and the other methods proceeded throughout the entire academic year. During this entire time, analysis was on-going and centered in fieldnotes and expanded fieldnotes which were keyed to participant observation and interviews/conversations with participants. Secondary sources included transcriptions of audio tapes, audio tapes of class sessions, cultural products and artifacts. The pilot study analysis served as a trial run and the same coding techniques were used because they proved effective. Transcriptions of audio tapes were coded as they were examined. To improve accuracy and to catch as much of the flavor of the communication, I often played the audio tapes concurrently with coding.

Field notes and cultural artifacts served as triangulation for data. One limitation of this data for analysis purposes is that I could not return to the real event of the interview or class session. The tape recordings, fieldnotes and other cultural artifacts were only a record of those events. This is why I played back the tapes and used other data sources to triangulate on those events. There was much more to each written transcription or text than words. For example, inflection in voice and emphases on words and phrases were captured in audio tapes. I also made note of other forms of non-verbal communication including eye contact and body language in fieldnotes and expanded fieldnotes. In other words, I analyzed events in as many ways as possible as I attempted to take a variety of perspectives.

For example, when Kyrsten describes impossible things like electrons, her facial expressions, body language, hand motions, and inflections of voice tell as much or more than her words. All of these forms of communication were captured as much as possible in the analysis of this interaction. Analysis must also be informed by who Kyrsten is, what she cares about, and what her relationship is with others present at the telling. Probably more important than what is said is why she might have said this at this time. Of course there is no limit to the depth of analysis or the different perspectives that could be taken on this event but I tried to capture it in as much detail and rich description as possible. The richness as well as the value of this analysis depends on all these considerations and perspectives. It is a very complicated matter.

Reflections on Methodology: Why did I do what I did?

In the first place, I did what I did because it needed to be done. The record of voices and stories of young people are very limited in educational literature. In the social constructivist perspective, families, peers, teachers, and institutions have vital cultural roles in a student's education. Student perceptions and shared meaning will open windows on these social, cultural influences and relationships. Therefore, in order to hear student voices, the methods of inquiry were interpretive and relied mainly on participant observation, field notes and interviews. The method fit the questions

Perhaps more importantly, the method fits me. My personal history and personality are bound in and related to what I study and what I want to study. They also fund the means I use, the assertions I make and the sense I make of the situation and its actors. Peshkin's work has been especially influential in the personal justification of this perspective (Peshkin, 1978; 1982; 1985). For me, he said it is fine to choose a research design that is personally significant topic and a method that "suits me" (Peshkin, 1982). Personal taste is of great significance and who I am predisposes me to this method. These predisposing factors are important and relevant. "I am a fieldnote." (Jackson, 1990) Fieldnotes "symbolize what journeying to and returning from the field means to us: The attachment, the identification, the uncertainty, the mystique, and, perhaps above all, the ambivalence." (p.33) And, I am a creator of the method as I go along. The literary style seems natural and comfortable and it allows me to attempt to illuminate concepts and relationships that are incredibly complex and convoluted psychologically, culturally and socially. It allows the participants to use their own words and experiences to teach us about themselves and what influences their actions and decisions. I make the assumption that their actions are purposeful and that they make sense to the actors in context. Mainly though conversation, the meanings begin to reveal themselves.

Evaluating the Design

Goetz (1984) writes that the quality of an ethnographic design can be recognized but articulating and defining the dimensions of a good design is more difficult. She identifies five attributes that contribute to the overall merit of an ethnographic study. Although exceptional studies also include creativity, uniqueness and other desirable attributes, her five are often used by journal referees, paper reviewers, and publisher's consultants. These are appropriateness, clarity, comprehensiveness, credibility, and significance. Rather than holding a personal standard for each of these, the primary referent should be the intent of the investigator and the research questions he claims to address. In other words, is the method used the best method for the questions asked?

In reflecting on whether or not the methods employed in this research are the best methods, I prefer to summarize these criteria in the form of two constructs and measures of scientific research. Is the study reliable? Is the study valid? Ethnography or fieldwork tends to beg the first question and rely heavily on the second.

Some Notes Concerning Validity and Reliability

> "In the cultural sciences, the knowledge of the universal or general is never valuable in itself" (Weber, 1949, p.80.)

Validity is attained when the assertions ring true, conform to fact, or at least are plausible. This research is located in time, place and in specific social circumstances. The talk was about the common experience students, teachers and participant observers had together. They all shared common experiences while each constructed personal meaning of the situation. Field-generated assertions were continually tested and modified to make a closer fit to the particulars of the situations and the consensus between the two research sites. The sites were chosen deliberately and yet pragmatically. Informed by my experience in schools and with the lessons of the pilot study, rather typical public high schools were chosen where a significant percentage of the student populations are college-bound and elect introductory chemistry. Although there were many similarities between them, even if it were possible, it was never a concern to sample two schools that are exactly alike. Although similar data could be collected almost anywhere there are high school, college-bound students taking chemistry, this study certainly provides site-specific information and rich descriptions of events. This is perhaps its greatest strength. ."..[P]articipant observation is among the most valuable types of social research because it does include a great deal of site-specific information. That is its appeal" (Cusick, 1992, p.134).

Reliability or in other words, generalizability, consistency or repeatability is a concern for any educational research. There is a social reality shown in the study of these students in these two specific sites. The students live in these situations, make sense of their words in the context of these two institutions and the social structures in and around them. Therefore, there is a generalizability that rests not in the promise of scientific laws generated with a lot of numerical data, but in the general "sociological assumption that since behavior is bound up with structure, then behavior that occurs in a particular setting may also occur in a similar setting" (Cusick, 1992, p.134.). The stories of students in both of these research sites and how they tell about science education should ring true for the reader if he or she is familiar with the typical American high school with College Preparatory Programs. It is reasonable to assume that schools of similar size, programmatic structure, and constituency will exhibit similar student attitudes and social structures. But after all is said, it is also the responsibility of the readers to test these described situations to see if they are similar to their own experience in other situations. If readers find this description sounds familiar, then a certain amount to validity and reliability has been reached. A field study, after all, is only one individual's attempt to unravel and explain a human meaning and action giving particular attention to the collective, social and cultural understandings of those who live and act there. "If the event is significant, and the account is intelligible and plausible, then the result can be of value to those interested and involved in similar events" (Cusick, 1992, p.135).

CHAPTER 4

The Setting and Participants: Two Schools, Two Chemistry Teachers and Their Successful Students

The following descriptions of the settings are derived from field notes, expanded field notes, and other data. For the class session descriptions, each session was selected from pages of field notes and selections were then examined to see if it was quite typical of all class sessions observed in each situation. In both cases, I felt the first choice was quite representative. The reader can get a feel for the typical class session in the lives of these introductory Chemistry students. All quotes are from field notes and audio tapes of the class sessions.

Both schools are suburban, Midwestern public high schools with a mainly Caucasian, middle class constituency. I chose these two schools for this research because they are quite typical of American suburbia which takes pride in high academic standards and a high percentage of students pursuing higher education after graduation. I wanted to look at success in settings where being successful was considered the norm and was expected. The front doors of the school remain unlocked all day, there are no hall guards and no one to check hall passes. All chemistry students intend to go on to college, several to prestigious institutions. In both schools, Chemistry is strongly recommended, though not required for the college-bound student. From the data summarized in Table 3: Summary Data on Two School Research Sites, 84% and 87% of the students in these schools enter college after graduation.

Perhaps these schools could be called academically elite because of their emphasis and pride in academic standards. Students here are understandably concerned with grade point averages and earning their diploma. None of the students observed in this study could be called disengaged with their Chemistry work. All of the focus students are very motivated to succeed and are considered good students by teachers and the administration. Therefore, these students in these situations can perhaps be considered examples of the American educational system's successes. These are examples of students who go about the business of school as good students; who have goals and high career expectations. Each has a personal history of success in school work and expect to succeed in chemistry as well. They are not extraordinary, and although they are a small group living in a specific time and place, they do not seem very different from the students one could find anywhere in mainstream, suburban America.

Table 3: Summary Data on Two School Research Sites

Setting Characteristic (1993)	**Green Lake**	**Suburban**
Total school population	653	1180
Graduating seniors	138	271
% of seniors entering college (fall 1994)	84%	87%
SES-- % family income above...	$50,000 38.9%	$60,000 57%
SES-- % family income below...	$25,000 29.3%	$24,000 .04%
Educational expense per pupil (district, 1991)	$4564.89	$5383.75
Mills of property taxes (district, 1991)	41.2	38.8
Race (1992) Caucasian-American Afro-American Asian-American Other	 95% .02% .02% 5%	 72% .05% 10% 18%
Graduation requirements--total Graduation requirements--science	22 credits 2 credits	21 credits 2 credits

The Setting and Participants: Green Lake High School

9:30 AM. Driving from this Midwestern city of 127,321 people (1990 census), I turn at a busy intersection and travel past the K Mart, the large shopping mall and the restaurants to residential suburbia. Down the road, workers are demolishing a barn and preparing the farmland for some sort of commercial development. Just past this development project, about a mile past the shopping mall, as the neighborhood changes to suburban residential, there is a small sign announcing Green Lake High School. The sign serves also as a small billboard to advertise the upcoming weekend football game. The school drive continues between the sprawling, single-story school on the left and eight fenced in tennis courts on the right. There are no other signs or directions to guide the visitor to the front door or to the office so even someone very familiar with suburban high schools wonders if turning left in front of the building is the way to the front door. An American flag in front of the building is a good clue as is the single row of cars parked along the drive opposite the school. Past this flag and parking area, trucks and other work vehicles are parked and the sounds of construction fill the air. I remember thinking that this is a sign of prosperity and a typical focus on athletics as these construction workers build a new addition. The most prominent part is a new gymnasium.

There are two front doors with the school office between them. Entering the school, the first thing I see is a large, trophy case on the wall opposite the door.

To the left, glass doors and glass walls isolate the school office. A hallway also leads to the right and another, straight ahead. Behind the glass doors of the school office, a few students stand at a long counter talking to a person who appears to be a secretary. I know it is expected that I enter that office, state my business, and "check in." Everything seems quiet and peaceful at first. Suddenly, a bell rings and almost before it stops, the mood changes as students stream through classroom doors into the halls. Student traffic moves at an almost intimidating, rapid pace shoulder to shoulder. Most seem to be on their way to their lockers and there is a lot of noise, laughter, and talking.

9:45-9:50AM. The students have five minutes between classes. During this time, they usually travel from their classroom to their lockers and then to their next classroom. Banks of lockers are located along some of the hallway walls and there seems to be a spirit of congeniality or friendship near the lockers. After students arrive at their lockers, they put some books and notebooks in and take out others. They either stand and talk to each other for a few minutes or they begin to walk toward the classroom where their next class is to meet. The traffic is very heavy as two opposing streams of students move throughout the halls. I move with the traffic while being constantly alert for students cutting across the stream to enter classroom doors along the length of the hall. It seems like a friendly place. As I move down the hall, it is not unusual for several students to smile and utter a brief "hi." Students do not usually seem to be in a hurry until the bell is about to ring. They seem to have this timed quite well because few panic during the last minutes and few are left in the halls after the tardy bell rings. Jack Honderd's chemistry students head down the hall and around the corner to the "chemistry lab." I follow them.

The Participants: Jack Honderd and a Typical Day

There were several important reasons I chose Jack Honderd's classroom as a site for this study. First, I was interested in finding a suburban school where a considerable proportion of students are college bound and goal driven. Green Lake High is close to the university where I work and therefore accessible. The principal was very interested in my work and very cooperative so he willingly granted access after I received district approval.

Honderd has been teaching all the introductory chemistry classes and has been teaching chemistry for his entire professional career of 7 years. He has a good reputation in this school district, seems to have a good relationship with his students, and according to the principal and AP Chemistry teacher, is very successful at preparing future AP chemistry students. I was introduced to Honderd and we discussed my research. He was very interested and offered his services. I began to observe several of his classes the following day. Gradually, we decided that his third-period Chemistry class would offer the best informants for my research. All of these students were college-bound, seemed very interesting, willing to participate, and were motivated to successfully complete Chemistry class.

Jack Honderd expects his students to be in their room before the bell begins to ring. Once in the chemistry lab, students make their way to single-person tables (called desks by teacher and students). There are 5 rows of 4 tables in each row and two rows of 3 tables facing the front of the room (see Figure 3 below). At the front of the room, there is a demonstration table with a sink and the teacher's desk at its end. There is a set of sliding chalk boards on the front wall of the room and a rather large periodic table hanging on the West, or left-hand (facing the front of the room) wall. An overhead projector on its cart is normally pushed against the West wall. There is an arrangement of "lab tables" permanently attached to the floor in the back half of the room.

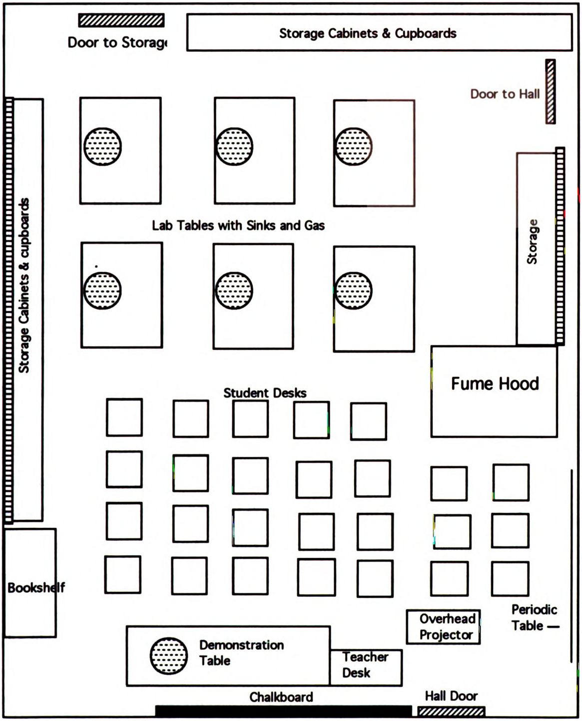


Figure 3. Classroom Map

There is only one lab stool available and students do not usually sit at these lab tables. The preceding sketch represents Honderd's classroom.

The students make their way into the room and the seats gradually fill up. They have chosen their own seats in the beginning of the year. Honderd passed a "seating chart" around the room for them to fill out, and since then, they are required to return to their places each day. Honderd takes attendance as they take their seats and vacant places help identify missing students. If students enter the room after the bell, they are marked tardy unless they hand Honderd an excuse. It is school policy that for the third tardy and each additional tardy after the third, the student must serve a one-hour detention. Usually, they serve this detention during the "Saturday Session", a time reserved for this purpose from 8:00AM till noon on Saturday at the school. No one was tardy or absent today.

9:50 Honderd is sitting on his stool behind the demonstration table and casually talks and jokes with a small group of boys who have taken their seats directly on the other side of the demonstration table. The topic of discussion is Suburban football, but it is unclear what the specifics of the conversation are. The bell rings to announce the beginning of the class and Honderd stands up, walks over to the overhead projector and turns it on. The objectives for Chapter 9 show on the screen in the front corner of the room. Honderd announces that there will be no school the next day and that they will be having a test on chapter 8 and 9 on Thursday of this week. He mentions that they should be sure to study these objectives in preparation for the test. At the same time, and it seems in competition, a female voice is heard from a speaker attached high on the front wall (an intercommunication system which delivers messages from the school office) making morning announcements.

9:55 Honderd moves to the front chalkboard and as he moves, he talks extremely fast (An attention-getting strategy I called "Fast Talk" in my fieldnotes.) about the fact that there is "so much to cover today so let's get busy." The boys in the front of the room joke about Honderd drinking too much coffee today and many of the students who hear this, laugh briefly. As he speaks, he writes the "electron dot" formulas for several elements: Li, Be, B, C, and N on the chalk board. He then reviews how students should use a "diagonal rule" to determine which electron orbitals "fill up." He says that if they "have any trouble with this, just go ahead and do the orbital filling diagram." Honderd explains that the orbital filling diagram is actually reporting the pairing of electrons in atoms. Honderd then uses carbon as an example and describes it as having only two bonds possible because carbon exhibits the following: (he writes this on the chalk board)

xx
x C x

Honderd picks up a meter stick from the demonstration table and then asks his students if there are any "trends" on the periodic table regarding the filling of electron orbitals. (This is a review question because this material was covered last week.)

Jill answers: "You add one electron for each atom as you go from left to right." Honderd nods his head in assent.

Honderd waits for a few seconds, there are no more trends offered and Honderd then explains that "this is the way they designed the (Periodic) table."

Another student, Joe, offers another trend by stating that in the "left column" (the Alkali Metals) there is one electron in the S orbital. Honderd tells him he is correct.

Honderd then describes the significance of the Roman Numerals I and II written above the first two "groups" on the periodic table. He points to the first two groups with his meter stick and tells his students that these represent energy levels and then uses his meter stick to point to Boron as an example of group III. This is followed by a discussion on periodic trends. During this discussion, several students, Kurt, Troy, Craig (Jeff is absent today) and other regular participants ask questions and respond to Honderd's questions. First, Kurt asks a couple questions about the positioning of He on the periodic table. He wonders if He is "out there because" it is a gas and because its outer-most orbital is filled.

Honderd then goes on to describe the positioning of the transition elements and how the "d orbitals" are filled in the He group. Troy brings the discussion back to why certain elements are positioned where they are when he notices boron "at the top of the group" and asks "Is that why B is there?"

As I wonder about Troy's use of the word "why", Honderd answers him: "Follow your diagonal rule-- it is incredibly important." (The "diagonal rule" is a commonly-used algorithm for calculating electron configurations.) And then he states that the periodic table is really organized around two things:

1. Rows in increasing atomic number.
2. Electron configuration.

Honderd implies that if a student just remembers these two things, they will be able to answer these "why" questions. He then reminds them about the "octet rule" he taught them during their Introductory Physical

Science course one or two years ago. He writes the words "octet rule" on the chalk board and says: "You definitely need to know this. There is a magic number of electrons every atom wants and that number is 8." He then mentions that there are two exceptions: He and H. He then uses his meter stick to point to He and then pulls the ruler down through the family: "now notice He and these elements-- they are called Noble Gases." A brief description of inhaling He effectively provides comic relief. Honderd mimics the effect as he briefly explains why He changes one's voice and students laugh. He then asks: "Why don't the noble gases react?"

Craig: "They follow the octet rule."

Todd looks at Craig and answers "Yes." Then, Honderd turns to the class and asks: "Now do you now know how the periodic table works?" Evidently to review and to give them practice, he then asks them to call out numbers which correspond to elements. One or two students at a time call out numbers and Honderd sketches the electron dot diagrams on the chalk board. As he writes, he counts the number of electrons in the outer shell.

After this brief session of calling out numbers and Honderd's responding, Honderd does a brief "fast talk." This seems to serve as a transition to the next item on Honderd's agenda for today.

10:25 Honderd says: "Take out a scrap of paper. We'll see how fast you can do this." He quickly writes the following numbers on the board: 17, 26, 39, 50, 37. About half of his students begin to write in their notebooks or on pieces of paper in their desks. They evidently know he wants them to write the symbols for the last energy level in the electron configuration for each numbered element.

10:28 Honderd begins to go over these examples and reminds his students that they should never call the periods "rows." It was not clear whether he was responding to something he heard as the students were working or if he just thought he should say that now. Having said this, he then asks students to call out the answers to the numbered examples written on the board. He does not call on any students individually, several at a time just call out the numbers of electrons they believe are in the outer energy level. It seems that some students are just randomly picking numbers or guessing numbers that could be correct. Honderd then takes the meter stick again, walks over to the wall, points to F and pulls the meter stick down the family. "These guys have how many?" Students call out the number 7. "How many electrons do they need?" They respond with the number 8. "How many do they want or need to pick up?" Several students respond by calling out the number 1. The tone of this last interplay is light and joking. Honderd's questions are asked in a way that makes his students laugh. I wrote in my field notes that he is role playing in order to keep their attention. His antics seem effective.

When Honderd asks about element number 26, the answer he gets from his students, 3d6, is evidently the one he is looking for and would have gone on. However, Kurt points out that he asked for the last energy shell so the answer should be 4s2. Honderd looks at Kurt and says: "I asked for the last set of quantum numbers." He then seems to confirm Kurt by saying "But that's right Kurt." Kurt does not respond.

10:35 Whether or not this satisfies Kurt, Honderd brings on another transition by saying "OK, you will have to do some memorization and the diagonal rule doesn't work perfectly all the time-- but we'll treat it as if it does. That will create less confusion." Then Honderd points to the chalk board where the assignment for today is written: Rd 167-172 Q's 2,3,5,6. P.177. These page numbers and questions refer to their textbook and he points out that this work is due Thursday. The students therefore have three days to complete their homework assignment. Honderd then gives his students the rest of the period to work on their assignments. Few actually work on this assignment however. Most students merely turn to each other and talk in small groups of 2-3. Honderd again talks to a few boys in the front of the room and everyone remains seated.

10:40 The bell rings to announce the end of third hour and the students file out of the room.

The Participants: Jack Honderd's Chemistry Students

Troy Troy likes to think of himself an artist and musician. He enjoys playing the trumpet in the school band and in his church's orchestra. His favorite sport is soccer and he plays on the school team. In the spring, Troy is on the tennis team. It wasn't until after the second semester began that he started an after-school job at a local fast-food restaurant. He complained about being too busy without a job and now is worried about this new time commitment. However, he also explains that he needs to save for college and needs some spending money.

During my first interview with Troy, talked about his desire to be a good student. He explained that his tendency to procrastinate often stands in the way of a higher grade. He seems to have a rather laissez-faire attitude about his school work. He accepts his 3.0 grade average and is quite satisfied with it. He is rather quiet, most often attentive and seems interested while in chemistry class.

Over all, he is quite satisfied with the education he is receiving, but also thinks there should be opportunities for some courses his school doesn't offer--courses that might prepare him for a life of service to others. He plans to attend a Bible college that has a good music department in which he can major and develop his talents to serve. He explains that it is therefore important to him that to be part of a band or music group while at college. He will also consider a Protestant seminary but is not yet sure he is called to the ministry. He seemed more sure of his calling later in the school year.

Paul Paul works at Flowerland where he does odd jobs, stocks shelves and waits on customers. He tries to keep his hours down to about 18-20 hours each week but also likes the money he takes home. He worked 35-40 hours in the weeks immediately before Christmas vacation selling trees. He explained that the money he earned was nice but it made it especially difficult to spend time or find energy for doing his school work. During their seasons, soccer and golf also compete for his time. Even out of season, he says he is very busy when he is not in school and finds it difficult to find time for his homework.

He likes mathematics and the mathematical part of the sciences but explains that grades take much of the enjoyment out of school subjects. Like Troy, Paul explains that B grades are fine but A's are better. Paul spends most of his time in chemistry listening quietly. However, when something catches his attention and seems interesting, he initiates a question-and-answer session with his teacher. These brief episodes happen about once each day and often involve two other students, Kurt and Jeff. I asked Paul why he asks questions like these and why he tries to engage his teacher in conversation. He said that it is because he wants to make the subject more interesting and challenging. He explained that this means he wants to understand in deeper ways. He explains that the questions come to his mind when he thinks he understands, and the material covered in class seems redundant. To show that he is describing his way of defeating boring redundancy, Paul uses what happens in English Literature as an example: "How many times can you sit down and write the same essay" (Interview, 10/19/93)?

He likes school and likes to think about practical applications for the information he is gaining because he wants to pursue a future in engineering. Paul's father and several other people in his family are electrical engineers. He says that there is a family expectation that he enter this or a related field. He explains that this is fine with him because he wants to go on in science and math anyway and it would be nice to follow in his father's footsteps. He knows college is necessary for him as is learning as much science and math as he can.

Kurt When I asked the person who was transcribing some of my interview tapes what she thought of what she was hearing, she immediately said: "Kurt is an interesting person. I would really like to meet him sometime." I asked her why she thought this, and she began to describe him as someone who seems able and willing to stand on his own socially and that he also seems very intelligent and articulate. Jack Honderd agrees that Kurt is interesting but also "an enigma." "Kurt will find more ways of offending social groups of people than anyone I have ever seen. No social skill at all. Very bright--extremely bright" (Interview, 5/10/1994).

Kurt also has a very difficult home life and as Honderd explains, this effects his academic performance. According to Jack Honderd, Kurt often does not do his school work. Kurt explains his lack of focus differently. In the beginning of the year, he explained that he did not have much use for school learning that is not practical. He still thinks there are some interesting things about what they do in his classes, but often sees no real lasting value for what he is expected to learn. When I asked him why he elected chemistry, he explained that he wanted to be in Mr. Honderd's class. He had the privilege of having Honderd for Freshman Science and enjoyed him very much. Even though he enjoys his chemistry class, he has a difficult time finding motivation to work hard on school work. He considers his lack of motivation his biggest problem and not ability or the difficulty of chemistry.

This helps explain Kurt' behavior in school. He seems to be struggling between mundane tasks and interesting, though more difficult subject matter understanding. This struggle is evidenced in his participation with Paul and Jeff in the question-and-answer sessions described above. Kurt and these other two boys ask probing questions about chemistry content that interests them. I asked Kurt why he asks those questions in class. He said that "[W]e're not satisfied." Kurt seems to consciously push himself conceptually. He and Paul explained that it is due more to the fact that they get bored and want to make the subject more interesting.

Andrea Andrea likes to think of herself a poet. Poetry is one of the ways Andrea thinks about her world. She explains that poetry is also a way out of boring classes. "I start thinking about other things-- like poetry." We laughed because then chemistry has some value because it stimulates poetry. A stanza from one of Andrea's poems serves to summarize her feelings about school learning.

So what about education?
The teachers-- are tired,
tired of teaching,
tired of seeing a lack of hope.
The students-- are tired of rules,
on top of rules,
so they act like fools.
The parents-- think the school should be the
educator.
(Written Artifact, 11/4/1993)

Honderd says she is a "real right-brained kind of kid... actually a bright kid. She's just not an analytical kind of kid" (Interview, 5/10/94). He explains that Andrea has a rather difficult time with her school work.

> She will always come in and get help and stuff like that. I have a lot of admiration for her. She really struggles. The only thing she ever complains about is how much all the teachers just go way too fast. And, I really don't go that fast in there. But, I can't convince her of that and she gets a little upset about that. She really likes me a lot--always has. I really don't know why. ... I have a real good relationship with her (Interview, 5/10/94).

Andrea elected chemistry for two reasons. First, like Kurt, she wanted to be in Mr. Honderd's class because she enjoyed his class as a freshman. Secondly, like most others, she was told that successful completion of chemistry would be expected for college admission. Andrea does not know what vocation she will pursue in college but she is concerned about preparing herself for further schooling and later, the world of work. Andrea wants her schooling to be related to the real world and the real world of work. And she explains that it is good that her school is more difficult that many others. But at the same time, she does not feel that she is mentally challenged. She links mental challenge to the world of work.

> But I don't get mentally challenged here. I mean what is going to stimulate us to get mentally challenged and like ready for a world where-- I am not saying that the school is a good pre. into life you know? It is not a very good one because they are teaching us book smarts and not like street smarts you know what I am saying? They are now going to teach you how you are going to be manipulated in the workplace and stuff like that (Interview, 11/22/93).

Kyrsten Kyrsten worked every night after school and Saturdays in a store in the local shopping mall. She explained that even though it was against Michigan law to work more than 18 hours, she is often asked to fill in for other, less responsible student workers who fail to come to work or ask for time off. She explained that her work schedule was probably the most important reason she was having trouble getting her homework assignments done. She tries to keep up with her school work during school hours but explained that there is a limit to how much can be done between classes and at lunch times. She also explained that her work schedule virtually eliminates her social life because it seems that she spends all her time either in school or at work. She said that her work schedule hurts her socially and academically but at the same time, she doesn't want to disappoint her boss. It is very important to keep her good reputation at work so that she can save money for college.

Kyrsten spoke often about the pressure she feels from family to do well. Her mother is a teacher in a local public school, and her father has a professional career. Kyrsten describes her mother as the source of most of the pressure from home to get good grades. But then she explains that it is really difficult to balance work, school work, and her social life. Kyrsten explains that it is not her work ethic, but her lack of motivation, lack of time and energy that stand in her way of getting excellent grades. She explains that her B average will have to be good enough.

Jeff Although he doesn't work outside of school during the school year, Jeff certainly has many life pressures to preoccupy him. This past fall, he became a 15 year-old father of twins. The mother is three years older and has graduated from high school, lives with her parents, and is suing for custody of the children. Jeff lives at his parents' home, and there are conflicting reports concerning how Jeff and the mother of his daughters get along. Jeff explained to me that they have a rather good relationship and he sees her about twice a week when she brings the boys to him. Sometimes, according to Jeff, this couple then goes out to a movie or something while Jeff's parents sit with the twins. However, a teacher who knows the mother well explained that Jeff and the mother don't even speak to each other and that there is much conflict between the families. This situation must weigh heavily on Jeff's shoulders.

According to Honderd, Jeff's family immigrated from Russia in 1980 and brought much of their Homeland culture with them (see page 179). Jeff told me that his parents are very strict and maintain many of the traditions of the "home country." According to Jeff, part of this tradition is to work hard in school. Jeff often described the pressure he feels to be successful specifically in chemistry.

Jack Honderd describes Jeff as a "fairly bright kid" who is "extremely naturally inquisitive" even though he might have a "little over-inflated ego" (Interview, 5/10/94). Honderd explains that although Jeff likes to think he is one of the best in his class, there are actually a few students who out-perform him and get slightly better grades.

> He thinks he's one of the top one percent. He's more like the top five or ten percent. So he is a strong student but he's not way up there with the top five or ten percent. So, he's a strong student but he's not way up there with the top gun kind of kids like he would like to think he is. And any time he gets anything wrong, he's going to challenge it. I have to really get nasty with him a couple of times when he said "well, that's just not right." I said: "Look, Mr. Merchand, I think after having a degree in chemistry and a degree in biology, and teaching this stuff for seven years, I may know what I'm talking about a little bit better than you" (Interview, 5/10/94).

Jeff, according to Jack Honderd, will "always fight for any point." Jeff explained that this is because his family is only interested in the grade he brings home and that an excellent grade is just expected. "Everyone in my family is either a doctor or a chemist, including my grandparents." His mother has her Ph.D. in Chemical Engineering and his father has a Masters in the same field. His sister and her husband are both chemical engineers and are continuing their graduate education. Because of this, Jeff feels that it is expected of him that he become a successful chemical engineer as well. He accepts this life goal because "It's the best field to go into right now... There is so much money in it right now." He explains that he wants to make at least $60,000/year as a chemical engineer. He also likes business ("I'm a business type person") and therefore plans to get a Masters of Business Administration along with chemical engineering some day.

The Setting and Participants: Suburban High School

Driving from this Midwestern city I travel through neighborhoods similar to those around Green Lake High school in residential suburbia. Down the road, about two miles past the shopping mall as the neighborhood changes to a mixture of landscaped lawns around prosperous-looking businesses and suburban residences, there is a small sign announcing Suburban High School. The small sign, also announcing an upcoming football game, is located in a grass field in front of baseball and football fields. In the distance, is a student parking lot and the school behind that. At the next intersection, I turn left and toward the school. There are no signs or directions to guide the visitor-- only a circle-drive in front of the sprawling, single-story school. There is a double entry door between what appears to be classrooms. This must not be the main entrance but I enter through these doors anyway. The first thing I see is a short hallway between classrooms. Another double door with glass windows looks like it leads farther into the school. Past this second doorway, the area opens to a large room with banks of lockers forming a simple maze of passages for students. To the left, there is a wall of glass doors leading outside-- this must be the main entrance to the high school. In front of me and to the left are the glass doors and glass walls of the school office. Another hallway leads straight ahead. Behind the glass doors of the school office, a few students stand at a long counter talking to a person who appears to be a secretary. I "check in" and inquire about the location of Jane Hatfield's chemistry room. The long school halls are almost empty of students and I can see banks of lockers on one side of each hall. A bell rings and students stream into the school halls just like they did at Green Lake. Busy student traffic moved all in one direction toward the banks of lockers--a controlled stampede of students heading my way. I back up against the wall. There is a lot of noise, laughter, and talking but because there is only five minutes between classes, the traffic soon clears and it feels safe to weave my way against the flow. The second door to the right leads to the Mrs. Hatfield's chemistry lab. A few students leave the hallway traffic to enter this room while others exit the room to join the flow.

The Participants: Jane Hatfield and a Typical Day

There are several reasons I chose Jane Hatfield, her students and Suburban High School for this research. In the beginning, during the groundwork for gaining access, I had narrowed my search to two suburban, middle-class schools where students would be college-bound and goal driven. Suburban High is similar to Green Lake High in many ways. However, there are also differences. Student life in each school is of course determined to a great extent by the teachers. At first, I wanted to spend some time in each school and then decide which school would provide the most interesting and valuable informants. I found very interesting students and situations at both sites and therefore stayed in each school for the duration of the research time. I feel this dual location enriches the study and provides some comparative aspects of student attitudes toward Chemistry and student choices. Jane Hatfield also enjoys a very good reputation within and outside her district and is very well known as an excellent Chemistry teacher. She spends part of her day at the school teaching one introductory chemistry course and one AP Chemistry course. The rest of her time is spent as an elementary curriculum consultant in her school district.

Jane Hatfield started teaching biology and chemistry in a different state while she worked on her Masters in Biology. Her undergraduate degree was in Biology with a minor in Chemistry. In 1970, she and her husband moved to Michigan, found a chemistry teaching position open at Suburban High and soon found herself teaching chemistry. The college she went to required chemistry "for their biology majors so it turned out that I had a much stronger background than most people would have and actually, I had all the coursework to be certified for chemistry." Since then, she took a few years off to raise a family and has gained 17 years experience teaching chemistry at Suburban High. When she started teaching chemistry here, the school did not use a chemistry textbook so she and her colleagues were responsible for developing their own curriculum. Hatfield tries to improve the curriculum each year in order to "teach for understanding" and still uses a textbook only as a reference. Actually, she said she uses the textbook because parents insisted on having one for their children. Parents seem to feel more secure if a textbook is used to aid instruction.

> I guess it all evolves and, I've taken lots of summer workshops and courses and so I think I've talked to some of the people that I consider

> the best chemistry teachers in the country over the years about what they do and how they do things... taking what I like and trying to make it part of what I do. ... And, I think it's in line with what everybody is talking about... The less is more and this teaching for understanding. You know, its like where we were 20 years ago when we didn't have the book. ... We have a book now and the reason was parents insisted on having a book because they felt that the kids have to have this book (Interview, 11/24/93).

Students enter the "Chemistry Lab" between 1:15 and 1:20PM. Most of them come in small groups as they talk to each other and make their way to their assigned seats. Everyone is in the room at the tardy bell and Mrs. Hatfield records their attendance. The physical setting and design of this room is very similar to Jack Honderd's. The chemistry room is rectangular, divided in half and the front half is arranged with student desks in 6 rows of 5 desks each. The back half of the room contains a permanent arrangement of standing-height lab tables with sinks and gas outlets. An overhead projector and its cart are located in the front or east corner of the room. A large periodic table and a sliding chalk board are located on the front wall. Hatfield is standing behind a large demonstration table in the front of the room talking to a couple students. By 1:20, all the student desks are occupied and all 30 students are present today. The "lab tables" in the back half of the room are vacant.

1:20-1:35 Hatfield begins by handing her students graded lab reports and graded quizzes. To do this, she walks around the room and hands each student both at the same time. When all the students have received their papers, Hatfield walks to the other side of the demonstration table and begins to talk about the lab reports. She is talking loud enough for the whole class to hear but looks at and concentrates on a few girls in the front of the room. The lab involved making a three dimensional model of ionization energy and radii trends on the periodic table. Later, Hatfield explained to me that they should have been done but they had run out of materials and were not able to complete their models. She then talked about the fact that she expected them to work in groups of four and instead, they worked alone. They had done this under the guidance of a substitute teacher and evidently, the substitute did not relay her message that there should be one model for every four people instead of one model per person. Evidently there is also some mistake in the instructions on the lab sheet and Hatfield discusses this with these students. Meanwhile, most of the other students talk to each other about their grades. When Karma, who sits in the front of the room asks a question about the lab report, Hatfield specifically calls for everyone's attention. Christine's question is about how she can be sure about the molecular formulas for KCl and H2O and other compounds. Hatfield uses this opportunity to remind her students that this material is actually review for them and that the tasks required for successfully completing this work were actually taught in their 9th-grade science class. Hatfield then briefly reviews how to use oxidation numbers to predict formulas. She explains as she writes some examples on the chalk board.

Then Hatfield goes on to explain that one of the questions they were to answer on the lab sheet was about oxidation numbers and that this "lab sheet" actually was written by another teacher. She explains that before she decided to give it to them, she reviewed it and at first thought they had covered all the necessary material in class. However, when she graded their papers, she noticed that number 16 was about oxidation numbers and "we haven't done oxidation numbers yet, so unless you remembered this from (your 9th grade science) you would have had a hard time with this." She explains that there were also other questions which required "prior knowledge" and because of this, they were "extra credit" and did not count against them when she determined their grade. In other words, they could have missed these questions and still received a perfect score. She thought that because this material was not in the chapter they were working on now, she could not require them to do these questions.

1:35-1:40 "Now, on the quiz that I just returned." Hatfield forms a transition to a session on "going over" the graded and returned quiz. "Most people did very well on the quiz." She also explains that she wrote the correct answers on their papers for the ones they missed so they can compare their answers. She then asks: "Are there any ones you want to talk about?" Kim raises her hand, Hatfield nods her head, and then Kim asks Hatfield to explain a question about first ionization energy. Hatfield and this student briefly discuss how to compare ionization energies using the periodic table. Hatfield uses a brief question answer session with Kim to explain how adding electrons or taking electrons away involves energy. Once it is determined that ionization energy is about removing electrons, predictions can be made about families of elements on the periodic table. Hatfield's questions are meant to challenge students to see trends for example: "Which family would it be easiest to remove an electron"? Comparisons of atomic radii are also discussed as related to ionization energies. A couple other students, in turn, ask other questions and Hatfield answers. Hatfield seems to be giving students the answers she expected for different questions on the quiz. Students initiate the topics with their questions but Hatfield seems to control the discussion with her explanations and questions.

1:40-1:51 There is a brief transition as Hatfield hands out a review sheet that is meant to be homework. This is a single page of questions which evidently is a review of the material and skills the students are required to know for an upcoming test. Hatfield points out that on the other side of the page she wrote the answers to the questions. She says that she did this so that her students can check on their own work.

Hatfield then picks up on a question asked by Carrie and begins teaching about electron affinity and energy states for elements. Carrie was actually asking Hatfield how do one of the homework questions they had been assigned from their textbook. It is not clear what this has to do with the review sheet she just passed out. This brief session is quite teacher centered and directed and yet Hatfield is using student questions to stimulate discussion or at least as jumping-off points for explanations or further questions. Often, Hatfield asks questions, waits briefly for student answers and then goes on to explain. She asks "Which family has the greatest tendency to pick up electrons?" Trent answers and then Hatfield follows this with another question: "Do metals want to gain electrons?' And then explains that elements "want to be like noble gases." She goes on to explain these trends in this way and then connects this to the relative stability of atoms and their ions. For example, she asks them to draw a graph or diagram to represent the energy released in the following reaction for some element Z: Z + 1 electron -- Z (ion) + energy. She then gives them about 15 seconds to draw and then draws what she expected on the chalk board. As she draws this diagram, she explains what happens in similar reactions that involve different energy states. She relates this to the theoretical behavior of electrons and explains how this might help explain electron affinity trends on the periodic table. Hatfield then asks her students to look at a table of electron affinities in their textbook and explains how this concept relates to electron positions, symmetry and electron configurations. It seems that she is trying to help her students see how these periodic trends relate to each other and make sense in terms of real atoms and molecules.

1:51-2:08. Hatfield then returns to the review sheet she passed out at 1:40. She briefly describes some apparent errors on the sheet and explains that the same colleague who wrote the lab sheet they worked on earlier had also written this review for his classes. Hatfield then asks: "Do you have any questions?" She then walks over to the overhead projector and uses it to begin a discussion about periodic functions and how this concept is used in the review sheet. She defines periodic function for her students and writes this definition on the overhead projector. Several students ask questions and Hatfield answers them. Most of these questions are about characteristics of atoms and whether or not they form periodic functions. The number of electrons or the atomic numbers are not periodic functions but ionization energies and electron affinities are, etc. Most of the students' questions are about specific questions on the review sheet that they had trouble with. Each time a student asks her to do a particular problem, Hatfield uses the opportunity to explain the related concepts and periodic trends. This question and answer session continues between Hatfield, Trent, Carrie and a couple other students for a few minutes and then Hatfield asks: "What about the rest of you, are you comfortable with it?" One more student asks a question and the session ends as announcements from the office interrupt.

2:08-2:10. Brief end-of-the-day announcements from the office serve to close the class session. After this announcement, Hatfield quickly reviews this week's schedule with her students: There will be no class Wednesday; Thursday, the schedule has been changed; and there is no school on Friday. The bell rings and most students begin to leave. A couple of students, instead of leaving, meet Hatfield at the demonstration table to ask questions about their quiz grades and why some of their answers were marked wrong. Hatfield patiently answers each student and then that person leaves the room.

The Participants: Jane Hatfield's Chemistry Students

Christine Like many of her peers, Christine is busy with a rich social life and activities outside of the classroom. She told me that she has a tendency to get involved in too many things at once. She has been so busy this year that she felt she had to quit something she enjoys very much--her flute lessons. These activities and demands on her time make it difficult for her to do what it takes to keep up with her school work.

Christine liked Biology class very much because her biology teacher was very clear as to what students were to know and be able to do. Christine seems to like to have expectations clear and well explained. She explained that If she knows what to do, she can just get down to business and do her work. Life is very efficient that way. It seems that Christine has a low tolerance for ambiguity. But expectations are not always clear in Jane Hatfield's class, and Christine often reacts emotionally. Hatfield explains:

> Christine can be a basket case on what she understands and what she doesn't. I mean she's into: "I don't understand anything" and then you find out that there is this one little thing which is no big deal. She had the units wrong or something. You know, she was in after school last night and when we finally figured out what she didn't know how to do, it didn't amount to anything (Interview, 2/24/94).

For a time, Christine felt very good about her performance in Chemistry. "Well I started to understand it for a while. That one chapter. Then I lost it again." And then she explains that in other courses as well, it doesn't take long for her to start another roller-coaster ride of understanding and not understanding. It seems as if she never really knows when she will be doing well and when she will not. One minute she describes herself as "smiley" and excited and the next day she feels like a failure. Once, she described herself as on the edge of failure most of the time. During the first semester, she maintained an A average in her classes but explained that her success was a mysterious process of suddenly understanding just before tests.

Later, at the end of the school year, when I talked to Christine about how she felt about chemistry, she explained that things have been going very well and that she felt very successful. She even likes chemistry now and is considering further science in college. She is thinking about medicine or the health-related fields.

Carrie When I observed Carrie in class, she almost always sat on her legs, leaning forward over her desk and evidently trying to engage in the lesson. She asks questions, takes notes, and acts like a model student. In fact, she has this reputation with all of her teachers. For several months, however, she looked sad and worried. Her father was very ill for several months and this took its toll on Carrie. She told me that it is very difficult to concentrate on any academic work or anything having to do with school while worried about her father's health. Several months later, after her father's condition improved and he was out of physical danger, she was again leaning forward in her desk apparently engaged in chemistry.

According to Jane Hatfield, Carrie should be characterized as an exceptional student and as a "tenacious learner."

> I did try consciously yesterday, for instance with Carrie , to make her say what she wanted to say because she's very verbal and she was gonna keep pushing at that until she finally got that. And you know when she first tried with the "Well you just subtract the products from the reactants" and you know tried to make her realize that wasn't the idea. You know and that it wasn't actually she wasn't even subtracting,

> because one was a negative number and one was a positive number so you're really adding a negative and a positive. But you know she was really good, but she is unusual. She was able to say "Let me think about it and I'll get back."... I am really impressed by her. She is a tenacious learner, and she is much more verbal than you see from most students, male or female. But she is impressive that way. I was really pleased (Interview, 2/24/94).

I asked Carrie about her college plans. She explained her plans in terms of her family and family expectations that she attend a prestigious college. She thought at one time that science might be a career option but this year, began to question this.

Jessie According to Jessie, not only does chemistry have little practical value, it is also sometimes very frustrating and difficult. Jane Hatfield explained that Jessie, along with Nicole, came to her at the end of the first semester and asked her for the pass/fail option for second semester. (Please see also Nicole below) Their high school has a policy that a student can take an elective course for a pass/fail grade. If this option is chosen, as long as a student does not fail, their grade-point average is not effected by their performance in the class.

> Jessie is struggling. She just tried to get me to sign a pass/fail slips and I told them both that I didn't recommend it. I guess I was very forceful when I said it but my problem is that a lot of times they (other students) take the pass/fail option and then they really do try to get a D-. You know? "I don't want to do any work" (Interview, 11/24/93)

I asked her why these two girls would choose this option. She explained that Jessie is very capable but has missed a lot of school lately and her grade isn't where she thinks it should be.

> (Jessie) got a C and thinks her grade point is ruined. But I hate to see them give up... and Jessie has missed a lot of school lately. They're both

> (Jessie and Nicole) capable of doing it but they've got to work on a regular basis and I told them, college is going to assume that you have a C or a D in here anyway. So you're not going to fool college (Interview, 11/24/93).

Besides her feeling that chemistry is ruining her grade point average, Jessie explained to me that chemistry seems uncertain and ambiguous in that there might be more than one solution to a problem and more than one way to look at something. Jessie does not like this uncertainty and doesn't like chemistry because of it. But as long as she knows what is on the test and understands the material on the tests, she will be satisfied.

Nicole Often preoccupied, Nicole seems sad and tired in Chemistry class. Nicole also works almost 20 hours a week at a local restaurant and can't keep up with her studies. Her employers are giving her a hard time because she had so many sick days. She explained to them that the reason is that her father and grandfather have both been in the hospital and therefore, she needs to spend so much time there. "You can fire me because, you know, my family's more important and I'm gonna be at the hospital" (Interview, 5/11/94).

She does not like chemistry because it seems too ambiguous and demanding. It demands her time, concentration and effort-- commodities she finds difficult to muster. It is ambiguous because the problem solutions seem uncertain and elusive.

As explained above, Jessie and Nicole went through a difficult decision-making process at the turn of the semester. According to Jane Hatfield, the main point was that chemistry was ruining their grade-point averages.

> Well, Nicole had a B- last term but she had a C the first term (9-weeks grading period). And her dad was really sick to she ended up with a C for the semester. So, she says it's (chemistry) ruining her grade point. ... And Jessie is the same thing. She got a C and thinks her grade point is ruined. But, I hate to see them give up... because you can go downhill so fast if you don't keep up with it. I think that it's kind of an invitation to failure when you do that and they have got to realize that this will go to an F you know? And pass/fail doesn't mean that an F is O.K. Jessie had a forty-one (percent) on the last test and hasn't taken it over. Nicole had a sixty and I told them both: "You haven't retaken the test, do you think taking this pass/fail is going to solve the problem? That it will be all right to have this mark on the test and we're just going to not bother making up any of the material? You keep going on like this and you'll have an F and you'll have a hole so deep you won't ever get out of it" (Interview, 11/24/93).

The hole Hatfield is warning these girls about is both made of failures on transcripts, which can look very bad on transcripts, and missed "material" or chemistry knowledge they should own by the time they complete chemistry this year. Nicole and Jessie must have taken Hatfield's warning seriously because they elected to continue with chemistry and maintained their grade averages.

Brad Brad says that his goals include getting into a prestigious college, getting a good job and earning a lot of money. He explains that for this reason, he needs to maintain a high grade-point average in high school. Jane Hatfield considers him very gifted and intelligent. His father, a university professor, agrees and proudly told me that he scored very high on his SAT's. He quickly and proudly pointed out that his score may have been the highest in the school.

Brad seems to be a mystery to many of his peers. They talked about him quite often in our conversations. They wonder aloud how he can be inattentive in class, do no homework, and still earn a 4.0 grade. Some think schooling just comes naturally for Brad, some think Brad has some secret about school that they should know. Brad seems to cultivate this reputation and quite often makes it a point to say he didn't study for the last test or didn't do his homework. I mentioned to Jane Hatfield that Brad claims to never study for her tests. She responded by explaining how Brad spends a lot of his time and energy cultivating social pretenses. According to Hatfield, Brad thinks it is important that others think he is so intelligent that he doesn't have to work hard in chemistry class to succeed.

Zack Jane, after explaining that Zack would make a good used-car salesman, said:

> He keeps telling me one thing and then he doesn't carry through. He's been playing, he's been really kind of playing a little game of deceit here about how "I really want to do better and I'm gonna come in and get some help." But he never came in (Interview, 2/24/94).

She went on to explain that for Zack, there is always something else better to do. He said just the other day: "I'll come in tomorrow since that will be better for you." She smiled and then explained to him that she will be in every day and it really did not matter which day he came in. She felt Zack was really just trying to procrastinate and at the same time, cover his tracks.

He is the youngest of five children in a family of professionals. A brother is a computer analyst, a sister is a rehabilitation therapist, the father is an engineer and his mother is a director of a local Montessori school.

He knows he is going to college and believes that his chemistry grades are important. According to Hatfield, at the semester break, Zack even considered a transfer from her class to another chemistry class taught by a teacher who has a reputation of being an easy grader. Hatfield explained that Zack decided to stay in her class because he felt he would learn more even though his grades might be lower than if he moved to another chemistry class.

> Zack's parents wanted him to switch teachers (at the semester). But Zack wouldn't. He said that he was learning more in my room, and he liked the things we talked about. He felt there was more background, more kind of those extra type things that if he switched to... a first-year teacher which is where his parents were going to send him. He said he just couldn't imagine that a first-year teacher would be as good as someone who has been here for a long time. ... So he stayed over his parents' objections. ... I frequently have kids who are not doing well, they're getting C's say: "but I really like this class and I think I am learning a lot" (Interview, 2/24/94).

Or, it is possible of course that his motives were more social--that he merely wanted to stay with his two friends, Sara and Ric. The three of them sit together in the back corner of the room, help each other with chemistry (actually, more accurately, Sara helps Zack and Ric), and talk almost continually during chemistry class.

Trent Trent considers himself a musician and is very involved in forensics and drama. Of all his classes, he likes English, poetry, and literature most. He is also the only young man in Hatfield's class that wears an ear-ring in one of his ears. He seems to take pride in his individuality. He plays in the school orchestra, is involved in a jazz band, a rock band, and takes private music lessons in bass and electric bass. "I play the double bass which is the big ugly thing that stands in the back that's about six feet tall" (Conversation, 10/3/94) He also plays the guitar. He began a new after-school job at the beginning of the second semester working in the kitchen of a local restaurant.

This year, for the first time, he began to see that science, specifically chemistry, can be interesting and that he can do quite well in it. He says that his interest is in some way related to how much effort he is willing to put into it. Trent also feels his performance is related to maturity and his ability to do the work it takes to succeed. However, at other times, he says he doesn't really like chemistry and that he has only developed a certain level of tolerance for it. Later in the year, perhaps because he now felt more successful, Trent changed his mind about chemistry. This change of heart could also have something to do with his new interest in architecture--a vocation that would allow him to be creative.

> ...seems kind of interesting to me that you can be creative for a living. It kind of makes you develop your total creativity like being an artist instead of having a real job. And my mother is an artist and I guess that helps. ... She went to school as an art major and she taught art in public schools in Indiana for a while and then we moved here. Now, she just does art (Interview, 5/16/94).

Summary of Setting and Research Participants

As stated before, the situations, participants for this study are not exceptional and people like them could likely be found in any suburban American high school that takes pride in its academic standards and good, college-prepared graduates. Each participant is an individual living and succeeding in the culture and social structure of their high school. Each is unique but each is like the other in that all have been quite successful throughout their educational career so far and expect to be successful in introductory high school chemistry. This does not mean that all of these students always like chemistry nor does it mean that they always enjoy learning chemistry for its own sake. However, they all consider themselves good students, have opinions about what it means and takes to be a good student in high school chemistry, and have goals which include higher education. These students provide the perspective of most interest in this research.

The setting and participants also form the cultural context for student decisions regarding their academic involvement in chemistry. The cultural milieus described in the model depend almost entirely on how the students perceive their world and the actors in it. The pressures for and against success, the other influences which help a student make choices are personified in the adults and peers involved in everyday life. It is our intent to understand these students in the context of their social lives and the culture of school.

Table 4: Summary of Participants

Green Lake High School Teacher: Jack Honderd	Suburban High School Teacher: Jane Hatfield
Troy--Artist and musician	Nicole--Sad and tired
Paul--Future electrical engineer	Christine--Intolerant of ambiguity
Kurt--The gifted/the individual	Carrie--Tenacious learner
Andrea--The poet	Jessie--Frustration and struggle
Kyrsten--Responsible worker	Brad--Social pretenses
Jeff--Father of twins	Zack--Future used-car salesman
	Trent--Musician and actor

CHAPTER 5

Data and Analysis–The Good Student and Chemistry

Introduction

In the last chapter, I described the setting and introduced the participants in this research project. The setting frames and describes the socio-cultural surround, or cultural milieu in which individuals are a part. In the model, this cultural milieu is divided into cultural spheres of influence that are derived from an analysis of participant perspectives. In this chapter, I present the main body of data with analysis. This data and analysis are organized in two parts. The first part corresponds to the socio-cultural influences that support students in their efforts to do the work, meet chemistry course expectations, get good grades and maintain their reputations as good students. The first four spheres of influence (self, peers, family, and institutions) in the Cultural Spheres of Influence Model support this student sense making and action. As represented in the model, students bring their conceptions of schooling and notions of what learning science should be like to chemistry classroom and expect to find life familiar, certain and safe. Teachers, represented in the fourth sphere if influence, bring their own versions of chemistry and what it should take to succeed in chemistry to the classroom. Therefore, the participants in context, co-construct the high school chemistry classroom experience.

Part II of this chapter presents the data and analysis of student voices about a different form of chemistry that goes far beyond day-to-day requirements for success to include glimpses of real things. These glimpses seem to approach the deeper understandings of the academic disciplinary chemistry located in the fifth cultural sphere of influence. The spheres of influence are my way of making sense of and organizing what I heard participants saying in conversation and observed them act out in the classrooms.

Part I: The Good Student and the First Four Spheres of Influence

The Cultural Spheres of Influence Model forms the structure of the following analysis. We will see that forms of knowing chemistry (or knowing some forms of chemistry) are closely related to being a good student in chemistry. Students' understanding of success in school is constructed in the context of the cultural spheres identified in the research model. We will find that in student perspectives, there are two types of success, each related to a different form of understanding, each with its own set of assertions. One form of understanding seems mainly related to getting good grades in what I shall call school chemistry.

1) School Chemistry: The traditional understandings and task performances required for success in high school chemistry class.

The first set of assertions in this analysis relates to school chemistry and this first type of success. Student understandings of success are formed in the context of cultural spheres, and these understandings are brought with them to chemistry class. Not only do they understand the meaning of success, they also are willing to do what is required of them. This willingness can also be understood in the context of these cultural spheres of influence. In order to find out what success, and "understanding" school chemistry mean to students, we begin with the first cultural sphere through which these students come to know school chemistry and make sense of their lives in chemistry class. School chemistry corresponds to the spheres of influence including peers, family, institutions and teachers as the students enter chemistry class and begin to make sense of their lives.

2). Real Chemistry: The disciplinary understandings of real substances and their transformations.

The other form of understanding that students describe seems to transcend conventional school performances and directly relate to what I call "real chemistry." When students speak of "something awesome out there," it has specific meaning. They appear to refer to chemistry (more specifically, kinetic molecular theory) as a unique way of comprehending the natural world around them. Therefore, this real chemistry seems to be what we might call disciplinary knowledge or as Barrow (1991) describes it, the study of real substances and their transformations--real things acting and reacting in the natural world. Real chemistry corresponds to visions of the outer-most sphere of influence: academic disciplinary knowledge. Students and teachers should make efforts to bring this real chemistry into the classroom.

All the quotations in this analysis are from audio tapes, transcriptions of audio tapes or from field notes. They are not edited and therefore are the participants' own words. It should be noted that a couple of the students quoted are peers of focus students who occasionally joined conversations or interviews.

The 1st Cultural Sphere of Influence: Students experience very significant and powerful positive peer pressure to succeed in school chemistry instead of real chemistry. Students set their own standards for success.

Peer relationships involve many influences and pressures on the individual's daily life in chemistry class. Most often, when people think of peer influence, they think of negative peer pressure or peer pressure toward forms of deviant social behavior. However, the college-bound students in this study also feel significant positive peer pressure to succeed in their academic work. These students are very concerned about maintaining their good reputation among peers. Student sense making is intrinsically, inevitably and profoundly social (Forgas, 1981). Excellent grades is one way this reputation can be maintained and attaining these grades supports a sense of pride in academic achievement (Atkinson, 1964). However, even if grades are not as high as they should be, it is important for others to know that one is able or intelligent enough (Dweck, 1986; Weiner, 1986). Sometimes these positive peer pressures are quite simple and straightforward and at other times, they are much more subtle. Often, peer pressure to succeed is socially complex and significant. Either way, peers share a folk psychology that makes things tick in daily life. What students value and know, their common sense of it, is directly related to the cultural norms among peers. This peer culture seems to help shape these students' meaning and action to the requirements in school chemistry and visa versa (Bruner, 1990).

Sometimes positive peer pressure is as simple as where one chooses to sit in the classroom. Some students describe seat choice as a message to peers concerning attitudes and dedication. Traditionally, serious students sit in the front of the room and those who don't care much about academic performance sit in the back. For example, since people choose their seats in Hatfield's class, some apparently group themselves according to their concern for grades. During one of our conversations, Nicole, Christine and I were discussing students' social talk during Chemistry class. I asked them why students who care about their performance in Chemistry talk during class. Nicole answered first.

> (Nicole) That's why I had to move to the front.
> (Christine) The back-- that's where the goof-offs are. Everyone talks.
>
> (Question) So it really does make a difference where you sit?
>
> (Nicole) Oh my gosh, yes! I'm in the front row...
> (Christine) People fight for the front row. People look for front row seats. That's why when we pick our own seats, the first two weeks, we took the front. Hopefully, she will not change seats because I can't sit anywhere else. That's it for me. Cause that's like how I do well I guess (Interview, 1/14/94).

Sara, Zack, and Ric regularly choose to sit in the back corner of Mrs. Hatfield's room. Sara explains that this enables her to tutor these boys in chemistry when they don't understand something. Mrs. Hatfield confirmed this by explaining that Sara likes to "mother those boys" and "take them under her wing. ... She's taken them in as her cause" (Interview, 11/24/93). These three students regularly and quite consistently conduct their own conversations during chemistry class. Actually, I observed very little conversation that could be characterized as chemistry talk or peer tutoring. Most of their conversations as observed, were about their social lives or other topics apparently unrelated to chemistry. The character of the talk is evidence of the social purposes of school and the importance and power of peer relationships. They support each other, care about each other, and occasionally help each other with chemistry. When they do talk about chemistry, it is usually in order to help Ric understand the homework or how to do the assignments. For Ric, chemistry is very difficult and he is consistently at risk in this class.

Positive peer pressure can be as simple as influencing seating choice, but it can also be much more subtle and more closely related to chemistry. For example, Sara mentioned that she heard from other students that the second semester of Chemistry will be more difficult than the first. Sara says she tries not to listen to other people's opinions but it is quite clear from what she says that they are in fact a matter of concern. She explains that grades are often connected to other people's opinions and therefore others' opinions influence a person's decisions about success. According to Sara, what other students say about a course often influences a person's propensity to succeed.

> No, I try not to listen to people's other opinions and I like to just judge myself so if I go into a class with an attitude that this is really hard and you will not get any better than a C . Then chances are that you will not try for anything more than a C.. So if you go into it with an attitude that if I study I can do this,... I don't think what I do doesn't have anything to do with what anyone else says (Interview, 10/5/93).

Peer pressure regarding chemistry is often much more complex and explicit. The majority of these students feel a great deal of pressure from their peers to take chemistry and be successful in it. Most of these focus students' friends are all going to college and they all take Chemistry. During teen-age years, if everyone else important is doing something, it must be the thing to do. It was quite common for the topic of positive peer pressure to surface during our conversations. On one occasion, Carrie, Jessie and I were discussing grades and what it takes a student to get good grades in Chemistry class.

> (Question) How much do you study?
>
> (Carrie) I always do chemistry at lunch.
> (Jessie) I almost never do it. ... No, I don't like it. ... I have a C last term.
> (Carrie) Don't be embarrassed Jessie.
> (Jessie) But I mean... . I know I can do better. But it's hard because I don't like it. It's just that if I would just look at the stuff a little more, I could bring up my grade. Sometimes I could just cry when I look at a test (Interview, 11/19/93).

Carrie evidently perceives that Jessie is embarrassed by her grades in Chemistry class and tries to comfort her. Jessie appears to justify her performance in the presence of her peer and the interviewer. It seems important to her that Carrie, an A student, understands that if she "would just look at the stuff a little more," (Interview, 11/19/93) she would do better in chemistry. Jessie apparently wants us to know that she is capable of getting better grades. Therefore, she is apparently concerned about not only what her peers think of her grades, but also what they think of her ability. It is not clear whether Jessie "could just cry" because she does not understand the chemical concepts included on the test or if she is concerned about being embarrassed again by a poor test grade (in comparison to Carrie's grade). Either way, her concern is peer related.

Of course, it is very understandable that these young people care about their reputation as good students. As explained elsewhere, they all desire this reputation. Brad is also very interested in maintaining his reputation as a successful chemistry student and goes to great lengths to develop and maintain this reputation. But Brad seems to foster a different kind of good-student reputation-- one, according to Jane Hatfield, based on pretenses. Although his teacher explained to me that he actually does all his homework and gets all his work in on time, he seems to want peers to think he can be an A student without much effort. Because of this, Brad also seems to be a mystery to many of his peers--something he apparently enjoys. Nicole was explaining her frustration about Brad when she said: "I noticed Brad. I don't think he ever does his homework but he always gets A's. That's because he can just sit there and understand it" (Interview, 11/19/93). His peers quite often talk about Brad in our conversations. Christine complained that...

> Brad... doesn't pay attention at all and he's a 4.0 in this class. It bothers me because I try to pay attention and try to see what she's saying to like work and work and work at least kind of a B. And then he doesn't pay attention at all and can talk to Alex Bailey and kid around with every one and still gets an A (Interview, 1/14/94).

Brad seems to foster this reputation and this sense of mystery about him. During a conversation with Brad and another chemistry student, Amy, Brad described the way he plays the system. "I get all A's on the tests and stuff but I get 50% on the labs because it's so sloppy" (Interview, 11/1/93). And then he goes on to explain his study habits in comparison to some of his friends. "My friends have to study really hard to get A's but I like to sit around and like watch TV and sleep and then right before the test, figure it all out. They study all week and get a C" (Interview, 5/10/94). When he talks about daily assignments, he makes it very clear to Amy and me that he rarely does them. "Well, I don't know if she really checks them or not" (Interview, 11/1/94). Then we talked about the times when he did not have his assignments done. "Yea it happens a lot." He explains that he hates school and that he would rather not put any effort into it if he can avoid it. "I'd rather get an A- and not work hard than work really hard and get an A" (Interview, 5/10/94). Brad also explains that he really does not need to study for tests.

> I still think it couldn't have been that hard because I missed two days of classes and didn't get any notes and didn't do the review. And, I didn't do the homework but I got a 98% on the test (Interview, 5/10/94).

However, it didn't surprise me when Jane Hatfield explained that much of Brad's talk is built on pretense. "He listens all the time in class... he is very, very bright" (Interview, 2/24/94). I told her about some of the things Brad said about homework and getting by with little effort. She said "It's bravado... I just counted up all the points and he is doing just fine." In other words, he is getting in all his homework and assignments. "He handed in everything. ... He likes to say that he doesn't study but he gets everything in and it comes in on time too"(Interview, 5/10/94). Brad's "bravado" seems to be a pretense fueled by a desire to maintain a reputation he carefully created under peer influence.

Brad's desire to be known as an excellent student is evidenced in another way. He rather consistently competes with another bright student in his chemistry class. Hatfield regularly adds "extra credit" essay questions to her tests that are intended to require deeper conceptual understanding than the rest of the test. "I try to ask questions on tests that go beyond. You know? That's why the test is worth 105-108 points. There are questions on there for Brad and James...and there's a bit of competition there to see whether you can get the perfect paper" (Field notes, 11/25/93). Therefore, according to Jane Hatfield, Brad is challenged by this competition with James for the highest grade in the class. Students feel significant peer pressure to succeed in chemistry class.

Some social pressures to succeed seem to be the result of personal decisions about short and long-range goals which are naturally comparable to peers' goals and aspirations. Students come to chemistry with preconceptions of the need for chemistry and its practical applicability and relevance to their future. Some students talk of pursuing a career in a field where chemistry understanding will be necessary. These students have a perceived, practical need for chemistry on their high-school transcript. Some students are concerned with keeping their career options open and therefore chemistry has only potential long-range value. They have what they consider typical plans for the typical college-bound student-- just get into some college somewhere, decide on a career and then pursue it. For these students, a B in chemistry is often just good enough. Students often explain that, when they apply for admission, any college of their choice will accept a B grade on their transcript. Others say that they want to have the option of applying for an elite or exceptional college and therefore believe that exceptional success in chemistry is necessary for admission. An A grade is the only option for these students. In all these perspectives, it is very important to students to maintain their high grade-point averages. As Trent explained:

> Well, for the short term, yeah, it's (knowing chemistry) important because I have to keep my grades up, hopefully. Long term, I don't know. I mean, it depends on what I end up doing. I really don't know yet (Interview, 5/16/94).

Some students talk of a desire to make excellent grades a personal challenge; in other words, to prove to themselves that they can get a good grade in chemistry. These students seem to take pride in attaining a good grade in chemistry because it is a difficult task. It seems difficult for students to separate this personal challenge to succeed from the concern for the future in terms of college admissions and career goals or from their concern for their reputation with others.

During one of my conversations with Zack, I asked him to explain what chemistry would do for him. He said: "I don't know what I want to be when I get out of high school. I know I will go to college but I just want to keep my options open." I then asked him if he thought more science was in his future. "Well, I don't know exactly what I want to do" (Interview, 10/5/93). He later explains that he likes history and the social sciences much better than science but evidently, because he doesn't want to commit himself on a narrow path, he wants to be ready for any change of heart. Many of the students in this study expressed similar concerns. Brad, in responding to my question about possible vocations, answered "[A]nything I guess, except a homeless person" (Interview, 11/1/93).

In November, when I asked Carrie if Science was an option for her and if chemistry is relevant to her future, she said that it was but that she was by no means decided what vocation to pursue. Later in the year, in May, when I asked her again if she felt science was a vocational option, she said she was becoming interested in a subject that relates very closely to chemistry.

> There's this one thing called environmental toxicology or something like that. It's really cool. Its like studying the toxins in water because there are a lot of them now... See, I'm really glad I took this class cause it's like the basics of chemistry but I think if I get into college, I want to take more sciences. Then chemistry and biology will all interrelate to something (Interview, 11/19/93).

Carrie therefore considers chemistry important for her because it is relevant and foundational to her future study next year and later, in college. In fact, next year, she plans to take AP Chemistry and AP Physics in preparation for college. This year's chemistry is therefore quite important to her and her interests have become much narrower than merely keeping her options open.

During a conversation with Kyrsten, Andrea and Jeff, the subject moved to the practical value of chemistry in these students' lives. Andrea began by stating that "[I]t's sort of interesting in a way, but for what I am going to do when I get older, it has no similarity" (Interview, 11/22/93). I then asked them why most college-bound students in her school take chemistry. Kyrsten answers and then Jeff explains that course sequences are about exposure.

> I think they are just wanting to take it because a lot of people in high school have no idea what they want to do or if they do know what they want to do, like set on one thing, when you get to college, they never really know what they would have liked.
>
> Jeff: It gives you a broader area of subject. They want you to be exposed to it. They want you to be exposed to different things . Otherwise, you get-- like we took general science and life science (Interview, 11/22/93).

Kyrsten seems to think that it is wise to keep one's options open and learn about chemistry in case it is needed later. The need might be related to a change of interest as one grows up and matures. She doesn't want to be limited or tracked into a vocation because she was not prepared for another. Jeff adds another dimension to this in his talk about exposure. It seems he is saying that "they", those who influence students' choices of courses, want students to test many waters before long-range goals are made and a person is entrenched in a certain path where the potential for escape or change of direction may be limited by a lack of exposure to other things. In both cases, it seems like these students would advise others to have many different disciplines and subjects represented on their transcripts. This is related to keeping one's options open and seems to be a theme in the peer pressures to succeed.

Some students explain that keeping options open involves study at a prestigious college some day because they believe more possibilities would be open to them. Students support each other in these expectations as do families. For example, Carrie talks about her family tradition of Yale and Cal Tech.-- "So it is sort of expected of me." (See also, family-based pressures described below.) She later explained that she at least wants to go to a small college where she can know and be known by professors and get a good, solid academic preparation for the future. She then explains that only an A average or something very close to it will be good enough for her. This is related to why she wants to take AP courses as explained above.

Brad also described his plans to be accepted at the University of Virginia or Indiana--

> A really good college, but very selective...because I'm trying to get into a really good college. They like you to take honors classes... Not so much (that I want to get) away from home, just get out of Michigan. Virginia would be better but they only take about 1500 out of state applications out of about 15,000. That's nuts, its very competitive (Interview, 11/19/93).

Brad explained that this is why he needs a high grade point average and why he needs high grades in courses like chemistry on his transcript. He believes colleges look for such things when selecting students. He feels that his acceptance at the college of his choice will depend on his performance and measured success in all his courses including chemistry.

Whether or not students consider a particular college, most of these students describe peer pressure to get excellent grades in high school chemistry.

> Well, I think there are a lot of different reasons why. ... Like I said, to get into a good college, my parents are really pushing me and everything and um, I don't know, my parents, my girl friend was

> pushing me,... and just proving to myself that I could if I really wanted to (Interview, 11/19/93).

When Trent said this, he was describing different reasons why getting good grades in chemistry were important to him and then identifies for us this third form of peer pressure-- taking good grades as a personal challenge just to prove to one's self, and to others, that it can be done. He describes a sense of personal satisfaction in getting the best grades he can and doing as well as he can.

> Well, I always want to get the most I can, the most I possibly can. But if I don't get a hundred and twenty out of a hundred and twenty (points on one of Mrs. Hatfield's tests), it's not going to be that I'm going to be crushed because I still got an A, but yeah, I mean, I'm always disappointed because I missed the questions. And even if I did get an A (Interview, 10/4/93).

Trent seems to be talking about getting the questions correct that gives the sense of satisfaction. His success here, seems to have little to do with knowing or understanding chemistry, it's about getting questions correct and getting a good grade so that he knows he is capable. It is about knowing he can do what it takes; knowing he has the ability to do very well.

There is not only significant peer pressure for success, there is also considerable pressure on these successful students from peer culture that tends to constrain success. Student talk is sometimes negative about school work and students find opportunities to support one another in procrastination. Like the rest of us, they often don't want to work. Sometimes even good students are apathetic or telegraph pretenses of apathy.

> Oh it's just like "I guess I'm going to science now so drag me over there." You know, never "I can't wait to get to science" (Christine, Interview, 11/19/93).

Troy used an example to explain to me how students will say one thing to an adult and another to a peer.

> They can get a good grade. They don't really know what's going on. I mean, what a lot of kids would say around adults they wouldn't say around other kids. Like for instance, if an adult was asking them: "So, do you like this? Did you learn it?" "Yeah, It's real interesting." But then to other kids they're like: "I don't want to do it." Cause they think it's like, it's like cool to not know what you're doing. If you really do know what's going on. ...
> It's just like if there's like for instance, if there's a kid that never does his homework or anything; and if an all A student. This is an actual example. An all A student asks him: "Well, did you do your homework?" And the guy's like: "I don't care! Big deal!" And the other all A student will laugh and say, and like, he'll get a lot of attention (because he did it without much work) (Interview, 5/10/94).

In Troy's opinion, some of his peers will say what the listener wants to hear. Maintaining a reputation with peers and getting attention seems to be a complicated thing of knowing what to say and when to say it. According to Troy, if a teacher or another adult asks a good student about chemistry, the answer will likely be positive (whether or not truthful). In addition, the peer influence Troy describes links "coolness" with pretenses or perhaps negative attitudes toward chemistry and academic work. In Troy's example, it seems socially preferable to at least say you do not try hard and do not care much about chemistry.

Students described at least four other significant constraints that work against a person's success in high school chemistry. All four of the constraints center on limits to a person's time and energy. Time and energy are limited commodities, and these students struggle with balancing the demands of academic work with these other demands and concerns. Like many other students in many high schools, these students are often very active in their school and preoccupied with busy social lives. Some also have jobs after school and on weekends that make demands on their time and energy. All of these significant factors stand as constraints to success in different ways and contribute to the common sense of schools and school work.

Although some struggle with these constraints more than others, all students seem to weigh their desire to succeed against other priorities and negative pressures. Many of these pressures against success exist within the first cultural milieu, involve student priorities and include other immediate demands on time and energy. In the first case, time spent on chemistry work seems to have the potential to interfere with a student's social life, with work after school hours, school activities and personal freedom. Some students seem to struggle with this more than others. For example, as Christine and Trent were discussing how much time they spent on chemistry at home, Trent explained that although he made a decision to make homework a priority this year, his music and drama take most of his time. Consequently, there is often little time left for Chemistry and other academic work. Christine also explained that she has only a limited time to spend on her homework She made no preliminary commitment as Trent did, Christine explained that her time is also very limited and other academic work often takes priority over chemistry. "That's all the time I have to do my homework" and because of other work, there is not much time left for chemistry. Christine's opinion seems to be much more common than Trent's. Generally, these students are very busy with other things during and after school so that finding time for any academic work is often a challenge for them. If Chemistry is not their priority, they often seem to struggle with the temptation to not spend any time on it.

Kyrsten also describes time as a factor which constrains her success. Like many of these students, Kyrsten has a rich social life, is active in seasonal sports, and works part time. For Kyrsten, it is not that Chemistry takes a lot of time. In fact, it seems that if one just spends a limited time on her homework, she will succeed. For example, when she was describing how she studies for tests, Kyrsten said: "Well personally, I didn't find the test hard, the only reason I didn't find it hard is because I studied all the objectives for about an hour. If you don't study the objectives, you know you will really do bad" (Interview, 11/22/93). The hour spent seems to be an important point. According to Kyrsten, if one can dedicate an hour to the objectives, success with tests is ensured. Even this one hour of study time is not often possible for her.

Trent, Christine, Kyrsten and others speak of the difficulty of finding enough time for work in chemistry. Too little time to spend on academic work is a constraining factor in the lives of these good students. All the things that are provided for them either in their schools or after school seem to compete for their time. Many speak as if it would be difficult or impossible for them to dedicate more of their time to academic work, even though most of them seem to feel that more time spent would be beneficial. For Jessie, there seems never to be enough to study for Chemistry tests: "You don't have time. One night or something is not enough" (Interview, 11/19/93). Although one night is much more than most of these students feel they have or need, Jessie seems to say that it is not enough to do really well. She apparently is telling us that she doesn't have the time to prepare the way she really should for tests.

One of the reasons it is often difficult for these students to dedicate time to their Chemistry work is that they have very serious social demands on their time. Most of these Chemistry students have very busy social lives. If they are spending time with their friends for social events they can not spend that time on their academic work. Many of these students are busy socially several evenings each week. For example, football games and basketball games are usually played twice each week for most of the year and many of these students attend most of these games. If they are on one of the teams, practice sessions are every day after school for one-two hours. In addition, many have dates regularly, parties, and other school and church sponsored events. All of these things compete for a student's time.

It is not only that they are actually so busy with social functions. Many of the social pressures and emotional stresses follow students through their day to distract them from their academic work. For example, Andrea, in a conversation with Kyrsten about a chemistry test, explained that she did not do well in this test because she was socially preoccupied at the time. Andrea knows that if she does not spend time on the chapter objectives: "Then you are going to get an E." She was clearly saying that is what happened to her.

To confirm this, Kyrsten responded: "Yes, so I'm sure Andrea didn't study those objectives" (Interview, 11/22/93).

I asked Andrea to explain because this grade is far from the typical grade for Andrea. She describes how her social life with boys and others preoccupies her emotionally and preoccupies her time. When Andrea thinks of those of the opposite sex, it is difficult for her to dedicate time to academic work. She explained that she had been having some difficulty with boys and was spending a lot of her time angry and frustrated. This effects her greatly and colors her outlook on life in school as well as out of school. When one thing seems to go wrong, everything seems to go wrong. It is difficult to care about school and academic work when all these other social factors take so much emotional and physical energy. At times like this, Chemistry is not at the top of anyone's list of priorities.

> I know what hurt me. I was not caring about school at all. I was thinking about the male species. (laughter) I didn't study. I don't think I even read the chapter. I was like mad all last week because I had to conform to seating charts OK? I mean I am so sick of seating charts, I was going crazy. I left one class because where I sit is in the middle of the English Lit room but it feels this big. (Motions with her hands) People around me talk all them time and I don't even like them. I was just going insane-- I just left. I went home. ... (I felt) claustrophobic. Last week I was mad about seating charts, this week its like I don't care. I am having a nice day conforming to seating charts (Interview, 11/22/93).

A less emotional constraint is related to the after-school jobs that compete for a student's time and energy. Students explain that it is difficult to find time for homework when they are involved in work after school. When they talk of work, they mean after-school jobs. Many of these students work in department stores, stores at the local shopping malls or other businesses to earn spending money and/or money for college. Kyrsten provides an example on one extreme of this time constraint factor. She often talks about her work at a store at "the Mall." Before Christmas, I was discussing this with her when she described her situation. "Yea, I have been working six days a week (after school)" (Interview, 11/22/93). In this state, employers are by law, not allowed to require minors to work more than 18 hours per week so I asked her about this. "Oh, no, last week I had over 30 hours. ... That's because other people couldn't for school plays or something like that. I had to cover for them so I had a lot to do. I don't normally work that many hours" (Interview, 11/22/93). However, she explained before that it was very common for her to work at least 18 hours every week. The store manager evidently makes the work schedule and assigns his workers hours as needed. If an employee for some reason cannot work according to the assigned schedule, he/she may get another employee to "cover for her." Kyrsten is evidently willing and therefore is often asked. Kyrsten complained that with even 18 hours of work, she often did not have time to spend on her studies. She doesn't talk as if her work at the mall is optional. Instead, she seems to consider it as a given and that she just expects to work this many hours during the week. In addition, she explains that her parents expect her to work. She explains that this work not only gives her some necessary money for clothes and discretionary spending, she is also able to put some money away for college. Her parents will help her with her college expenses, but there seems to be an understanding between Kyrsten and her parents that she should try to save as much money now as she can. In this sense, working is expected of her.

Most of the focus students in this study work regularly with schedules similar to Kyrsten's weekly schedule. On one occasion, Paul, Kurt and I were talking about work after school hours. Kurt is an exception who does not have a job, and therefore does not work during the week.

> I have a really busy schedule and I don't have that much free time at all. So, you know, I didn't really want to add a job until this summer came. And then possibly flow through it. But the way things are working, my Dad wants me to get a job as soon as I can get a car. I'm-- my Dad's sick and tired of driving me around everywhere so he wants me to get a job and get a car.... Some students like, you know, get money from their parents for doing absolutely nothing, but their parents will pay the insurance on their car or at least help them buy their car or some of them, like Paul. Paul, you had to buy everything didn't you (Interview, 1/12/94)?

By "flow through it", Kurt was explaining that if he did get a job this summer, when school is not in session, he will consider trying to keep it part-time when school begins again in the fall. But apparently, his reasons are different from Kyrsten's. First, Kurt explains that he does not work now because he is too busy with other things. He explained on other occasions that he does not spend much time on academic work, so he is talking about his social life, sports, and Church activities. He is quite active in his Church youth activities. Unlike Kyrsten who just assumes work as a priority, in order for Kurt to work, he would have to fit it into his already-busy schedule. His reasons are also different. Kurt apparently wants the freedom of movement that a automobile would potentially give him. According to Kurt, his father also feels he would be less burdened by Kurt's involvement if he had his own can. Kurt evidently will settle for what he calls a "student car", an inexpensive "junker" he can afford to buy and maintain himself. Saving for college did not come up in conversation with Kurt.

Paul's relationship to after-school work is similar to Kyrsten's. Paul works at a local nursery stacking shelves and waiting on customers. "I worked 35 hours before Christmas. That's too much." Christmas time is a very busy time for this business because they sell Christmas trees and all the trimmings. Consequently, they usually expect a lot from their employees during the weeks before Christmas. Paul went on to explain that he usually works about 20 hours every week. Like Kyrsten, he seems to feel that because to his work commitments, it is very difficult to find time for school or a social life. He explains that he must work in order to support his car and save money for college.

Nicole works at a local department store. There are many constraints in Nicole's life and her academic work is often not a priority. As explained before, she finds it very difficult to study and concentrate on Chemistry when her father and grandfather are so ill. Mrs. Hatfield also explained that Nicole is constantly, emotionally preoccupied with these family concerns. She seems caught in a complex emotional tangle of family, academic and after-school work concerns. "Yeah, especially working too...I work eighteen hours a week." She went on to explain that she had just turned in her notice to quit her job because she could not keep the pace. "I can't work and study and they just treated me really terrible" (Interview, 1/14/94). This was confusing to me because I knew that the store she works at has a rather good reputation with their employees. I didn't know from this whether she felt her work was interfering with necessary academic time or if the business's treatment of their employees was the problem. I told her about what I heard about this business having a rather good reputation with their employees. Her response led me to believe that her work was mainly in conflict with her family concerns and responsibilities more than with academic work.

> Well that's probably from someone else, but they were giving me a hard time about having sick calls. But it's like I told them, 'You can fire me because you know, my family's more important and I'm gonna be at the hospital. You're only allowed a few sick calls-- six sick calls a year. And I'm like-- I quit (Interview, 1/19/94).

For Nicole, it seems that between work, family responsibilities, and school work, there just isn't enough time or emotional energy to go around. Because of this, she seems frustrated and concerned that she can do none these things, including her school work, as well as they should be. Understandably, she finds it very difficult to spend her time, as well as her emotional energy, on Chemistry.

It is not just pressures from activities and commitments from outside high school that constrain success. Some students also explain that their potential for success is limited by activities more closely related to school life which compete for their time. Many of these students are very active in extracurricular activities including sports, marching band, and school plays.

These activities are very important to them and demand much of their after-school time. They seem to feel that these social activities are a necessary part of their high school experience. Constraints often seem to require compromises through which students decide what it means to be successful and thus complicate the story about what academic success means to students. For example, when I asked Christine what extracurricular activities she was involved in, she smiled.

> Everything. Well, I have cross country and marching band which I have to do. I quit flute and I like that a lot cause I did a lot of that in past years but I just do marching band. Anyway, you have to do it--all those combined. There are times when I don't have time to do a lot of homework. And that's just in the fall. I think the fall is the hardest time for me (Interview, 10/4/93).

Trent also explained how busy he was with music and forensics. Trent plays the bass, electric bass and guitar in a jazz and rock bands, the school orchestra and another band that "does things for churches." With practices and performances, he stays quite busy on week days as well as on weekends. He explains that his music is a priority and sometimes it is very difficult to find any time to spend on academic work.

A few of these students, like Christine, are involved in extracurricular athletics which demand a lot of their time and energy. Christine is on the cross-country team and plays in the marching band. As explained before, she even felt she had to give up her flute lessons in order to have time to keep up with her school work. Especially football and basketball in this school take a lot of student time. Practices last a couple hours and are almost every day. Games are often twice a week. Christine must practice with her marching band regularly and participate in every game.

Brad is on the football team this fall as a linebacker. "We finished our season last Friday but that takes a lot of time" (Interview, 11/1/93). During football season, he finds his time very limited. With sports, not only time, but energy is limited. Football or basketball practices are most often very physically demanding as well as time consuming. It is often very difficult for a student after the usual difficult practice to feel energetic enough in the evening to spend time on academic work especially if the work is difficult or demanding.

Troy plays on the school soccer team, Paul is a member of the golf team, and other of these students play tennis or compete on the swimming team. Several play instruments in the school band or orchestra and also take private music lessons. A couple girls are involved in gymnastics and one takes dancing lessons. All of these activities and commitments demand time, emotional and physical energy and potentially compete with academic work. As further evidence of the competition between extracurricular demands and academic demands, Jack Honderd has a personal policy to never require homework on game nights and regularly reminds his students that chemistry homework should demand only a limited amount of student time outside class time.

The 2nd Cultural Sphere of Influence: Families, especially parents, put pressure on students to succeed in school chemistry instead of real chemistry. Families help set standards for success.

There also seem to be pressures from parents on these students to first elect and then succeed in Chemistry. The first kind of parental pressure students talked about is a rather direct coercion. For example, Paul (Paul is not a focus student) is a member of a family which recently immigrated from

Vietnam. He spent several years in schools in Vietnam and his parents evidently believe the Asian educational system is far superior to the American system. Consequently, when his parents moved to Michigan last year, they felt strongly that their son would be far ahead of the American students and should not be held back intellectually and academically. They therefore insisted that Paul take chemistry during his freshman year in high school so that he could be challenged and get a head start on his AP courses. Paul himself, told me that they felt he should not waste his time in the regular freshman courses. Paul's parents were the driving force for this decision. Incidentally, Paul is maintaining a 4.0 grade-point average this year.

Although most of the focus students in this study experience less direct pressure than Paul, parental pressure is still very much a part of their decision-making process. In a conversation with Jessie, Andy (another student in Jane Hatfield's class) and Carrie, we were discussing why anyone might want to take chemistry in high school. I asked them if their parents put pressure on them or if it was their own decision to take Chemistry. Their parents seem to influence them in the form of academic expectations. Evidently it is a family assumption that they will go to college and it is assumed that Chemistry is necessary for attaining that goal.

> (Q) It is just expected that you go to college?
> (All Three) Yes. (laughter)
> (Jessie) Yeah, it's not something I always wanted to do but there was never really any question about it. They don't really put pressure on me but they always like say you're going to college. Not in a mean way but just like a fact; like as a matter of fact.
> (Andy) Something about it is just expected.
> (Jessie) The only question is like how to afford it and stuff like that. Like how much school. In Michigan for me, because I can't afford to go out of state and so how am I going to pay for it (Interview, 11/19/93)?

A few students also talked about their parents' expecting them to not only take chemistry, but to do well in it. It is often just assumed that they will take chemistry as part of the college preparatory plan and now, once the assumption is made, most of the pressure concerns grades. Kurt and another student, Craig, provide one example when Kurt tried to explain why he started to "get serious" about chemistry and "kicked it in" during the second quarter.

> Oh yeah, my dad, oh. He got, he was really disappointed which surprised me. He didn't yell at me. Just made me feel rotten which kind of led me to go: "All right" (Interview, 1/12/94).

Kurt's father was evidently disappointed in his performance in chemistry and made it quite clear to Kurt that he should be doing much better. When I asked them, both of these students were quick to explain that the main, at least the first reason they thought of for doing well in chemistry is the wishes of their fathers. "My dad motivates me. Yeah, very much!" Fathers put obvious pressures on these students to succeed in chemistry. At least Kurt responded by improving and raising his grade.

Troy also feels pressure from his parents about his chemistry grades.

> Well my parents usually always tell me that I'm capable of doing better than what I do. Or like I remember when they would tell me on my report card or something you know: "you can do better than that you just don't try." But I'm sure I know I don't because I've gotten bad habits. It's not like I go home and do my homework right away and study and stuff. Like if I can, I usually leave it to the last minute (Interview, 10/19/93).

At first, Brad surprised me because when I asked him if his father (the university professor) pressures him to take chemistry, he said "no." But then, to press this farther, I asked him if his father gets involved in his education.

He answered: "He tries to get me to take AP English and 'Dead Lit.' and stuff like that" (Interview, 11/1/93). It is very likely that if Brad would not elect to take chemistry or not work for good grades in chemistry, his parents would object. I don't think this would be a surprise to Brad. It is taken for granted that he will succeed and will go on to college having chemistry on his transcript. He doesn't really think about it, just accepts it as fact. This just makes sense in the context of the second cultural sphere and parental influence.

Several of the students in each of these schools are members of university families and all of them tell similar stories of family influence for success. I found Ric, Sara and Zack at the local Burger King for lunch one day so I asked to join their conversation (Suburban High has a "closed campus" policy so this means they were truant.) Ric, talking about his family situation, explained that his father is a statistician and professor of industrial relations and his mother is a teacher at a local Headstart program. He explained that this puts a lot of pressure on him to not only take a college prep program but also to maintain an excellent grade-point average. His explanation came as a response to my asking Sara if she would be going on to college.

> (Sara) I don't really have a choice. It's just expected of me.
> (Question) Does that mean you don't really want to?
> (Sara) Well, I really don't mind.
> (Ric) You didn't ask me if I want to go to college. (laughs) I don't know, I just learn from life and I guess I will go to college. ...Well, my parents want me to go to college. What my parents want and what I want are not exactly the same thing.
> (Sara) I guess that's the way it is with any teenager.
> (Ric) Well sure, but Mexicans are different see. We can just do anything we want. ... I can just go to Florida and I will never have to go to college (Sara laughs) (Field notes, 10/19/93).

Ric went on to explain his recent family history. They immigrated from Mexico when his father came to the university to do his doctoral work. Under the joking about being Mexican, Ric was certainly describing family pressures to do well and other ethnic or cultural pressures regarding school work. He and Sara also make it quite clear that sometimes the goals and expectations of parents are not exactly in tune with those of their teenage children.

Family tradition seems to play an important role within many of the families represented in this study. This places the second sphere of influence in an historical framework. All of the students in this study are from families that have a generational history of preparing to go to college during their high school years and later preparing for a profession. If one of these students would choose not to go on to college, he/she would be breaking with tradition. Within family tradition is the belief that successful completion of chemistry is prerequisite to a college career. Parents and grandparents and other relatives who are considered successful all took chemistry when it was their turn. It is just one of the things to do in high school. For example, Carrie explained this when she was talking about her family. Both of her parents took chemistry, went on to college and consider it a family tradition. The precedent is set for Carrie and she doesn't resist it.

Family pressures also seem to constrain success. One of the forms these pressures take is related to student perception that parents are merely interested in the grade and that it doesn't matter if a student learns any chemistry. This might simultaneously be a pressure for one form of success that is defined by good grades and another success that could be defined as learning how real things behave in the natural world. When I was talking to Kurt and Chris, they stated explicitly that their parents were "mostly interested in the grades." Kurt went on to explain briefly that he is not just interested in the grade and "We have conflicting views" (Interview, 1/12/94). These conflicts of opinion it seems, would tend to stand in the way of a student's desire to succeed. At least , this parental opinion would tend to stand in resistance against a student's desire to learn. Craig joined in and said: "So you feel successful in a sense that you've learned stuff but you don't feel successful in terms of grades." Kurt went on to explain. "That's just how things work. ... I don't really care about the grade that much. I'm glad I got a good grade last semester" (Interview, 1/12/94).

I asked many of the focus students about this parental expectation for grades. In one conversation, I asked Trent explicitly if it is the grade that his parents wanted or if they wanted him to learn chemistry. he thought about this for a few seconds and then responded.

> Yeah, actually, I think my parents just basically say good grades. Yeah, I don't know if they would be too thrilled if I was failing a class and said: "Well, I think I understand. I just don't do any work" I don't think that would go over too well. (laughter) Well, yeah, I mean getting good grades is important, understanding is important.
> (Question) Do you think they make the assumption that if you get good grades you understand it?
> Yeah, I think so (Interview, 5/16/94).

Trent not only identifies the parental expectation for good grades but also a similar conflict between getting grades and understanding chemistry that Kurt and Craig identified above. Again, this conflict stands against one form of success.

Other family pressures and responsibilities might also stand in the way of a person's success. Jack Honderd explained how Kurt is under pressure from very a complex and difficult situation at home. According to Jack Honderd, this often drains Kurt of emotional energy and preoccupies him with things that seem so much more important than success in chemistry. Honderd emotionally explained that Kurt is gifted but under extreme family pressure so that chemistry sometimes seems rather inconsequential.

> He is extremely bright but under a bad family situation, very bad. His step-mother hates him, just hates him. I would have a hard time dealing with her day in and day out. She is cruel to him and this creates a rather negative situation. It's not uncommon for Kurt to go six weeks and not turn in a single homework assignment. ... The first marking period, he didn't turn in a single assignment until the last two weeks. Then he got an A and got a decent score on his final exam so he ended up with a good grade (Interview, 5/10/94).

Jeff also at times feels like his work in chemistry is inconsequential in comparison to his other family responsibilities and pressures. Jeff is a 15 year-old father of twin girls (see p. 100).

According to Jack Honderd, some of the pressure he is under has to do with his parents' cultural background and ethnicity. Honderd explained that Jeff was born in Russia and because of differences in outlook, his family does not necessarily get along well with the mother of the twins.

> You know, the Eastern Europeans are more authoritarian oriented. His father is the patriarch of the family and is definitely in strong control. He (Jeff) has twin daughters which is a strange situation. His parents have not made him accountable for his actions very well at all. They are just kind of taking care of the babies all the time. ...It's kind of an interesting situation because of the way the father is, you know. I don't know if they got married or not or what was goin on with the whole family. She was really having a hard time because he wants to control the entire raising of the children, and she is still the mom. She graduated from high school (She is Honderd's former student) and she has a much more independent nature than dad is used to dealing with. That's caused a lot of friction there (Interview, 5/10/94).

Jeff is not married to the mother of his daughters. In fact, according to another teacher who knows the mother well, they don't even talk to each other unless they have to. She apparently tries to keep Jeff away from the girls and is suing for custody. When I mentioned to Jack Honderd that Jeff must have a really hard time concentrating on chemistry, he responded by saying: "I would think. I would think so."

There are many other examples of family situations that constrain a student's concentration or ability to do school work. Andrea is one of the students who's father and mother separated and divorced during the school year. This family strife, according to Mr. Honderd, was very difficult for her. Andrea has been in a lot of trouble that might or might not be related to her family situation.

> I know she gets in a lot of trouble. She dates much older guys and that's gotten her in some trouble at home. I know she has been out of the house for periods of time. ... She does about as well as she could given all the cards she's dealt." (Interview, 5/10/94).

If there is trouble at home, these young people must bring these concerns with them to chemistry class. There has been a different kind of trouble in Nicole's home as well. Her father is very sick this year with what they thought was lung cancer. The diagnosis is very uncertain, however, and doctors are suspecting some other mysterious and dangerous disease. The uncertainty of her family's future is very difficult for Nicole to deal with. In addition, her grandfather recently had stomach surgery and is not recovering very quickly. Nicole says she spends much of her after-school time at the hospital. "Yeah, the nurses there, they all know my name because I'm there so much" (Interview, 1/14/94). She is of course very concerned and often preoccupied with her family problems. She finds it difficult to concentrate on her studies. The uncertainty of her father's condition is evidently one of the most difficult things for her to deal with.

> And they took the mass out and it turned out to be some disease that you can get. They took it out and thought that just by treating it with antibiotics, but that was why he was loosing weight because there was a chemical imbalance or something. And that's why he is losing so much weight and everything. But then he quit smoking because you know, it was by his lung and everything. He's been really good. He hasn't smoked since Christmas. And like the very beginning of January he got sick again and started losing weight again. They put him back into the hospital and did testing, but I guess there is something wrong with his kidney or something. They gave him pills for that and now he is regulating. And then my grandpa went in. It was a planned surgery for his stomach because something went wrong and he's been in the hospital ever since (about a month). Things keep going wrong (Interview, 1/14/94).

Her father and grandfather were in the hospital in serious condition at the same time. I asked her how she handles all this. In response, she said "Oh, you just balance things out, you get your priorities straight." She explained that because she spends so much time in the hospital, her job is at risk and she has missed more than the allowed 15 days of absences at school. (Suburban's attendance policy allows no more than 15 excused absences) She says she isn't really worried about the school absence policy.

> It's not because I've been skipping school you know! I've been up at the hospital and you know, stressed out. I get sick easily too, so."I guess my dad said they'd call. If they try to take away my credit or whatever, he's gonna go down there and sign something or talk to them and explain to them what's going on (Interview, 1/14/94).

She went on to explain that Mrs. Hatfield has been very understanding and is letting her catch up with all the assignments and missed tests. This year has obviously been very difficult for Nicole to get any school work done on time or to concentrate on what it takes to succeed in chemistry.

The 3rd Cultural Sphere of Influence: There is also significant institutional pressure for success in school chemistry and not real chemistry. Institutions help set standards for success.

Although institutional pressure for success was not a common topic of conversation, it was considered very significant by students. The school as institution is made of "overlapping collectivities," or groups of stakeholders with similar concerns and interests which greatly influence life in school (Cusick, 1992). Unlike others who resist (McNeil, 1986; Solomon, 1992; Willis, 1977) the students of this study respond quite positively to this pressure or at least take the institutional expectations for granted. Students describe institutional pressures that are based in the assumptions that college-bound students need chemistry on their transcript and also that good grades in chemistry are necessary for college admission.

Students apparently believe that a good Chemistry grade on one's high school transcript is required for college admission. Both of these schools have lists of core courses that are required for all students, a set of "shopping mall" elective courses for anyone who might be interested (Powell, Farrar, & Cohen, 1985) and another list of requirements and suggested electives for college bound students. The chemistry students have been told that chemistry is required of them directly or indirectly by their parents and other adults involved in the institution. It is therefore the students' perception that the school expects, even requires its college-bound students to take Chemistry. As stated before, there is no official policy to require Chemistry on a college-bound student transcript. It doesn't really matter though because students believe it is required in one way or another. For example, Brad and a chemistry classmate, Amy (Amy is not a focus student of this study), were discussing this in response to my question: "Why are you taking Chemistry?"

(Amy) It's required.
(Brad) It's not really required but it is required for the college-bound path. ...

(Question) (later in the conversation): So, chemistry is required by the school? I mean, did they tell you that you had to take Chemistry to go to college?

(Amy) No, I think freshman year we got a packet and it said that route you can go through.
(Brad) You can go through the normal (freshman) science, Biology and then Chemistry. We can choose our senior year what we can take.
(Amy) It's safe to take it because it's kind of needed for college (Interview, 11/1/93)

Amy begins stating that Chemistry is required for graduation from high school but soon agrees to qualify that statement and agree with Brad that it is only required for college-bound students. His statement that they can choose in their senior year was apparently meant to explain that their senior year is, in a practical sense, the college-bound student's only chance to take elective courses. This is a very common student perspective but in fact, according to the *Student Handbook*, students are only required to take 2 science courses during their high school careers. There is no mention of Chemistry as an official requirement. However, as Amy describes, high school counselors often strongly suggest that college-bound students elect introductory Chemistry. At the beginning of their Freshman year, the counselors unofficially placed each of these students on a college-bound sequence of courses. Later, Jessie explained this to me quite clearly. "Well, you have to take a certain number of years of science in order to graduate and go on to college. We are on a sequence. Chemistry is next" (Interview, 11/19/93). Whether or not the sequence is officially a tracking system and a list of official requirements, the students at Suburban High certainly feel pressure to take Chemistry.

Also at Green Lake High, the *Student Handbook* states that 2.0 credits of science must be part of the 22 credits required for graduation. A credit is given for each full-year course. Which science credits a person must take are not specified. In their *Educational Planning, 1993-1994* booklet, the Green Lake high administration states in the "Suggested College Preparatory Program" section, "the Presidents Council of State Colleges and Universities states that successful completion of the following core courses will be required for admission to any of the 15 public universities in Michigan." Among this list is "2 years of biological/physical sciences; 3 years strongly recommended." Chemistry is not specifically mentioned as a requirement. During their first year at Green Lake High, students design their high school course plan according to this booklet and submit it to the counseling department. At this time, evidently, chemistry is strongly suggested as partial fulfillment of the science requirements for graduation. In both schools, although there is no official requirement that students take chemistry, they receive the rather clear impression that it is expected both for graduation from the college-bound track and for college entrance.

Zack and another student, Sara also explained their views on this subject when I asked them why they were taking Chemistry.

> (Sara) It's required.
> (Zack) No, just like 3-4 credits of science... .
> (Sara) I know I had to take it. I had to take 4 years of science. So it was either adaptive chemistry or chemistry. I didn't want Adaptive Chem. so I might as well take this Chemistry. I didn't want to take it, I mean... next year I will take physics... just regular physics, I don't need to have AP Physics... .

(Zack) It's not that bad of a class really. If you have to take science anyway. I really don't know what I want to be when I get out of school. I just want to go to college (Interview, 10/5/93).

Again, there is a disagreement about whether or not Chemistry is actually required by school policy. However, it doesn't really matter if official policy requires Chemistry because college is definitely in their future and most of the students in this study feel they must take it. Troy, at Green Lake, confirmed this when he said: "I'm taking it pretty much because it's a requirement. You have (to take) two years of science... . Chemistry is next in line after Biology" (Interview, 10/19/93). Trent also explained that at his school, "They kind-of say if you plan on going on to college, you should take it" (Interview, 10/4/93). Many of the other students described similar beliefs. Whether or not they will ever have to know any chemistry later, they are quite willing to take chemistry now as something they have to do for college. I tried to get a student, Charles, at Green Lake to describe his feelings about taking chemistry just because it is required versus taking it to learn chemistry. First, he gives both of the reasons and then goes on to say that unless a student wants further study in chemistry, learning it has little practical value:

(Question) So you have to take chemistry because you want to go to college? Who told you that you have to take it for college?
(Charles) Well, if you want to go to college, you have to take it. You sort of need it for the future.
(Question) For the future. For what?
(Charles) I don't think any of this stuff that we're learning right now we're going to use in the future. (laughs) I mean, It's good to know, but all this math stuff and, you're never gonna use that. I mean, unless you're going on to college and then you're going on with this stuff, you're going to have to know about it. ...I mean if you go to college and then you get a good job or whatever, you might not know

> how to do this stuff, but let's say if you're just an average Joe, You know, you don't go on to college or whatever, you can just get some kind of job. You don't really know all this algebra crap and stuff. That's what I think (Interview, 10/19/93).

Algebra is probably on Charles' mind because this conversation took place during a unit on molarity and molality. It seems to be somewhat of a mystery to Charles why colleges would require chemistry on a graduate's transcript other than for those who wish to go on in the sciences or need it for a future vocation. Other than "it's good to know," it seems to have little use or intrinsic value for him.

Troy explains that there are more people associated with the school who have vested interests in whether or not a student does well in chemistry. He was explaining to me that colleges require a good grade in chemistry on a student's transcript. He then began to complain that "they put too much emphasis on getting a good grade." I asked him who "they" are. He said: "The teachers, the school board, everyone" (Interview, 10/19/93). According to Troy, everyone associated with the institution put various pressures on students to get good grades and thereby be successful in high school chemistry.

The 4th Cultural Sphere of Influence: Teachers put significant pressure on these students to succeed in school chemistry instead of real chemistry. Teachers help set standards for success.

The fourth cultural sphere in this conceptual model represents the teacher's influence in how students view their world in high school chemistry. Teachers and students meet each other in high school chemistry to form relationships with each other, with the subject matter of chemistry (Hawkins, 1974), and they both contribute to the formation of local norms of action or moral orders (Harre, 1994). Essentially, the teacher is in control of his/her classroom and therefore, student experiences in chemistry depend on how the teacher constructs and facilitates them (Brickhouse, 1989; 1990; 1992b). But the pathway toward success is a two-way street. Even though the teachers have much power, they depend on student cooperation and participation (Tobin, 1994). Because of this codependency, we will examine this fourth cultural sphere of influence first in the teachers' perspectives and then in the students'. First, I analyze the teachers' perspectives on how they establish rules, expectations and procedures in order to provide student pathways toward success. Then, there are student perspectives on the role relationships and behavioral expectations understood between teachers and students which help facilitate student success.

Teachers organize chemistry so that students can earn a good grade without really understanding any real chemistry

The two chemistry teachers in this study told about student success and what it takes to be a good student of high-school chemistry. According to our model, students look out at their world through spheres of influence so that chemistry and what they know of it is filtered through the teachers' cultural influence (Roth, 1994). To many of these students, the only chemistry they will ever know is filtered through their teacher's perspectives. These students do not read scientific journals, do not experiment on their own, and many don't even read chemistry textbooks. Their entire experience with chemistry is orchestrated by their teacher. We therefore look briefly at the teachers' perspectives on success in chemistry. Like students, they speak of "understanding" in two ways. First, they talk of students knowing what behaviors, attitudes, and task performances are necessary to succeed in chemistry. Secondly, they talk about success as possessing an understanding of chemistry concepts and applications. This second understanding seems much more nebulous, uncertain and difficult for teachers to describe.

Teachers talk about helping students know what behaviors, attitudes, and task performances are necessary to succeed in chemistry. When Jack Honderd talks about student "understanding," he sometimes seems to be describing a form of task completion and performance. To succeed in his class (get a good grade) students need to know what to do and how to keep up with their work. To Honderd, it takes discipline. "She (Kyrsten) doesn't have near the discipline she needs" (Interview, 5/10/95). A student must have what he calls a "work ethic" to be successful in his class. He repeats this term quite often in class when he talks about homework and preparation for tests. One day, he was frustrated by Kurt's lack of motivation. He explained that he just "won't do any work." In contrast Andrea "works hard and she tries really hard" and in response, "I'll give her every break in the world." And, he explains that "that work ethic will sometimes carry a lot farther than raw ability" (Interview, 5/10/94).

According to Honderd, Troy also could be much more successful if he only would learn to work harder.

> If he worked harder, he could do better, you know. He might be able to get himself up there where he can stay somehow in the B range. If he were getting a B, he'd feel a lot better about it. ... so (he says) "I don't know how to do that." The only thing, he needs a strong teacher so he needs a lot more interaction where somebody is asking him questions continually, or he's having to process that information and can find out what he doesn't know about what to do (Interview, 5/10/93).

Therefore, "understanding" chemistry involves knowing what to do and having the "work ethic" that it takes to succeed. A student must know what tasks to complete, how to complete them, and have a personal ethic of work. Honderd considers it his responsibility, as a "strong teacher" to make it very clear to students what to do and how to do it. For example, in Honderd's words, he tries hard to let his students know clearly what they have to know and do on the next test: "I'll tell you what you need to know" (Field notes, several occasions) and then several times, explained that this is in order to "relieve anxiety" that might be associated with any uncertainty about what the test will require of them. "[W]hat they need to know" refers to the chapter objectives, term definitions, and any task performances required for successful test taking. He thus gives his students very clear instructions about what content will be covered and therefore memorized or "understood" and what tasks they will be able to complete on the test.

Mrs. Hatfield also is careful to communicate with students and make correct responses clear. One of the more subtle ways she does this is through non-verbal cues. During a conversation about the impulsiveness of students in her class, she used Christine as an example.

> It's like when you ask one of those rhetorical questions and the first words out of their mouth is the wrong thing. They're just gonna give you an answer. And then she does that other thing where you say: "Well, would you expect it to increase or decrease?"
> And she says: "Increase." And then she looks at you and says: "Decrease." You know? I mean she does that if you watch her. It's kind of like: "Christine, you really don't know, let's not play this as a guessing game." And she usually gets the words out before anyone else in the class even gets a chance to (Interview, 2/24/94).

Although the topic of this conversation was impulsiveness in students like Christine, Mrs. Hatfield also gave non-verbal cues to Christine so that she was able to respond with the correct answer. This is just one example of some of the more subtle ways Jane Hatfield intentionally makes the correct answers or appropriate performances clear to her students.

Jane Hatfield also considers it very important that her students know what to do, how to complete assignments, and what to study for tests. She often uses worksheets and old tests to provide students with practice questions and examples of potential test questions. She regularly checks their homework to make sure it is done and tries to make it clear to students what is expected of them. However, when she talks about understanding, she seems to concentrate more on the second form of understanding. Another teacher, a friend of Hatfield's who has been teaching with her for many years, explained Hatfield's philosophy to one of her students early in the semester when he came to complain to her about Hatfield's difficult chemistry tests. She told this story:

> He came to me in home room so I said: "How is Chemistry"?
> He said: "Terrible, it's too hard. Mrs. Hatfield doesn't explain anything and just expects us to know."
> And I said: "She expects that you are old enough that you can read it and figure it out. She's not going to explain."
> He said: "But you explained everything in Biology."
> I said: "That was Biology and I just happen to explain everything but now, she (Hatfield) expects you to turn out to be a student." He didn't like to hear that and then I ran into him the other day and he said he was doing better and finally he said that he was enjoying chemistry more now (Conversation, 2/24/94).

There appears to be a second meaning to the word "understanding" in Honderd's perspective. Teachers also talk about success as possessing an understanding of chemistry concepts and applications. During one conversation, he was explaining that Kyrsten sometimes has difficulty in understanding chemistry. When I asked him if he thought she was able to understand some of the more difficult concepts in chemistry, he said: "I would say that keeping on top of stuff would make a dramatic improvement as far as understanding. As far as ability, it is hard to assess" (Interview, 5/10/94). He seems to say that a teacher needs to assume conceptual ability and if a student is consistently "keeping up on stuff", she will understand also. During one conversation, Honderd was explaining that a group of students is "not a real hard working group in my opinion" and that they are quite "grade conscious."

> A lot more than normal. I keep trying to reiterate to them that if you really try to learn chemistry, the grade is going to come. You won't have to worry about grades if you're really trying to learn what this is all about--those objectives and things (Interview, 5/10/94).

I wondered if trying "to learn chemistry" in such a way that they would not have to worry about grades meant that there really is an understanding that goes beyond task completion and work ethic. I then asked him if a student can get a good grade in his class without learning much chemistry.

> Yeah. (pause) Now, you can't get an A. You can get a B and really not understand a lot of chemistry if you have a real hard work ethic. The opposite is also true. I've had kids that have failed the class and I think they know quite a lot of chemistry.
> [Well, how does that work?]
> Well, you have to be consistent across the board to get an A. That means you have to have the discipline yourself on the homework but you are also going to have to perform on the tests. And on my tests you can't fool me because they are essay; short answers type of tests--define, differentiate, compare, contrast. And, you can't BS me on that. You can't even cheat. Even if I show you the test ahead of time, which I do with the objectives basically, you've got to think about process and stuff. And the final exam's kind of the catcher. People who have played points all semester do poorly on the exam. I catch a lot of flack on my final but the final is fair. It's just that the kids have been grade getters and point getters rather than learners. And it's funny, the kids that are the true A students usually get an A or B on the final. Those point players and game players usually are not (Interview, 5/10/94).

According to Jack Honderd, there is an "understanding" that amounts to doing what it takes to get a good grade that involves "point playing and game playing" and little learning of chemistry. This form of knowing is good enough for a B grade. There is another understanding that involves learning chemistry and knowing chemistry so that one can do well on his exam. He knows who masters this second understanding because those who do can do well on the exam and end the course with a better grade.

Jane Hatfield and I were discussing some of the possible reasons some of her students were having difficulty with some of her essay test questions. She said that "I think some try to memorize rather than understand." I then asked her what she meant by understanding in relationship to test taking. I asked her by quoting something Christine said during the last test review session. Christine said: "Hey, I get it! I understand this!" (Field notes, 2/23/94).

> Some of it I really think, is just learning style. Because there are some kids who, and there are not very many, who want to know why and they do a problem and then they'd look at it to see whether the answer made sense or not. The majority of the kids plug the numbers into the calculator, they get a number that's absolutely absurd, and then they'll say something like: "But I used a calculator!" And there are very few of them who will actually look at it and say: "That number doesn't make any sense." What I really try to do, because it is so easy to tell by the way they write, and the kinds of questions they ask. I take someone like Christine and I really try to make her see that she is a far better student than maybe somebody who can get a higher test score because she is understanding. And try to build that for Christine. "This is really good. That is good. What can you do if" (Interview, 2/24/94).

This understanding is deeper than merely understanding the tasks to perform on assignments and tests. Jane Hatfield describes how she tries to encourage her students to strive for deeper understandings by getting them to think about their answers to problems and asking themselves if the numbers make sense. She tries to convince her students that better students understand even though they might get lower grades than some others. This seems to suggest that hard work on daily assignments and homework is more central to getting good grades than understanding.

Students expect teachers to set clear standards for getting good grades in school chemistry

"It really depends on the teacher. I think that's one of the things."

There seem to be understandings and expectations acted out between teachers and students that can help explain the teacher's influence as students look out at their world through these cultural spheres. One way of describing these relationships is as mutual adaptations (Sedlak, 1986, p.5ff) that students and teachers make to each other in the context of the social and cultural world of school and life outside school (McRobbie, 1995a; Roth, 1994). According to Sedlak et al., there is a bargaining process in which implicit and sometimes explicit understandings and behaviors make practical sense to the participants. This is not intended to be a negative or cynical interpretation of life in school. Instead, it is rational, understandable in context, and seems to be designed in part to make students' and teachers' lives in school pleasant and rewarding. As in any negotiation or bargaining process, there are sides or parties in the process--each having different, though complementary and mutually adaptive roles. The first role discussed in this analysis is that of the chemistry teachers. These teachers are significantly in control of what happens in their individual classrooms. They set their own standards for success, clear pathways toward good student grades, and create a classroom ethos (Grant, 1988). Students have perspectives on their teachers' appropriate cultural roles. Students also come willingly to the bargaining table with their own perspectives, values and beliefs concerning their roles in the process of gaining success (Labaree, 1989; Sedlak, 1986). We are interested in the ways teachers and students adapt to each other and see their world in and around school.

It is also quite clear from students' conversations that students are convinced that it takes a good teacher in order for them to be successful in Chemistry. It is no surprise that according to these students, a good teacher is quite important in ensuring success. However, it is interesting that they brought up only a couple ways in which a teacher can make a significant difference in the grade one receives in Chemistry-- a grade that is equated with success. Apparently, according to these students, success doesn't really have much to do with how much the teacher knows, how much she loves the subject matter or even that the teacher is a creative pedagogue. Although students described an appreciation for entertainment and teachers who give them chances to laugh, they feel that one's final grade, a most important product in success, is actually determined by test grades. Therefore, it makes sense that the most commonly cited quality of an effective, success-facilitating teacher is an ability or willingness to make it very clear what will be on the next test. Students rarely speak of the teacher explaining difficult concepts well or making chemistry understandable. "What is going to be on the test?" They seldom ask about chemical properties, chemical transformations, or puzzling problems. Although making it clear what the test includes is certainly not the only important characteristic of good teachers, it seems very significant that it is by far, the characteristic most often brought up in conversation.

However, a few students, (and the teachers themselves) occasionally mentioned two more important characteristics of teachers. First, several students explained that it is important that the teacher makes himself/herself available for giving help between classes and after school. Although both teachers in this study attempt availability for this kind of student contact, few actually take advantage of the offer. It is curious that students say this is important and still do not take advantage of teachers' offers. Perhaps they just want to know the teacher cares about them and is willing to make the offer. Second, and for several reasons, students feel that it helps them get good grades if there is a good personal relationship between teacher and students.

During one conversation, Christine, Carrie, and Trent were trying to help me understand what it takes them to succeed. We were discussing how one knows or anticipates what will appear on the next test. Perhaps because they did not feel comfortable talking about their present science teacher or perhaps because it was early in the year and they did not have an opinion about their relatively new Chemistry class, they began describing the teachers they had last year for Biology.

> (Trent) "Yea, she (Mrs. L., a biology teacher) explained everything she wanted like one big thing and all you had to do is just do that. It was very clear what she wanted."
> (Christine) "Yea, and I think that was really good. It was my best class. ... Mrs. L. just showed you exactly what she wanted. It was really hard but it was just Biology and she was like excited about everything. ... She's awesome."
> (Trent) Like right in class she prepared on overheads and said this is what you have to do. And if you did not understand something, all you had to do was just ask her.
> (Christine) After school. Like you came in after school. I came in all the time and everything was very clear. It was a really good class because you really knew what you had to do. For quite a while I did

> not know how to study. ... She just taught us so that we wanted to go home and learn it I guess.
> (Carrie) He (Mr. K., another biology teacher) used the overhead a lot and used markers. He color coded all the diagrams and he would explain each step. He would assign stuff in the book and stuff but he would not necessarily teach the facts out of the book. He would teach it so that you understood it. His diagrams were different from those in the book. ...Different so that we understood it--like they were really technical and showed like every little thing, you know? He wasn't a really good drawer so... (laughs). He was really good. He tested whatever he put on the board. It was not like learning facts from the book. (everything he put on the board) was guaranteed to be on the test (Interview, 10/4/93).

What impressed me most about this is that these students seemed to feel that it is vital for the teacher to make it very clear "what you had to do", or what tasks to complete and very clear what would be on the test. In this conversation, "understanding it" seems to simply mean understanding what will be on the test so that there will be no surprises. This doesn't necessarily mean that students are not challenged on deeper conceptual levels. However, even if they are, it is understood that as for tests, there should be no cause for saying "you never covered this in class." There seems to be an agreement between these teachers and their students that every requirement is spelled out, provided, and practiced so that all one must do is feed back knowledge or skills. At least in one class this student felt this was "guaranteed." In this perspective, exemplary teachers show students "exactly what they wanted" on tests so that students can get their grade if they so desired.

Andrea also, in a similar discussion about success in her situation compared Jack Honderd to Mr. Price, her former Biology teacher. It is possible that Mr. Price would ask questions on tests that were applications or extensions of what they learned in class and from their textbook. Andrea explained that in Biology, this is what effectively stood in her way in terms of getting good grades on her tests. Mr. Honderd, in Chemistry is not like that. She seems to be saying that Mr. Honderd makes everything explicit so one can prepare and have no surprises during tests.

> I think if someone gets a bad grade on Mr. H's (Honderd's) test, its not his fault, I think its the person's fault. Not like Mr. Price. Mr. P. would assign a chapter in Biology and 42 vocabulary words and say study the whole chapter and then put things on the test that were not even from the chapter. You know what I mean? And I never passed one test in there. You know what I am saying? Mr. H. tells you. See, he is not playing games with you. I mean he tells you exactly what is going to be on the test (Interview, 1/12/94).

According to Paul and Kurt, Mr. Honderd not only makes test questions very explicit, he also makes sure that everyone understands the topics before he goes on to another topic. The emphasis, again, is on the grade. Mr. Honderd will make sure that his students "get a grade." "Mr. H. is a good teacher. He'll stick with you until you get a grade before he leaves and goes onto the next topic." Kurt qualifies this a little when he said: "Unless he's hard pressed. If he is, he'll say: 'Well, come to me later and I'll explain it'. But other than that, he will stick with you until you figure it out" (Interview, 1/12/94). Kurt seldom actually goes to his teacher for help after school, but it seems important to him that Mr. Honderd makes himself available for that just in case he would ever need it.

Often, in conversations, the focus students of this study linked understanding of chemistry to relevance. However, it was not always easy for this researcher to know what it meant to them when they said chemistry should be related to their world or related to everyday things. For example, Carrie mentioned that she appreciates how Mrs. Hatfield "makes chemistry relative to life." I wondered if she meant that chemistry was about real-world substances and transformations or if Carrie's relevance involved something else. Carrie said: "Oh she does. But she does that to make it easy to understand the concepts. Like I understand the concepts but I don't care about the concepts in the greater sense of life" (Interview, 5/11/94). Understanding the concepts is in some way different than understanding how chemistry relates to the "greater sense of life."

About two weeks before the high school prom, Jane Hatfield was teaching the relationship between activation energy and chemical bonds. She drew a graph on the chalk board and plotted eligible boy heights against the number of prom dates in the Junior class. With the use of this graph, she made the point that the more tall boys there are available, the greater the chance of an individual girl getting a tall prom date. She then used this as an analogy to explain the relationship between collision theory, energy and chemical reaction rate. The concept was thereby related to students' lives. As Carrie explained:

> It's not like the moles actually have anything to do with getting a prom date. Like biology. I mean, not that I care about these things, but biology might like give you why your hair color will change and that's like more relative. (I mean) relevant. Activation energy really has nothing to do with our lives. ... (Relevant) is the learning process she can give us. She relates it to us to help us understand what the concept is but the actual concept, I don't know (Interview, 5/11/94).

Making chemistry relevant in this context merely means making using real-live connections for understanding concepts and skills. In this case, knowing how to read a graph and knowing how to explain collision theory and activation energy. Chemistry still has "nothing to do with our lives." Chemistry still is not about real-world substances and their transformations.

According to Mrs. Hatfield, it is important that a teacher develops a relationship with her students that would facilitate communication and students feeling free to come in for help after school. She feels this is a fundamental, though indirect, way a good teacher helps her students succeed. She realizes that it is important for student success to break down barriers that might stand in the way. For example, if a student wants to come in after school for help, that student should not only feel encouraged to do so, she also should feel comfortable doing so because of the relationship that supports this action. Jane Hatfield told a story to help make her point.

> I had a kid last year that brought in a snake almost every day. This one boy had a snake collection and he was really into it. He had a very good collection. But one of his biology teachers (Mrs. Potter) was really interested so he brought in the snakes to show the biology teacher. Well, then he would bring them into my class. He's just a quiet kid so I started to pay attention to him asking "What was in the pillow-case type thing"? And he'd bring it out and we'd just have a few minutes where we would just look at his snake. One day he brought out this huge Boa. It was unbelievable. Several of the girls--one of the girls did put the thing around her shoulder and let it go--and the boys didn't quite like that. But it seemed like we kind of as a class, you know, we're kind of a family sort of because we had this--we had these times where we knew each other as something other than what we were doing. When we had the snake, we would talk about things. I mean , sometimes kids will break class conversation up and they'll talk about things that have nothing to do with the class. You know, you've got smaller classes and they'll start talking about homecoming or what they are going to wear. Sherry brought me pictures of homecoming so I could see what dress she wore, and how her hair was done that night. And she wanted to talk to me about who she had been with. And Sara was after school with me Monday night for 45 minutes talking about things that have nothing to do with chemistry whatsoever. You know, they are just kids.
>
> They feel really comfortable with me. In fact, they were really funny yesterday when they started that fire. Did you catch that?... Brad and Trent. Nothing was going to happen you know. I think they were really surprised when I said "Well, it was really good how calm you guys were. And that you didn't pick that up and throw it or you know, panic or whatever." If other kids would have said "Yeah, it was very good how calm..." , they would have been just teasing. But I think they were surprised. ... You could tell they were getting a kick out of

> the fact that they hadn't thrown me at all and I was kind of chiding them about what had happened (Interview, 2/24/94)

It seems important to her that she works at developing these comfortable relationships with her students so that they can feel better about being in her class but also feel better about being with her. She uses this story to show that people like Sherry and Sara, if they need help or just attention, will feel very free, safe and comfortable with her.

<u>Students believe it is their responsibility to meet teacher-established standards for getting good grades in school chemistry</u>

> I'm good at being a robot you know? I can just sit and write down what she's saying and writing on the board without really listening and without even thinking about it (Brad, Interview, 5/10/94).

Nicole explains that she would rather earn her B grade and understand something than earn an A through memorization. Whether or not students feel their grade and therefore success is earned through hard work and effort, they all have rather clear perspectives on what it takes to succeed in Chemistry class. Evidently, attaining success involves getting good grades on tests, lab reports, and daily assignments and homework. It also takes other, less important contributing behaviors such as getting help from family and friends, listening in class, and "giving the teacher what he wants to hear." Jack Honderd very clearly described his reaction after he told me how Andrea tries to fulfill all these expectations: "I'll give her every break in the world" (Interview, 5/10/94).

Responsible students usually work to get good grades on tests. I asked Jessie and Carrie if it was a matter of just choosing to succeed in Chemistry class or if it takes a lot of hard work or high conceptual ability. Jessie responded first:

> It is for me but I don't think it is for everybody. I mean I'm not saying that I would be getting A's if I decide to study because I don't think I would. But I could be doing better than I am doing now. ... Most people have to work for it, I don't think (I have to work) that much.
> (Carrie) Not that much. I don't go home and study chemistry for 5 hours. You just take 20 minutes or so just to do the work.
> (Jessie) Yeah, most people are like that. There are a few people that work more than that and do not understand it still. I don't know why, but I know people like that who need to do that and then I know people who can just listen in class and I know people who can just sleep through class and just do a few problems on the worksheet and still do well on the test (Interview, 11/19/93).

Carrie and Jessie describe themselves as representative of the majority of chemistry students. Expending only a limited amount of work in order to succeed seems to be a central theme in the bargaining process. The prize of the bargain is a good enough grade considering the amount of time, effort and work expended. In my conversations with students, the work necessary in preparation for tests and examinations is described as most efficient and useful. Therefore, in students' perspectives, good grades on examinations is the most traveled and clear path toward success.

During a conversation with Ed, Troy, and Paul, we were discussing what a good grade in Chemistry is and what it takes to get a good grade. All of them said a B is good enough but they would rather have an A than a B. I then asked them what it takes to earn an A instead of a B. Paul said that to receive a B grade, you just have to work "everyday, do everything every day and you will get a B" (Interview, 1/12/94). The main concern is to consistently complete the required tasks (do homework assignments). There was nothing in his comment about quality or deep thought about real substances and understanding of chemical concepts. The student's role is to just do the work required, or at least never get caught without it done. There seems to be some sort of understanding that if work is consistently done and credit given, a B grade is assured. The process seems traditional and well in place before the individual enters the bargaining process. In other words, others before them seem to have done their bargaining for them. Troy, in his answer to Paul is criticizing the school system and thus gives us his perspective on this aspect of the bargain. Troy seems to confirm the impression that getting good grades is about getting assignments done and not so much about learning chemistry subject matter:

> One thing they should change about school is it's not--they don't test you on the knowledge of things. ...Yeah, like I said earlier, They give you assignments and you do them, and if you get them wrong, they just kind of go over it, and they mark you down as a bad grade and they just like, they go on and they don't make sure you've learned it. And it's like, I don't know, It's not that they put too much emphasis on grades. I mean that's the only way they can do it really so that they can test to see, like what colleges you can get into, but they put too much emphasis on getting the good grade. ...Because there are people, a lot of times like on tests people don't even care if they learn it. They'll cheat just so they can get the good grade. They don't care if they know it or not. ...I'd rather know it and get an E, than not know it and get an A (Interview, 10/19/93).

I questioned Troy about this and he said he really would rather understand chemistry if it came down to a choice between understanding and getting by with a good grade without knowing anything. Ed joined the conversation and tried to explain.

> Sometimes I can get by in classes without doing much of the homework and then, like on the finals, I can get average grades, like C's. And I don't see how you can take a whole course and like fail the course and then get an average grade on the final.... Because I did that for Biology last year. I failed the course but I got an average grade on the final (Interview, 10/19/93).

Both of these young men were doing what it takes to make their way through high school chemistry. Although Troy seems more concerned with getting a good grade than Ed, both of them spoke as if they were concerned with the system and how it seems to reward grade getting with little concern for understanding. I'm not sure Troy or any other student would really accept testing "on knowledge of things" but it is significant that both describe their academic work this way. Apparently, a good student just does assignments to get them done, get a grade, and move on. According to Troy, this is just how schooling is. People often "don't even care if they learn it" and will just do what they feel is necessary or efficient for the grade. And Troy adds that students will do this even if it means cheating. In the conversation that followed, they explained that cheating is widespread in their school. The grade is the goal.

When I asked them again what it takes to succeed in chemistry, Troy said: "Just doing your homework and study." I asked him if that meant memorization instead of trying to understand chemistry. He responded: "Yeah, just study and do homework and you'll get an A. (What it might mean to understand instead of memorize is discussed later in this report.)

By "study" Troy means study for tests. Sometimes in student conversation, studying for tests is included in doing one's homework. However, daily assignments are almost a mundane getting the work done while studying for tests is homework that includes something more or at least different. Webster's dictionary defines study as "the acquiring of knowledge" or the "careful examination of a subject or event" which suggests deep or careful thought about a subject. The way these students use the word, they seem to be saying that study happens only before tests and requires little deep, careful examination. It might mean the acquiring whatever the teacher is asking for on the test. But Troy seems to be saying that tests do not test on knowledge of things and therefore, studying for tests must mean something different from acquiring knowledge through deep and careful thought. It seems to be about taking tests and knowing what the teacher is going to ask so that the student can merely give the correct answer.

Jack Honderd's Tests

Jack Honderd begins his next chapter (A unit of instruction in the textbook that is always followed by a test) by placing a list of chapter objectives on the overhead projector and asking students to copy them into their notebooks. Students systematically do this. Instruction related to this chapter corresponds to this list of objectives as they are "covered" in order. When all the objectives are "covered", a class session is usually devoted to review of the objectives list and the chapter test follows on the next day. During the test review, Honderd places the list of objectives on the overhead projector again, goes through them orally and asks for student questions. According to Jack Honderd, this is done in order to make it very clear what will be on the test

Table 5. Jack Honderd's Tests: Objectives For Chapter 9:

Objective	Objective Explained
1.	Explain the organization of the periodic table.
2.	Define and apply the diagonal rule.
3.	Identify different groups within the periodic table and determine reasons they are placed in groups
4.	Differentiate metals from non-metals and metalloids.
5.	Describe electron configurations from the periodic table.
6.	Classify elements according to groups.

and what the students need to know to do well. "I want to tell you what things you need to know" (Honderd, quoted in field notes, several occasions).

Jack Honderd's Chapter 9 Test (11/16/93) questions are reproduced here:

1. Answer the following Questions concerning the element I (iodine).
   a) To what group and period does it belong?
   b) How many electrons does this element want to gain or loose?
   c) What is the name of the family to which this element belongs?
   d) What is the last two sets of quantum numbers in the electron configuration?
   e) What is the electron dot structure?
   f) What will all the elements in this period share in common? (be specific).
   g) Name two things everything in the same group will share in common with I?
   h) Why will everything in this group have properties in common?
   i) Identify this substance as a metal, nonmetal, or metalloid.
   j) Give at least two characteristics this element can be expected to have based on the classification you gave it in the last question.
2. What are the 2 major characteristics by which the periodic table is organized?

(End of Test)

The following are quotes from fieldnotes the day Jack handed back graded tests (Fieldnotes, 11/18/93):

- Each question was weighted equally and worth two points.
- Jack Honderd, after the test was graded and immediately after he handed them back to the students, read each question and very rapidly gave the correct answers. After giving the answers to part I- d), he said: "That's just memorization."
- For the question 1-g), students were expected to give two or three of the following answers:
  - Elements have the same electron dot structure
  - Elements will react similarly
  - They share things in common.

- They will react with group 1 (Alkali metals).
- They will tend to gain one electron.
- They are all non metals.

- For the question 1-h), Honderd expected answers to include:
  - elements in the same group have the same electron dot structure.
  - elements in the same group have the same number of electrons in the outermost shell.

  Honderd then briefly explained to his students that understanding why is necessary in chemistry and therefore questions like #I-h) are important.
- For question 2, Honderd explained that a good answer would include the idea that elements are arranged in increasing atomic number and electron dot configuration.

The most commonly articulated reason students gave for low test grades is the lack of study. When I asked Andrea, Kyrsten and Jeff about their most recent test, Andrea was first to respond. She responded quite emphatically:

> (Andrea) I think it sucked. (laughter) Maybe I didn't study for it . I got an E and I still don't understand it.
> (Kyrsten) I got a B.
> (Jeff) I got a B. I didn't study very much either. It was the worst test I have had so far. But I figure its not so bad because he counts up points you know? I have a 4 so on the overall grade thing, that isn't that bad you know (Interview, 11/22/93)?

It is unclear from this what Andrea meant by "understand it" (This will be examined later). The point here, is that she felt that the reason she did not do well on this test is that she did not study for it. Kyrsten and Jeff seem to feel the same way. Their lower-than-normal grades on this test are due to a lack of study time. There seems to be a consensus that one must study the night before tests in order to get a good grade but this is not to say that students always study before tests or that each student has the same study habits. An hour of study time seems to be the maximum and students seem to feel that if this hour is dedicated this way, a good grade is expected regardless of any other academic work at other times. According to student conversation, there seems to be no clear connection between tests and other assignments, laboratory experiences and reports. The way to a good grade on tests is quite clearly marked in this brief study time the night before tests.

Some students explained in more detail their methods and the substance of these study sessions. According to all students in Mr. Honderd's class, the main thing to study is the chapter objectives. Jeff was the first to explain this to me as I probed more about what it takes to prepare for tests.

> I don't have to kill myself. ... I studied a little bit you know? I studied those objectives. I didn't spend any more than a half an hour, maybe less studying. ... I didn't really go sit down and go everything repetitive over and over you know? I just looked over my book and OK , I know that one and I know that one, I need to look that one up. Then I spent about 15 minutes studying for this (Interview, 11/22/94).

To Jeff, the key to studying for Jack Honderd's tests is going over the chapter objectives one-by-one. If he knows them he must be well prepared. If he does not feel comfortable with an objective, he tries to "look that one up." As stated before, his teacher gives them the chapter objectives when a new chapter is introduced and students copy these into their spiral notebook; the one they use for taking class notes. Jeff evidently reads these before the chapter test and then, for the objectives he feels insecure about, he looks them up in his Chemistry textbook. Mr. Honderd's chapter objectives are also stated in the textbook and Jeff is one of few students who apparently finds the textbook useful in "looking them up." When he feels he understands each objective, he is well prepared for the test.

Kyrsten also in describing her performance on this same test explained that "Well, I studied all the objectives, so I knew everything" (Interview, 11/22/93). Again, knowing the objectives means knowing everything necessary for getting a good grade on the test. At first, this seemed to be a contradiction because just said she was not satisfied with her performance on this test. I asked her if this test was especially difficult or out of the ordinary for Chemistry tests since she "knew everything" and still did not do as well as she would have liked.

> Well personally, I did not find the test hard, the only reason I didn't find it hard is because I studied all the objectives for about an hour. If you don't study those objectives, you know you are really going to do bad. ... So I'm sure Andrea didn't study those objectives. ... I just memorize them. Yeah, I knew what they meant but some of them I already understood perfectly but others I just memorized (Interview, 11/22/94).

She seemed to feel that although she made "dumb mistakes" during the test, she "knew everything" there was to know in preparation. The objectives are a list of what one needs to know. Even though there seems to be a difference between understanding and knowing in terms of memorization (see philosophy section) either, according to Kyrsten, results in a good grade on tests. I was still confused by this apparent difference between knowing and memorization for tests. I therefore asked her to explain what she meant by knowing something for the tests. Science, for Kyrsten might be a little more difficult but it still requires mainly memorization of facts and concepts like in most subjects:

> I think tests, mostly all tests except for math, are memorization. I mean like in history, all you have to do is memorize facts and dates and Science is a little harder but a lot of it is just memorization. I know there is also memorizing concepts (Interview, 11/22/93).

Mr. Honderd tries to make everything they need to know explicit and clear with the use of these objectives. All one has to know for tests is in those objectives. In Andrea's words, Mr. H. ."..tells you. (You) see, he's not playing games with you. I mean he tells you exactly what is going to be on the test" (Interview, 11/22/93).

Jane Hatfield's Tests

Hatfield's test for Chapter 5 covers similar chemistry content (periodicity and the periodic table) to Honderd's chapter 9 test. Her test consists of 50 multiple choice questions and 6 "short-answer essay questions." Each question is worth two points for a total of 112 points possible on this test. 100 points earned results in an A grade. Because 100 points is an A grade and there are 112 points available on the test, there are 12 points of what Hatfield calls "extra credit." Most of Hatfield's tests throughout the year have a similar format and similar extra credit points available. A sample of the multiple choice questions from this test and the complete list of "short answer essays" is given below so that the reader can get a feel for her test questions (Test given 11/9/93):

1. In the modern periodic table, the elements are arranged according to their
   a) increasing atomic weights
   b) decreasing atomic weights
   c) increasing nuclear charge
   d) decreasing nuclear charge.

4. As one moves from left to right across the period, the radius of the neutral atoms generally
   a) increases
   b) decreases
   c) remains the same.

5. As atomic number increases within a family the ionization energy

   a) increases

   b) decreases

   c) remains the same.

6. As atomic number increases within a family, the metallic nature of the elements

   a) increases

   b) decreases

   c) remains the same.

7. Which of these atoms require the least energy to remove an electron?

   a) 1s2

   b) 1s2 2s1

   c) 1s2 2s2

   d) 1s2 2s2 2p1

   e) 1s2 2s2 1p6

(Note: *The numbers that correspond to these test items are as they appear on the test. Jane Hatfield often uses questions from an item pool and sometimes does not bother to change the numbers.*)

35. Among the elements of the sodium family, the most active of those listed here is

   a) sodium (atomic number 11)

   b) potassium (atomic number 19)

   c) rubidium (atomic number 37)

   d) cesium (atomic number 55)

The short-answer essays on this test are reproduced below:

51. In measuring ionization energies why do we start with a gaseous atom?

52. Explain why helium and beryllium, both containing two electrons in the outer level, are not at all similar in properties.

53. Explain why atomic radius is a periodic property, but number of electrons is not. Would number of valence electrons be a periodic property?

54. Why is the first ionization energy of nitrogen higher than that of oxygen?

55. Family VIII-A have negative electron affinities. This means energy would have to be added to the atom to add an electron (in fact the electron affinities cannot be measured so they are estimated-- no one has figured out how to "glue" an electron to an atom that "does not want" an electron) Explain in terms of structure why family VIII-A has a negative electron affinity and indicate which species would be lower in energy, the noble gas atom or the negative ion resulting from adding an electron.
(end of test)

The following are quotes from research field notes written on the day Jane Hatfield returned graded tests to her students (Field notes, 11/11/93).

- Jane Hatfield handed the graded tests back to the students at the end of the class session two days later. Hatfield explains that 100 points are required for an A grade and that no one earned a total of 112 points. She explains that the extra 12 points are extra credit for those who wanted to "go for it." In other words, a student can leave all the essay questions blank, get all the multiple choice questions correct and still receive an A grade.
- Jessie seems upset with her grade. The student sitting next to her asked Jessie what grade she received and Jessie refused to tell her.
- Sara received 91 points and seemed very satisfied.
- Brad turned to James , smiled and laughed (according to Hatfield, Brad and James continually compete with each other for higher grades on tests). Brad's score was 106 and James' score was a couple points lower.

Sara voiced her opinion and described her methods of studying for Jane Hatfield's tests when I asked her if she spends much time on her homework. Sara most often completes her daily assignments and lab reports but doesn't seem to consider this studying. Studying is something she does for tests and not for other homework.

> Not in Chemistry. I do in other subjects but not necessarily in Chemistry. When I study for a test I usually spend 45 minutes to one hour on it but that's about it. ... (I study) just for the tests. I don't need to study for anything else. The last test, I did not study, only about 15 minutes. So that's why I got a B on it. When I study for a half an hour or so, I usually get A's (Interview, 10/5/93).

Brad explains his approach to study in Chemistry in similar ways, he evidently spends about the same amount of time studying for tests as Sara and only studies the evening just before tests. However, he was a little more explicit about his method of studying.

> I memorize everything. I memorize everything in about an hour. ...I put it all on note cards or something. ... I'd rather get an A- and not work hard than work really hard and get an A (Interview, 11/1/93).

"Everything" seems to be terms, procedures, formulas and so forth. He is able to put what he needs to know for tests on note cards and therefore it seems to be a matter of practice or rehearsal. It seems significant that he also speaks of a difference between getting the easy grade instead of a higher grade that would take more time and effort. He evidently doesn't want to "work hard" at Chemistry if he can avoid it. Here again, getting good grades does not necessarily take much academic work.

When I asked Carrie, Jessie, and Christine how they prepare for tests, Christine answered this way.

> I just did all these problems on these sheets that I've never done so I just kept doing those. Like cause I didn't do them when we were supposed to. And then I check the answers. ... I usually don't study. And she has a review sheet. But usually I don't study. Like the last test I didn't study for. Its cause its like in your-- it's like mental. It's like in your head (Interview, 11/19/93).

A couple days before each test, Jane Hatfield gives her students review sheets which are often tests from previous years or other chemistry classes. Then, the day before tests, Hatfield asks for student questions regarding the problems or questions that were included in the review sheet. In this way, they review and practice for tests.

Doing problems on review sheets and practicing in preparation for tests seems very different from learning chapter objectives. I wondered how doing problems would prepare these students and if this practicing meant something different from rote memorization of procedures, algorithms and concepts. I then asked Christine if she memorizes or practices doing problems. Practice might imply learning a skill or learning to deal with mental problems, studying in the sense of deep and careful thought.

> Yeah, you have to like--if you don't I mean you don't really have to study before the test if you do all the problems you're supposed to do. But I don't because I'm too busy with other things (Interview, 11/19/93).

Therefore, according to these students, getting good grades on tests requires practice on problems given on daily assignments and review sheets, not just studying objectives before the test. If one practices these problems, one will do well even without much studying the night before tests. The content and expectations for tests might be just as clear for Hatfield's students as they are for Honderd's, but, according to Hatfield's students, getting good grades on tests takes practice with problems and questions that are similar to the ones to be expected on the test.

The extra credit points on Jane Hatfield's tests also identify the greatest difference in perspective between these two chemistry classes relative to the preparation for tests and receiving a good grade. Jane Hatfield explained her reasons why she includes the extra credit points on most of her tests.

> I try to ask questions on tests that go beyond. That's why the test is worth 105-112 points... there are questions there for Brad and James... and there is a little competition there to see whether you can get the perfect paper. And there are questions there that they can't just memorize. They have to put some things together" (Interview, 11/24/93).

Although putting questions on tests that ask students to "put some things together" might not change the way most people prepare for tests, if Hatfield is correct, it might challenge some students like Brad to think deeper conceptually. She means that if he wants to go beyond the memorization and rather easy (for him) preparation for the multiple-choice test, the opportunity for more intellectual challenge is there in the short-answer, extra-credit essays at the end of the test. Peer competition might fuel the interpretation of these "more difficult" questions as challenges. Hatfield considers this policy of providing extra credit opportunities on tests as a challenge to the "brighter students" in her class.

However, when I asked Brad which test questions he likes better, multiple choice or essay, he said he likes multiple choice. "It's easier, a lot easier." The essays are much more difficult because "they don't give you any options. Cause on the multiple choice, you can just figure out from common sense what's right and what's wrong" (Interview, 5/10/94). He seems to believe that a significant part of success on tests is skill in multiple choice test taking. Essays take more than just figuring out from common sense. He implies that the good student needs to know some chemistry in order to answer the essay questions while common sense can result in good grades in multiple choice tests or parts of tests.

I asked Trent if he appreciates the extra credit questions on Jane Hatfield's tests.

> Well, I never before had a teacher where I could go into a test, guess on twelve questions and still get an A.
>
> (Question) Do you appreciate that?
>
> Well, yeah, I do. (chuckle) I mean, I don't know it makes things easier. But I don't know if its a good thing. You probably work a little harder if you didn't have that extra lee way. ... I'd study a little harder. A lot of people, when they hand in the test, they say: "Well, I didn't know a couple of these questions but it doesn't matter. I'll get an A because of the points. ... I guess there is satisfaction (in answering the extra credit questions correctly). ... I feel a little better if I get the questions at the end right because it takes extra work. And you have to work things out. You basically have to think. Whereas the other stuff is just memorization (Interview, 5/16/94).

Trent went on to explain that once or twice, chemistry tests have been all essay questions that were similar to these extra credit questions. He said he would prefer this because he would prefer to be challenged to think on tests. On the other hand, he isn't likely to complain because he also likes the fact that most of his tests are set up for a rather easy grade. This way, according to Trent, thinking is often quite optional.

There also seems to be a feeling that it is necessary in Jane Hatfield's class to just give the teacher what she wants to hear. Hatfield describes one of her students, Erica, who has a habit of just blurting out answers to questions in class apparently just to please the teacher.

> They're just gonna give you an answer. (laughs) And then she does that other thing where you say "Well, would you expect it to increase or decrease? and she'll say "increase." And then she looks at you and says "decrease." You know, I mean if she does that if you watch her. It's kind of like "Erika, you really don't know, let's not play this as a guessing game." And she frequently gets the words out before anybody

> else in the class even has a chance to. I can count on it being wrong you know (Interview, 2/24/94).

Erica seems to look for cues and read her teacher's expression as she responds to questions. Her responses seem to be designed to please and seems to be more than just impulsiveness. "Giving the teacher what she wants to hear" also was described in some student conversation.

In addition, there is another way some students apparently succeed by getting good grades on tests. One day in the beginning of second semester, Honderd seemed upset and angry at the end of a Chemistry class when he said in an angry and apparently frustrated tone: "Some of you are not doing your work" (Field notes, 1/11/94). Honderd rarely expresses his emotions like this and because I rarely observed this attitude in Honderd, I asked Paul and Kurt to explain why he was upset. Paul explained first.

> He said some kids have been copying. Cause teachers know that. This goes on all the time.
> (Kurt) Yeah, Mr. Kelly was telling us "You get caught copying on the test in one class, then after that you'll get caught in every single class if you keep it up." They talk to each other you know? They have their own little information network going on.
> (Paul) They know who cheats. They know who does it. ... And he says that once you get that reputation, then the reputation will follow you for a long time (Interview, 1/12/94).

If cheating is in fact so wide spread as Kurt and Paul describe, for our purposes here, it serves as further evidence that success is getting an adequate grade in chemistry and one does what it takes, sometimes even at the expense of integrity, to get that grade. Troy was first to call this to my attention by saying "They'll cheat just so they can get the good grade" (Interview, 10/19/93).

Responsible students usually do their homework. When Trent talks about getting his A grade this year, he explains that Chemistry and mathematics are the first things he does when he sits down to do his homework. However, this has not always been the case for him. "Before, last year, I just like would never come home, sit home, do something, come back and at night, I would just squeeze in just what homework I had to do. ... But this year I go home and do it" (Interview, 10/4/93). Trent's Biology teacher from last school year explained that Trent must have decided during the school year to become a more serious student. He quite suddenly "started doing his work" (Conversation, 11/24/93). Before, he was one of those students who, although very capable, seemed to do as little as possible. It is interesting that deciding to "get serious" about school means doing one's homework. Therefore doing one's homework is another way success is secured.

Troy also clearly explains the same idea that one merely has to do his homework and thereby keep up with his academic work. However, doing one's homework does not necessarily mean that much learning is required. Troy implies that learning is not necessarily required to get good grades.

> The way I look at school, like I said before, just seems like if you just do your homework and study, you'll get the grades. I mean, there are some straight A students that learn everything, but they take it upon themselves to learn it (Interview, 5/10/94).

These straight A students, according to Troy, are interested in going beyond what is required to something optional. This optional learning or the "something awesome out there" also gives evidence for the idea that what actually is required is doing one's homework and studying for tests. Troy explains that of the two, he spends much more time on his daily assignments and very little time studying for tests. In his perspective, very much like Trent and others, doing daily assignments is an important path taken to a good grade. The main emphasis seems to be just on getting homework done so that credit is given. There seems to be little emphasis on learning from homework in some way or doing high quality academic work.

Brad describes a very different view of daily assignments. He says he hardly ever does them. I asked him why he never does his homework assignments. "Well I don't know if she ever looks at our daily assignments or not" (Interview, 11/1/93). I wondered about this comment because I had witnessed his Chemistry teacher moving about the room at the beginning of class checking their assignments on several occasions. I mentioned this to him and he responded by saying that "sometimes (she does check daily assignments) but you never know what she's going to check." I then asked him if she catches him off guard. He said yes, laughed and then said: "it happens a lot" (Interview, 11/1/93). He then went on to explain that he often "plays the odds" of whether or not he will get caught with his homework undone. I asked Mrs. Hatfield about Brad and whether or not this was true. She contradicted him and said that he always gets his assignments done and does them well. She explained that Brad, although he does not have to work as much as some other students, does everything necessary to get his A grade. She said that doing one's homework is one necessary component of a good grade. She explains that he always does his homework even though he sometimes wants others to think he is not. Brad seems somewhat successful in his alleged pretense. Carrie explains. "He (Brad) ever does his homework but he always gets A's. That is because he can just sit there and understand it" (Interview, 11/19/93). Brad's pretense, for whatever reason it is important to him, is further evidence that doing homework is a vital component of what it takes to succeed. Even when someone like Brad establishes and maintains pretenses about homework, he evidently still does it regularly.

In Mr. Honderd's class, a high proportion of the daily assignments are problems or questions in the book. The Chemistry textbook has a set of questions, problems and exercises at the end of each section and after each chapter. Mr. Honderd might assign 3-8 questions in the book each week. He regularly states that these assignments should take about 20-30 minutes of the student's time each week. Typically, the answers and procedures to follow can be found in the text of the corresponding chapter. Students seldom read the whole chapter and instead, read the assigned question or problem, page back through the book for the answer or a description of the procedure to follow. They then write this answer down or do the problem using the procedure described. His students therefore find the book more useful on a daily basis than Mrs. Hatfield's students. On the other hand, this does not mean all of Mr. Honderd's students find the book useful only for doing assignments. Andrea, points to another traditional function of the textbook as a resource. After a rather disappointing test grade, she stated: "I think what I have to do personally is go back and try to study the other two chapters before I can get this" (Interview, 11/22/93). She evidently thinks the book has information and is also useful for remediation.

Instead of assigning problems and questions from a textbook, Mrs. Hatfield usually uses what the students call worksheets as homework assignments. The textbook is rarely used in Hatfield's class unless Hatfield refers to a chart or table reporting useful data or information. This doesn't seem to bother most of her students and instead, they seem to take this for granted. When I asked Carrie if the Chemistry textbook had value in Mrs. Hatfield's class, she responded this way:

> You know, I didn't even open it up until today. I just opened it up. It was, I mean there was nothing there. Like "What do I have to do?" And it was all stuff that we did before, so. Except where it showed how to do equations (Interview, 11/19/93).

She explains that she once opened the textbook to find out what she had to do and found the text quite useless except as a resource for equations and procedures. Several of Carrie's peers have similar views of the textbook. Most of them fail to see it as even a resource.

Zack, another student in Mrs. Hatfield's class at first gave the impression that he does not feel the same way as Carrie and others in her class. When we were discussing what it takes to succeed on tests, Zack actually described the textbook as quite useful. "A lot of stuff she puts on the test though, she did not really go over so you really have to read the chapter carefully" (Interview, 10/5/93). However, his emphasis seems to be on the word carefully. I wondered about why he thought he really had to read the book carefully. Later, during a conversation with Sara and Zack, I took an opportunity to ask Zack again if the book is really helpful. His answer focused on how the book is so difficult for him to read and understand. It seemed as if he was saying that even if one tries to use the textbook to help in understanding, its use is limited by the way it is written. It is not clear from what Zack said what makes the book difficult nor is it clear what is wrong with the way it is written.

Sara agreed with Zack and tried to explain further about the problem with the way the textbook is written:

> Not the way it is written. I mean you have a problem down there and you got all the steps in about that much room and then it just gives an answer. But you have to go through it to figure out what they did first and what they did next and how they got this and how they got that. It

> doesn't exactly go through it step-by-step and show you what they did--like it does in the math book (Interview, 10/5/93).

Therefore, it appears that in the perspective of the students in Mrs. Hatfield's Chemistry class, the textbook has very limited use value. In other words, reading the textbook has little to do with what it takes to succeed in chemistry class. In fact it may almost be an hindrance to some. With limited time and energy available, the textbook requires too much careful reading and "figuring out" to be very useful.

On the other hand, in Mr. Honderd's class, the textbook provides Honderd and his students handy questions and problems which then contribute to a student's grade. Apparently, some of these students also feel the textbook has some value as a remedial tool to read if a concept or idea is difficult to understand. Even these students confess that they rarely use the textbook this way at least in part because they feel it is difficult to read and understand.

Responsible students usually do their lab reports. During the first semester, Jack Honderd requires few laboratory experiences in his introductory chemistry class. Since his students do so few, he counts them as only about 10% of the student's grade. During the second semester, there are more laboratory experiences provided and they contribute up to 25% of a student's final grade. "That's the way I break it down. We do a lot of the theoretical aspects first and the application second."

I interviewed Paul and Troy after they did a laboratory exercise involving the Milliken Apparatus. They were to observe and discuss what they saw.

(Question) What did you think about the Millikan Apparatus?
(Troy) It was-- I didn't seem much of anything, so. I really don't know what I thought.
(Question) Did you see anything, Paul?
(Paul) Yeah, I saw some little dots.
(Question) What was that supposed to show?
(Paul) I think that was supposed to show negative and positive.
(Troy) I believe it was supposed to show dots that floated around.
(Paul) And up and down.
(Question) What is the significance of those dots?
(Paul) Showing negative and positive charges.
(Troy) And controlling them. He said if you use it correctly, you can find the speed of them and do a bunch of other stuff.
(Question) So, what do you think it is supposed to show you about chemistry?
(Troy) Well, nothing because he told us we didn't have to write anything up on it. ... It was sort of an observatory kind of thing. ... Just one of his little fun things I guess (Interview, 10/19/93).

These students were evidently making few conceptual connections between charged subatomic particles and what they were seeing or supposed to see. "Little dots that floated around" probably have little to do with real subatomic particles and their properties. It is also interesting in this context that they felt this demonstration had no value for them beyond fun. To them, the test of its value is whether or not they are required to write a lab report on it. Since they do not have to "write anything up", the exercise seems to have little value to them. The grade that potentially results from a lab experience seems to be the major concern instead of any learning about chemistry or technology. If no written lab report is required and therefore not turned in for a grade, the experience appears to be: "Just one of those fun little things I guess."

When they are required to write a lab report, the reports are important to students because they apparently are another way for a student to raise his/her grade average. Some students even consider the lab reports a personal strength and therefore a chance to make up for other components in the grade that seem more elusive or difficult. For example, if a student does poorly on a test, it is sometimes possible to make up for the poor test grade by getting a better grade on the next lab report. Troy explained this function and that his lab reports are one of his strengths. "This semester, I got really good lab grades" and he feels this made a big difference for his grade. He explained this in the context of describing how his test grades are not consistently what they should be. He seems to understand what is expected and therefore often does very well on lab reports.

However, in contrast to Troy's understanding, it is not always clear to other students how to succeed at writing lab reports. Students speak of a learning process concerning lab report writing. They seem to consider it a skill to be learned or a rather rote process to follow. Troy was complaining to me about time schedules and one-hour time blocks and never really having enough time to learn. "They don't give you enough time to actually learn." And then he went on to use chemistry laboratory experiences to explain what he meant.

> I think it's just that they (teachers) just like tell us how to do it, and then we do it and we have to all go back to our seats. Like for instance, the last lab we did. I wanted to observe like all the different forms of sulfur and when I was observing one, the other lab guys (other lab group members-- labs are done in groups of 4-5 students) had already looked at it once and they wrote down then they threw everything else away. So, I didn't have time to look at it all. ...You know, then it's just like rush, rush, rush and so, I didn't even get a chance to finish the lab because I was like looking at them and trying to get the sketches down that we had to do (Interview, 5/10/94).

Troy was frustrated by the fact that he wanted to spend more time wondering about these substances while gathering data to inform his lab report writing. At the same time, according to Troy, his classmates were mainly interested in doing the minimum amount of work in the quickest time. I wondered which student strategy was more likely to succeed. I asked Troy.

> They can get a good grade. They don't really know what is going on half the time. I mean, what a lot of kids would say around adults, they wouldn't say around other kids. Like for instance, if an adult was asking them: "So, do you like this? Did you learn it"?
> "Yeah, This is really interesting." But to other kids they're like "I don't want to do it" cause they think its like cool to not know what you're doing. You get a lot more attention if you act like you don't care what's going on (Interview, 5/10/94).

Therefore, Troy was saying that in Honderd's class, success is likely even if a student quite rotely follows directions and gets the work done as quickly and painlessly as possible. Lab reports seem to be mainly about getting a grade with minimum investment of time and energy. Students follow recipe-like directions, gather a limited amount of data, and answer a few questions about what they have seen (Barrow, 1991; Bodner, 1992; Ealy, 1994).

Jane Hatfield's students have similar feelings about laboratory experiences and lab reports. As Christine explained, "They seem really confusing. They are not explained very well as to what to do." Therefore, at least part of this skill involves learning what the teacher wants and how to give the teacher what she wants.

> You kind of have to find what, like on labs, find out what she wants to hear. Be exact like in the first two labs, I remember it was more general than specific and she cracked down on that. I didn't get very good on it. ... you have to make sure you are tuned into what she wants. ... At the beginning, I did bad on them because I didn't know what she was looking for, but now I am doing better (Interview, 10/4/93).

Brad explained that even though he doesn't like the laboratory exercises, they are worth doing well because they are worth a lot of points. "I don't like the labs but they're worth a lot of points." I asked him what this means and he said "Some are worth as much as twenty and twenty five points" (Interview, 11/1/93). Tests are worth 100 points in Jane Hatfield's grading scheme so a lab report completed and done will is worth about 1/4th as much as a test.

The only time Brad admitted to me that chemistry can be difficult was when he was describing the process of writing lab reports. "I don't think the labs are easy at all. I think it's the hardest part of the course. ...Because you have to do things yourself." I was confused by this so I asked him if the lab reports were difficult. "The write-up is not hard. But, the labs... you have to listen and a lot of people don't listen. I don't listen. So once you get in the labs you don't really know what to do." When I asked him what was necessary for a good grade on a lab report, he said: "you have to be neat, Neat little tables and stuff. ...I don't know if there is such a thing as deep thinking (required in lab report writing)" (Interview, 5/10/94).

Responsible students have other strategies for doing work. There are other, more indirect strategies that seem important in getting good grades in Chemistry. The first of these involves getting a little help from the teacher. One would think that since teachers regularly offer after-school help for students that they would take advantage of this. Very few students in this study actually do. This is troubling to these teachers because even though the offer is standing, they wonder why students are unwilling or unable. Andrea is one of few exceptions. She explains: "Yeah, you have to go with specific questions and it is not like in class where you can't keep asking like 20 questions" (Interview, 11/22/93). To Andrea, after school is an opportunity to ask questions she could not ask during class time. She explains that she would not feel right about asking too many questions in class because this would burden the teacher and other students. She explains that the teacher has his agenda and if everyone would take his time for personal questions, nothing would get done. Therefore, she knows from experience that "I mean if I come in after school, he will help you out" (Interview, 11/22/93). Andrea therefore goes to her teacher once or twice each week after school to ask specific questions. Her questions are usually about homework assignments and associated problems. She evidently finds this process helpful in getting her work done well. She also told me that it helps her convince her teacher that she is willing to put effort into her Chemistry work. She seems to think it is important for him to know this about her.

However, Andrea in one of very few who actually asks the teacher for help on a regular basis. Several other students voiced the opinion that since there are so many other students in similar situations, they would not want to bother the already-busy teacher with their personal problems. Whether or not this is truly their concern or if this reason is actually a rationalization, few actually ask teachers for help either in class or after class.

Another apparently significant, although less discussed strategy for doing work and getting good grades in chemistry involves finding friends or parents who are willing and able to help. Some students apparently find it easier and perhaps more helpful to go to friends for help than to go to the teacher. Sara and Zack were discussing the problems they were assigned and how sometimes they are difficult to understand. I asked them how they "figure them out."

Zack responded: You just ask each other.
Sara then gave an example: Yeah, how do you do this one? Or, you go back and try to make sense of the problems in the book.
(Zack) Usually I can't though.
(Sara) Then, I have to have someone explain it to me. Usually I have my dad explain it to me (Interview, 10/5/93).

Sara and Zack have this kind of relationship. At least on part, it seems to be Sara's initiative to create this small community of help. Sara, according to her teacher, has "adopted" a couple boys who sit around her. She and they often help each other on their assignments when there are difficulties. Most of the help is evidently unidirectional however as Sara apparently does most of the helping. According to Sara, when she needs help, she goes to her father whom she considers quite helpful in explaining how to do assigned problems.

Troy has a similar strategy based on his relationship with one of his friends. During one of our conversations, I asked Troy to explain how he studies to another student who expressed difficulty knowing what to expect on tests. Troy explains that he writes the chapter objectives down, takes them home and then goes over to his friend, J.B.'s house.

I just write down what the test is going to be over. J.B. lives right next door to me. You know J.B. don't you? You know, the guy that sits right in front of me? He's like an A student. I'll just study with him (Interview, 10/19/93).

Therefore one key in understanding Troy and his strategy for success is his relationship to this friend. Evidently studying together for tests is a regular pattern for them. I wondered if this helping relationship included more than just studying for tests. Therefore, later, I asked Troy what he does if something in Chemistry gets difficult to understand. He said that instead of going to teachers for help and trying to struggle alone with the book or class notes, he tries to study the difficult material with his friend. "I've never studied on my own for tests. When I'm with a friend, If he's studying, then I'll study and like if I have any questions, I can ask him" (Interview, 10/19/93). Apparently, the only time they spend time together is in preparation for tests. Perhaps this is the only time when difficulty with chemistry concepts is an issue. According to Troy, his friend acts as a tutor or at least a resource explaining the objectives and helping him prepare for upcoming tests.

Christine, a student in Mrs. Hatfield's class, also finds a friend very helpful when doing her school work.

> Also what's helped for me is like I had a friend Liz did a problem for me and was showing me how to do it. And then every time I did a problem, I just used her example in different ways and I finally figure it out. But it takes a whole because when there's like different ways you can do it and you finally figure out how. I understand it when she does it and I can do it like if she says "OK try this one" I can do it then, but I get home and it's not there. ... Also, if I have a question, she is right there for my questions as soon as I forget what they were, the next day or whatever. If I don't understand what I'm supposed to do then she's right there and I can say: "Help" (Interview, 1/14/94)!

When I asked her if she went to Mrs. Hatfield for help, she said she did when there was a specific question or it there is a "specific thing I don't understand... but then when I go to Liz, I guess I do whatever is easiest" (Interview, 1/14/94). "Easiest" seems to mean more convenient but it also seems to mean that her friend is also more able to explain things in ways that are easy to understand than Mrs. Hatfield is. It also seems that Christine considers Liz more help than Mrs. Hatfield in the long term since Liz demonstrated her abilities in introductory Chemistry last year. Liz is one of Mrs. Hatfield's AP Chemistry students who is regularly working in the chemistry lab after school. This makes Liz very accessible and very able to help. Christine seems to feel that Liz is able to explain how to do the chemistry problems in ways that help her more than anyone else is able to help. Therefore, Christine considers this friend vital in her formula for success.

I responded by saying: "I used to explain to my students that very often, students could explain to students better than teachers could."

Nicole heard this and responded by explaining that she has no one like Liz to help her. "Well the girl that sits next to me, like, we were gonna study together and neither one of us really knows what we're doing so we can't really study together. (laughs) And Brad talks all hour" (Interview, 1/14/94). Therefore, Nicole feels hemmed in by people who are no help or who, even if they wanted to help would be of no help. In other words, she seems to agree with others that a friend who is willing and able is a valuable asset in the quest for good grades.

Another indirect student bargaining strategy that seems important in getting good grades in Chemistry involves listening in class and sitting in the front of the room. Both Mrs. Hatfield and Mr. Honderd, although in different ways, are careful to control the seating arrangements in their classrooms and both change the seating arrangements several times during the school year. In the beginning of the school year, Mr. Honderd allowed students to choose their own seats and seating arrangement. Since then, apparently because he now knows his students better, he assigns their seats and thereby has taken control. It is as if the teachers feel that where a student sits is the teacher's responsibility in the bargaining process.

It is clear that seating arrangements can and do effect student attitudes and performance. Although she was describing another classroom and another teacher, Andrea explained how this procedure can effect her performance.

> I was like mad all week because I had to conform to seating charts OK? I mean, I got so sick of seating charts, I was just going crazy. I left one class because where I sit is in the middle of the English Lit room but it feels this big (motions with her hands). People all around me talk all the time and I don't even like them. I was just going insane. I just left. I went home (Interview, 11/22/93).

In Mrs. Hatfield's classroom, however, students sometimes get a sporting chance to choose where they sit. They changed their seating arrangement once during the first semester. She asked all of her students to stand in the laboratory section of the room and then called out different possible clothing characteristics. For example, she said "All those who have the color red on, may sit down." Several students who were wearing red then chose a desk and sat down. This was repeated with a different characteristic until every student was seated. It was interesting to see where students sat. It was clear that some students sought places in the front of the room and some looked for places in the back of the room. Sara and Zack chose seats in the back of the room so I asked them why. Sara explained that they like to sit in the back of the room so they can work together. Actually, they seem to spend a lot of time socializing so I think they actually just like more freedom to talk. I asked Mrs. Hatfield why she allowed them to choose these seats for social reasons. She explained that if they want to sit in the back and talk, they are old enough to decide that for themselves for whatever reason.

Carrie explained before that she would rather sit in the front of the room . In this last seating change however, she was one of the last persons to get a seat and had to take a desk in the back of the room. She is willing to tolerate this but doesn't really like it. She now sits near Sara and Zack.

> I don't want to say anything because I'm usually the one who's doing most of the talking anyways, like when people want to listen like she doesn't tell people to be quiet. Like all my other classes, they are really quiet and you take notes and nobody talks. Here, you do whatever you want. ... A lot of times when people are talking though, they are not trying to figure out a problem.
>
> I asked her why she thought Mrs. Hatfield allowed this.
>
> Cause a lot of people around me are talking but like they're trying to figure out a problem. They don't understand so someone else is helping them. That's what is around me and I'm like: "Be quiet." And then they're like doing their chemistry assignment (Interview, 1/14/93).

Nicole responded to this and said "Uh huh, that's why I had to move to the front." More people in the back of the room talk than in the front. I asked them again if where they sit really makes that much of a difference. Carrie responded: "Oh my gosh yes! People fight for the front."

Then, Christine explained: "Yeah, people look for the front seats." I wanted to know if she felt all students wanted the front seats and therefore asked her if she thought Sara chose to sit in the back of the room. "No, she wanted the front." Apparently, Christine and Nicole think all students, even Sara, would prefer the front of the room. Nicole is perhaps the most convinced that her success is linked to her placement in the classroom.

> I'm sitting in the front every time. I don't care. ... (laughs) Hopefully she won't change seats because I can't sit anywhere else. (It's necessary) for me. Cause that's like how I do well, I guess (Interview, 1/14/93).

Part II: The Good Student, the 5th Cultural Sphere of Influence, and Glimpses of Real Chemistry as a Way of Comprehending Selected Events in the Natural World

The Fifth Cultural Sphere of the model represents chemistry as subject matter and its influence on student attitudes, beliefs and behavior. This cultural sphere represents the influence of academic disciplinary chemistry, real chemistry (Barrow, 1991), as knowledge within the discipline before it is translated by the classroom teacher and before it is filtered through the teacher's influence. It represents what science knows about real substances and their transformations regardless of the teacher. As I will explain, some students develop a personal relationship with chemistry mediated by social conditions (Danziger, 1990). As we will see, this is rare and seems to exist in fleeting moments of student epistemological awareness and interest. It does exist though, and students know it exists even though it sometimes seems quite removed, almost impractical, and is usually seen quite dimly through the filters of the other cultural spheres of influence.

The focus of this research is on student perspectives of success and being a good student in high school chemistry. The influence of the fifth cultural sphere helps determine students' emotional, intellectual and academic responses to chemistry class as influenced by the epistemology of chemistry (Danziger, 1990). The epistemology of chemistry is a cultural issue because chemistry is known by students as they look out through the lenses of the other cultural spheres in the model. Chemistry usually does not exist to students separately, out there, removed from the rest of the student's world. The few students who speak of chemistry as something separate, out there and removed from daily lives are perhaps the best sources of information concerning its sometimes mysterious nature.

Through the influence of the first four cultural spheres, success in chemistry seems to have little to do with learning about real things in the natural world. But often, students talk of something far better and potentially more rewarding in Chemistry than living and acting under the influence of such an operational definition of success. True feelings of success therefore often include some deeper understandings of chemistry concepts and ideas.

Context: A Vignette on presenting the periodic table as self referential (Field notes, 11/8/93)

On Friday, about 20 minutes before the end of the 50-minute chemistry class period and after a brief quiz, Honderd began to introduce the next chapter; Chapter 9 of Merrill chemistry: A modern course (Smoot, 1987). To introduce each new chapter in the textbook, Honderd always gives his students a list of learning objectives. According to him, this practice relieves any uncertainty in expectations because the final chapter test is taken directly from this list of objectives. He placed a prepared transparency of the chapter objectives on the overhead projector and turned the machine on:

Students will be able to:

1. explain the organization of the periodic table.
2. define and apply the diagonal rule.
3. identify groups within the table and determine reasons elements are placed in groups.
4. differentiate metals from non-metals and metalloids.
5. describe electron configurations from the periodic table.
6. classify elements according to groups

He then gave students some time to copy these objectives into their notebooks. Most did this. About 10 minutes later, Honderd began describing the periodic table as a tool designed by Dmitri Mendeleev who "found out about trends" and thus organized his periodic table. (Mendeleev was introduced during a previous class session.) He explained to his students that originally, there were "holes in Mendeleev's table" and yet Mendeleev could predict the properties of the missing, still undiscovered elements by looking at their position on the table and the properties of nearby known elements. Honderd explained that elements within the "groups" of elements have similar properties so that we can predict the properties of any element by looking at how others in its group behave. Honderd then said that the alkali metals could be used as examples of a "group of elements with similar properties." He walked over to the fume hood and began to drop small samples of lithium, sodium and potassium into a small beaker the water one at a time. As he dropped a small piece of sodium into the water, Honderd told a story about students from one of his previous classes who stole a very large piece and later threw it into a pond. Honderd's description was animated and entertaining and students asked many questions about the size of the piece of sodium and whether or not the reaction at the pond was similar to what they were watching under that fume hood. There was laughter, noise and excitement as students imagined and discussed what must have happened at this pond. After the sodium reaction and as the students calmed down, he dropped a small piece of potassium into the same beaker of water. As he did this, he jokingly said: "This creates fire instead of putting it out." The immediate, small explosion under the fume hood startled everyone as "sparks" and "smoke" (Honderd's terms) flew up into the air, though a crack under the upper edge of the fume-hood glass and into the room. A couple small red-hot pieces of reacting potassium flew through the air and started to settle on student desks. Students quickly, though in a surprisingly controlled way, avoided them. Honderd calmly walked to these desks as they all watched the particles lose their color. Obviously students were very impressed by the reaction and liked the "smoke and fire." Honderd laughed with them and said that perhaps he chose a rather large piece of potassium for that demonstration. Everyone laughed. His point about the relative reactivity of this family of elements was well made.

After people and things settled down, Honderd walked to the chalk board and wrote the symbols for the alkali metals with their corresponding valence electron configurations. He then turned to his students and asked what all these elements have in common. Several students knew that each has an S-orbital half filled. The statement was made that this similarity can provide a reason this group of elements react similarly with water. Several students asked questions about sizes of samples, explosive forces and even land mines. Understandably, Honderd's students were very impressed with the explosive character of these reactions they have just witnessed. They seemed less interested in using electron configurations to explain reactions or recognize trends on the periodic table. It seemed that Honderd's students also were quite convinced that the half-filled orbital and the position on the table were in some way the reasons for the chemical behavior they had just observed.

The next day, Monday, Jack Honderd began his class session by again placing the chapter 9 objectives on the overhead projector and telling his students that they will be especially interested in objectives 3 and 5 today. He then wrote the electron-dot formulas and electron configurations for H, Li, Be, B, C and N on the chalk board. He left a gap between Be and B and pointed this out to his students. (He writes x's and calls them "dots.")

As he wrote on the chalk board, Mr. Honderd explained that his students will be expected to write electron-dot configurations and electron configurations like this themselves.

x				
H				
1s1				
x	xx	xx	xx	xx
Li	Be	xB	xCx	xNx
				x
1s2	1s2	1s2	1s2	1s2
2s1	2s2	2s2	2s2	2s2
		2p1	2p2	2p3

"If you have trouble with this, just go ahead and do the orbital filling diagrams for these elements first." Then, he explained that "this is the pairing of electrons" and electron location is "shown and proved" by diagrams like this. When his chart was complete, Mr. Honderd turned, asked his students what trends were evident here, and waited for raised hands. One student explained that as one moves from left to right on the chart, another electron is added in each column. Another student pointed out that for each row added on the chart, there is another energy level added. A student then said that in the left column, there is a S-orbital half full. Honderd then complemented them concerning their correct answers and summarized: "This is the way they designed the periodic table." More discussion followed and questions were asked about the position of He, transition elements filling D-orbitals, and why boron is placed where it is. Honderd summarized again: "the periodic table is organized around two things: (1), rows in increasing atomic number; (2), electron configurations." Then, as if to add a third factor, he explained that his students "definitely need to know that there is a magic number of electrons every atom wants. That number is 8." He called this the "octet rule" and then mentioned that hydrogen and helium are exceptions. Mr. Honderd then picked up a meter stick from the demonstration table, walked to a large periodic table hanging on the wall, and pointed to the "helium group." He identified this group as "The Noble Gases" and began to talk about helium as an example. The students seemed to enjoy his description and his mimicking of the effect of breathing helium gas. He explained that these gases don't react with anything and that is why they are called "Noble."

A student then asked Mr. Honderd why the noble gases don't react with anything. Before Honderd could respond, another student answered: "Because they follow the octet rule." Honderd agreed.

Honderd then asked his students: "Do you understand how the periodic table works?" Before anyone answered and apparently to assess their understanding, Honderd immediately asked students to call out numbers that could correspond to atomic numbers. Each time a student said a number, Honderd repeated it, pointed to the corresponding symbol on the periodic table with a meter stick, and then walked to the chalk board and wrote the electron-dot formula for that element. For each, he asked his students how many electrons were found in the "last energy level." This was repeated for 5 different elements. Next, Honderd asked his students to " (T)ake out a piece of scrap paper and we'll see how fast you can do this." He then wrote the following atomic numbers on the chalk board: 17, 26, 39, 50, and 37. He waited for about 3 minutes as a few of his students did what he asked. The majority sat quite still, many with folded arms, and appeared to wait. Soon, Honderd pointed to each number in turn, and students called out the number of electrons in the outer shell. After he wrote these numbers on the chalk board, Honderd walked over to the periodic table with his meter stick in hand. He pointed to the Fluorine family and asked: "These guys have how many?" Students call out the number 7. "How many do they need?" Students called out the number 8. "How many do they need to pick up?" One.

About 5 minutes before the end of this chemistry class period, Mr. Honderd said to his students: "OK, you will have to do some memorization and remember the diagonal rule doesn't work perfectly all the time-- but we'll treat it as if it does. That will create less confusion." The assignment for tomorrow was already written on the chalk board and Honderd gave his students about 4 minutes to work in class. Some did.

It is significant that the way chemistry is presented is deliberately designed by the science department of this high school as a preparation for more work in the sciences. Honderd explained that he teaches all the introductory chemistry classes in this school so that all the students' preparation can be equal and geared to the expectations of AP instructors and college instructors. He is well respected in his school and most students do leave his classes satisfied and well prepared for future high school classes. Advanced Placement Chemistry students and their teacher explained that they are very satisfied with the preparation they received in Honderd's classes. Mr. Honderd's students like him very much, enjoy his classes, and some explained that they actually elected to take chemistry because of his reputation and so that they could be in his class.

Although Mr. Honderd's students are usually motivated to take chemistry and to gain the knowledge, tools and abilities needed in future classes, we should examine the nature of the chemistry presented and learned. I chose the sessions described above for their content as well as the instruction that occurs. Although there are many insights possible from this rich information, I will use this vignette to examine the nature of the science presented in this chemistry class. More specifically, the presentation of the periodic table in this vignette reveals a certain epistemology of chemistry. The periodic table is presented as an on-paper tool to study and learn--it is itself an object of study. Instead, the periodic table could be *used* as a tool in inquiry and a representation of real things.

As Barrow (1991) states in his discussion of alternatives to real chemistry, there are "two quite general indications that students are expected to keep their eyes and their minds firmly on paper" (p.451). One indicator is the use of the factor-label method. The other indicator is "The periodic table: A highly annotated periodic table is often treated as a display of, rather than an organizational tool for, the chemistry of the elements" (p.451). In this vignette, the periodic table is presented as a symbolic display of elements and their chemistry instead of an organizational tool for discovering the nature of our world. Students seem to study the organizational tool for itself and have no sense or way of using it in the study of real substances and their transformations. On-paper elements are the way they are not because of their real chemical properties and predictable behavior, but because of their location on the periodic table. The periodic table is self referential, symbolic, ritualistic and not grounded in reality. The focus is on the symbols and the symbols are the reality. The symbols serve as things to manipulate and use in following rules.

In the beginning, Mr. Honderd introduces real substances to his students and leads them through an entertaining and interesting survey of similar elements and their properties. The brief description of Mendeleev's work and the demonstrations of the alkali metal reactions seem to provide a powerful perspective on how scientific knowledge develops and is historically and socially constructed as scientists search for patterns in the natural world. The lesson is dramatic and students will not soon forget the effects of alkali metals reacting with water. It is also very clear that sodium reacts more violently than lithium and that potassium is the most reactive of the three. Students now know that they would not necessarily want to try the same reaction with francium or cesium. Trends in the behavior of substances are presented and one gets the impression that these substances behave this way because of what they are and what properties they possess. Watching this demonstration, students get a vision of real, mysterious things and hints of their potential applications. Mr. Honderd describes the periodic table as an organizational tool for "groups of elements with similar properties," and a product of historical development of knowledge. However, within a few minutes, the situation evolves into something very different as Honderd and his students take their eyes off the real things and reactions to focus on the alkali metals of the periodic table and the charts of electron configurations.

In the course of one class session, the teacher leads his students through a transition to a very different, task-oriented focus. After the transition, participants get down to a more typical business of doing school work. Trends noticed by students and confirmed by teachers seem to be trends on the table, not trends in properties of real substances. Although Helium is a very real substance to students when they remember it breathed, helium atoms actually don't react readily with other atoms "*because* they follow the octet rule." It also seems that the "diagonal rule" is *the reason* electrons behave in certain ways. An element is apparently more or less reactive *because* of its position on the table and "because they follow the octet rule." The rule becomes the method we use to write answers to questions about elements and their electrons. For example, one uses the "octet rule" and the "diagonal rule" to determine the number of electrons an atom "needs to pick up" and to enable them to write electron configurations and orbital diagrams. The anthropomorphism is useful and practical in answering questions even though it might encourage misconceptions and might not help explain real reasons things do what they do.

This transition also marks a shift to the skills and information needed for success in evaluations. As explained above, the session began with demonstrations of real elements and their behavior but these things quickly became peripheral to the business of doing one's school work. Student understanding was judged by the ability to use only symbolic representations. In using the periodic table, the ritual became the goal or the rite of passage. The test of understanding was whether or not students could quickly call out the number of electrons in the outer shell as symbols for elements. Students learned to recite the correct answers by knowing the symbolic trends and relative positions on the periodic table. Students were learning and memorizing information and demonstrating performances associated with the table. The ability to perform these tasks were later tested, graded and judged as an assessment of how well they understood how the periodic table works.

"Something Awesome Out There" The Fifth Sphere of Influence

Several students described a chemistry that exists somewhere; a chemistry similar to Nicole's "something awesome out there." These students explained that although molecules and atoms must exist in the real world, they can't seem to picture or see electrons, protons, and other such things in their minds. They made distinctions between believing that these unseen, unimaginable things really exist and picturing or visualizing these things moving, reacting and behaving in the real world. The latter is much more difficult and harder to believe even though understandings that relate to them would seem better and more useful in life than simpler understandings. But the reality of it seems almost too amazing and too "out there." But this "out there" chemistry is wonderful to those who describe it and it inspires awe in them even though it is not really necessary for success in chemistry class. Sometimes it disturbs them and bothers them to know this awesome world exists. Most often these relationships with real chemistry seem to develop in a way that transcends or bridges the teacher and normal requirements for task completion, performances and grades. For example, Troy explained in detail that there are very distinct differences between learning chemistry for a grade and learning chemistry.

> There is a difference between just learning it for the grade. I have found that with most teachers, the tests and everything, are just made so that you just memorize it and you don't learn it. You just memorize it and for that one test, then you write it down and after that you just remember that basics and everything else that was real specific, pretty much forget that because you will never use it again in high school. ... You just study and do homework and you'll get an A but you don't have to go beyond to the knowledge and comprehending stuff. ... There are some students who learn it, but they take it on themselves to learn it (Interview, 10/19/93).

Troy seems to be saying that to "learn it" involves something quite impractical, beyond what is required for a grade, and voluntary. But learning in this way is also described by these students as something better, something worth pursuing. Like Brad explains, "we have to know that it's there (conceptualization of atoms and molecules) but I can't really grasp it. It just doesn't make sense to me that all this stuff (tables and chairs) would be made of little things" (Interview, 11/1/93). But understanding about the structure of molecules and atoms are not necessary for getting a grade in chemistry and that makes it voluntary for those who like that sort of thing or at least have the ability to understand.

> I think some people just don't understand chemistry no matter what they do. And others, it just depends on how much effort they put into it. Like, a lot of it can be effort but some people just can't understand it like I have some friends who I have seen just balling because they have an F and they tried to go to the teacher (not Mrs. Hatfield) for help and she says like "I'm failing your class and I just don't understand it." ... I think its so hard to understand the concepts. Like why am I leaning this? It just doesn't make sense. If it doesn't make sense, you just don't understand it. It just can't be real.

(Carrie joins the conversation in order to help clear up the meaning of understanding.)

> You just have to take yourself away from-- I know this sounds really bad to say, but if you can understand what she is saying today in class. Like on the periodic table, this electron will transfer to this and form a complete outer shell-- you get a picture in your head, OK, then fine, you understand that. But then you get a chair and you don't understand that there are electrons in that chair and like where they are actually doing all this stuff and how it makes it in the big picture. But if you understand what you are actually learning, then it's OK. Maybe that's not really it but that's how I understand it.
>
> I said: It sounds like you are putting understanding on a couple levels?
>
> Yeah, in tables and chairs, it's just hard to see any electrons and it's hard to see how they put that together. Like how can it be a concept if you can't realize that it is there? You can't know its there by just looking at it. ... And I don't think that everybody in this class all this different ways of trying to work and understand-- that kind of understanding they are aiming for is how to draw a covalent bond and what it means and how to transfer this and this. I don't think it's necessary to know how energy is involved-- but the bonding, like how it relates to everything else. I don't know anyone who really relates in terms of that whatsoever. ... its like math to me. Chemistry is similar to math. Like I was doing all this really strange stuff in math and I don't know why but I know how to manipulate the numbers and know what I am looking for but I don't really know why in the world I

> need to know what a sin and function is and that doesn't make any sense what it really is. It just doesn't really matter to me and it is the same for chemistry (Interview, 11/19/93).

Carrie seems to be explaining that there is an extra understanding that goes far beyond how to, on paper, draw bond diagrams and explain how electrons behave. This understanding must involve practical applications in the real world and explanations of how the real world works. There is an understanding of what is necessary for getting a grade and doing well on tests and reports but there is another understanding that involves those why and how questions of real-world applications. Jessie gave her summary for this conversation:

> I think they (most students) are understanding what she is explaining in class but I don't think they are shooting for some greater understanding. She bases her class on what you need to know for the tests. She doesn't expect us to know it any differently than that (Interview, 11/19/93).

Troy and I were discussing the reactivity of different elements and predicting their corresponding behavior. Was Troy "shooting for some greater understanding?" He was explaining that he looks on the periodic table in order to tell how reactive an element is.

> Fluorine is because it's right there before the--what do they call it? The Noble gasses. And that just wants to gain one electron so it has the highest reactivity and then the other elements at the other end are like sodium and potassium. Those are the most violently reactive but those are not the most reactive because they don't want to gain electrons. They just want to lose one. And the elements that want to gain an electron want that electron more than to gain is more reactive than to lose one (Interview, 5/10/94).

Troy then went on to explain that their relationship with the noble gasses determines the reactivity of any element. I wondered about if he was describing real substances and their transformations or if he was just picturing the periodic table in his mind as a list of information and answers to potential test questions. I asked him: "When you are explaining all this, what are you thinking about? Are you thinking of fluorine as a real substance or are you thinking about the periodic table?"

> I'm visualizing the table. The reason is that I can't picture the real thing. I can't picture fluorine as it actually is. I think about the periodic table because I don't have enough experience with the real element fluorine and the other elements. The only thing I work with is the periodic table so that's what comes to mind when I'm explaining this (Interview, 5/10/94).

Troy only works with the periodic table and therefore it is what he has to picture in his mind and what he has to know. Conversations with Mrs. Hatfield's students show that problem solving with the mole is similar. Carrie, Christine, Jessie were discussing how to do problems which involved moles and chemical equations.

> Like in grams to moles or moles to grams. ... And it's like the equation right here from the last test. It's always that you're getting a mole and you gotta convert this mole into whatever, like copper. So this equals this and this is copper and then you times it by that and it's grams. And then you just--if its asking for moles, you just remember that there is a procedure. Like if you're looking for moles and you have grams times moles per grams and cancel out, it equals moles. I'm not really memorizing formulas, I just know what I'm supposed to look for and I know what I am supposed to do. But I guess you just have to plug it in (Interview, 11/19/93).

Mrs. Hatfield calls this the "plug and chug" method of using formulas. The point here is that there seem to be two forms of understanding in these conversations. One form involves this understanding what it takes to do well on test questions and therefore receive a good grade. The other understanding seems to involve much more depth of knowing. The second is most often described as something better and it's pursuit more noble, if not necessary. Troy struggled explain that if there were no grades, he would feel more free to try to learn for the sake of learning.

> I think it best way for me to explain would probably be to stress more on learning in and not getting a grade. If grades were eliminated, and the people who wanted to take, I mean the only reason people come here--I mean, there are people that don't want to be here, in high school, but they still have to get a good grade to graduate and get a good job. I think if there were no grades, the people who didn't want to be here (would leave) and the people who wanted to learn it would come (Interview, 5/10/94).

Kurt describes the situation in similar terms.

> Some of us are interested in what we learn. Most of us, most people here just don't care about anything. "Just give me an A and let me go to college and let me get a job and let me make lots of money, and then let me die..".. Everybody wants money so they gotta get good grades so they can go to a good college so that they can get a good job. Pretty stupid, but-- I like some of these things but I like learning more. I like learning things. ... You're not required to learn anything in school. You're first required to memorize it for a week or two and be able to take a test and then memorize everything you have learned and then re-memorize it all at the end of the year again and take the final. ... You get your grade and that's it. You don't learn anything. Hardly anybody learns things here. You know, unless you're really interested in the subject, you don't learn anything because you don't care. You know, all you want is the grade-- that's what everybody wants (Interview, 5/10/94).

Although Kurt sounds rather fatalistic here, he is describing two forms of understanding. There is the "going for the grade" understanding and the deeper understanding that involves actually learning chemistry. This duality exists in both classrooms in this study. Carrie tried to explain these two forms of understanding and said that they are not necessarily easily separated. In other words, it might be difficult to say that a student chooses either all the time. In reality, students seem to waffle back and forth between the forms of understanding depending on the situation at hand. I mentioned that "there seems to be this difference between understanding something and just going for the test." She answered by first saying that "Yea, I still do a lot of that." She just does what she has to do to do well on the test. I then asked her to explain in more detail.

> I think it's all mixed up together. Like you understand something and some things you just do because you have to, you know? ...You can understand in order to do the tests. ... Just go over the work she gave us, all the work sheets and ... understand so we can do all the test, not understanding for our well-being (Interview, 5/11/94).

"[F]or our well-being" suggests that a student chooses the second form of understanding because it is something beyond requirements to something that will benefit the student's later life-- something will be learned that will benefit a person beyond the grade. Carrie explains that she likes chemistry in part because she likes to work at understanding difficult things. "When I don't understand it I don't (like chemistry). I like to work, like I like to really work at trying to understand it. Like I stay after school if I don't understand something" (Interview, 5/11/94). This is why Mrs. Hatfield calls Carrie a "tenacious learner." Success to Carrie is much better and more meaningful if she understands in addition to getting a good grade.

The Nature of Understandings of the Fifth Sphere: Student assertions

Success in high school chemistry, in students' perspectives seems sweeter if there are deeper understandings of chemistry and chemical concepts. This section describes student perspectives on the nature of this deeper understanding of chemistry. In conversations that correspond to this sphere of influence, students seem to be discussing understandings of academic disciplinary chemistry, real chemistry instead of school chemistry.

Understanding in deeper ways is not easy for them to explain and our conversations often involved struggle in attempts to inform this researcher concerning what it means to know real chemistry in ways that go beyond school chemistry and what is required for getting a good grade. They often found it helpful to compare chemistry to biology (i.e. Gold, 1990). Biology seemed different to them and requires a different intellectual approach. They also described this deeper understanding in chemistry as seeing and imagining pictures and/or real atoms and molecules (i.e. Fortman, 1993; Rowe, 1983) Deeper understandings also seem to involve struggles with ideas and concepts and solving problems. To understand chemistry in this way also involved forms of relevance to real-world analogies, objects and materials. I was often surprised that this deeper understanding, according to students does not involve mathematics beyond basic multiplication and division. In some way, the quantitative nature of chemistry was absent in student descriptions. As Troy explained, "[T]here is no real difficult math, it's just dividing. The only thing we've ever done in chemistry with math is dividing and multiplying...add and subtract-- it's simple." Even mole problems do not necessitate much mathematics because students are required to "plug and chug" units and/or numbers in formulas.

> Mole problems aren't that hard. There's just a line and there's a mole right here and the amount of moles you have and then the amount of substance you have, you just divide these two and you get the answer. Mole problems are easy" (Interview, 5/10/94)

Kurt explains the same procedure when I asked him if they ever had to use algebra so solve problems in chemistry. He responded affirmatively but actually described the same algorithmic "sideways ladder" which involves little mathematics.

> During the mole part, yeah we did. We did a lot of algebra type stuff. We had these huge long columns with all that little things to Be able to cross out this and add that right-- where you had to multiply it all and divide it all (Interview, 5/10/94).

- Some students assert that understanding real chemistry involves "seeing" and imagining real atoms and molecules.

Early in this study, Brad described success in chemistry as merely memorizing things and repeating them on tests for a grade. This does not mean that there is not a deeper understanding of chemistry lurking in the shadows waiting to be experienced. When I asked him if he wanted to learn about real atoms and molecules and their behavior, he said: "I'll never grasp that anyway-- never, ever. I can not imagine it because I can't picture anything made up of little things like electrons, protons, and neutrons." Brad was the first student to use this sight metaphor to describe what is required to understand the mysteries. It didn't surprise me that the metaphor was used quite frequently (Lakoff, 1980). When I asked him if he needed to see real substances this way to succeed, he said:

> No, how could you? ...You don't actually have to picture it. ...You have to know like what is there but I mean I knew that it is there but I can't actually grasp the concept. I could never be a physicist or anything-- it just doesn't' t make sense to me. ...That all this stuff (motions to tables and chairs) could be made of little things moving around" (Interview, 11/1/93).

Brad seems to be making a distinction between knowing atoms and subatomic structures exist and understanding in a real-life conceptual and sensible way. He can say the correct words and relate the correct explanations but it is different thing to truly picture or visualize the theories being played out in the real world. Reality seems too amazing, almost too far fetched to bother with. If we believe him, Brad chooses to back away from this deeper understanding, not to engage with chemistry on this level, and just do what it takes to get a good grade.

Many of these students explained this "something awesome out there" in similar ways although they did not necessarily make the same choices as Brad. Like Carrie who describes herself as not a visual person (see below), many students describe seeing and visualizing real atoms and molecules and chemicals behaving in real substances. She explains in a very lively conversation with Jessie.

> (Jessie) I don't really know what to do with it--like all these electrons and stuff. Like are they really there?
> (Carrie) I know, like, why are we studying this? Like all these charts and stuff. It seems to me they are so small that it doesn't really matter.
> (Jessie) I know, like why do we even care? What do we want to know about this for? (laughter) No, seriously, in everyday life, what are we going to do like say: "Oh that has two electrons and a negative confirmation state or something like that? I mean, Never!
> (Carrie) They're just too small (Interview, 11/19/93).

How can something so small and mysterious actually be important for us to know? It seems to these students that the reality of these concepts is too difficult to imagine. Kyrsten explains in her own way: "You know, we were talking about electron configurations. I mean, I'm OK when we did this with electrons, but once you say like electrons are in this table... (she looks up and throws up her arms) Whoa!" (Interview, 11/22/93). She knows how to give electron configuration for elements and knows how to answer test questions about chemical substances, but she makes the point that there is a big gap between these abilities and procedures and being able to understand in a deeper, conceptual way. It is almost too much to think that these things are really real and actually doing things in objects like tables and chairs.

Trent explained at the end of the year that it has been difficult for him and his peers to find understandings. "It's just that it's kind of hard to, kind of hard to find understanding. You know? It's kind of strange. ... Well, I guess you can just get picture in your head of things like that" (Interview, 5/16/94). I wondered what he meant by "things like that" and what he meant by picturing them "in your head."

> Well, I mean part of it was like I said before, you look at some of the stats, you get a problem and part of it is that. You try to remember how she did things (in class) Yeah, I usually go into a test with like a picture in my mind of certain things that we're supposed to learn. I guess you could call that understanding. ... (I asked for an example) Well...with the atoms, I don't know, they have pictures in the book-- nucleus here and electrons floating around it and stuff like that. ... I don't think about it often. I try not to think about it-- drive yourself crazy (Interview, 5/16/94).

He is evidently remembering the pictures and diagrams given in his textbook and in other resources; he seems to know they are meant to represent real things in daily life. But again, he is willing to picture the textbook representations but tends to shy away from making real-life applications. They seem too messy and difficult to imagine. When students communicate this reluctance, it becomes quite clear that deeper understandings of chemistry involve struggles with concepts and ideas.

In a discussion about the nature of chemistry and what it means to know chemistry, Nicole asserted that "seeing" atoms and molecules was quite necessary but very difficult. Nicole begins by explaining that seeing is related to understanding but also her like for a subject.

> (Nicole) Just being able to see that atoms--I guess I am a visual person because I can't see it so I can't understand it. And like even in the diagrams, I don't understand the diagrams. So I just don't like it. ...If I can't see something, its boring to me--I can't take an interest. I don't care, I don't care what a reaction is you know?

> (Question) So its the abstractness of it?
> (Nicole) Yea, I mean, I just maybe it's just a negative feeling. I don't care what happens when two things combine, you know? Just doesn't interest me at all (Interview, 1/14/94).

In my experience listening to students, the word "boring" can mean several things. Here, I think Nicole means difficult or difficult to imagine when she uses the word. She says that she can't take an interest in chemistry because it is difficult to visualize these real things we call atoms and molecules. "I don't care" seems to be related to the idea that the things and transformations in chemistry are abstract and hard to imagine, hard "to see."

The teachers also use the sight metaphor to describe what makes chemistry seem more difficult for their students. When I asked Jack Honderd what it is about the nature of chemistry that makes it more difficult, he answered this way.

> You can't get a hold on it. You're always talking about stuff that's never right in front of you. You're talking about atoms, electrons, protons, and neutrons and all these things are happening on a level where you really can hardly ever see it. And you know, when we're talking about chemical reactions, these are happening in mass quantities. Talking about equivalent weights and things like that (Interview, 5/10/94).

Jane Hatfield uses the same metaphor when she tries to push her students to conceptual understandings. She was comparing herself to some other chemistry teachers. "I tend to do a lot more of the drawing pictures. You know this idea of getting a picture in their mind of what's happening" (Interview, 2/24/94). In her perspective, pictures help her students learn how difficult things to imagine are like and how they work. Both she and Mr. Honderd use all the typical models and drawings usually used in chemistry instruction because these representations help people visualize real things.

The student perceived conceptual difficulties lack of practical, life applications associated with chemistry were evident even in the beginning of this school year when I asked students to compare chemistry to other science courses they had taken in the past. Kyrsten did not hesitate to say that "I liked biology a lot" (Interview, 11/22/93). She went on to explain that not only did she have a very good teacher, he made everything fun and interesting. I asked her reason for liking biology was just due to the teacher. "Biology is, I think biology is better. I just like it better than chemistry. But he did make it a lot more fun." She went on to explain how her teacher told interesting stories about his own life and family. In comparison, chemistry seems to her "kind of dry." I didn't know exactly what she meant by this and later in our conversation I had the chance to ask her again. Biology seems to her more practical, related to her life, and therefore worth more to her in the long run: "It has more worth I guess. But if I, I mean I don't think I'll have anything in my occupation or anything to do with it. ...And biology is much more interesting than chemistry. A lot more." Later, it became quite clear that "interesting" was related to difficult to imagine. She explained, like several of her peers, that it is more difficult to imagine and get excited about little, invisible atoms and molecules in things. According to her, it is much easier, and therefore more interesting, to relate to one's own body, animals and plants.

These comparisons were most often made in the beginning of the school year and they were always quite brief. For example, when I asked Sara and Zack about their histories in science, Zack was quick to say: "Last year I had biology and it is not exactly like chemistry" (Interview, 10/5/93). It was clear to me from the tone in his voice and how he said this that biology was much more enjoyable so far (Expanded field notes). Andy stated that "biology and I just got along well" and by this he implied that he and chemistry did not necessarily get along well (Field notes). In one of my first conversations with Brad, he made a more detailed comparison. He was trying to explain that chemistry had little meaning or relevance in real life. "Not like biology--all the plants and animals and like what's going on in the world of nature and stuff. Chemistry is too--out there." I asked him what he meant by "out there."

> Biology is just right there. You can see the plants and animals and that stuff is so much more interesting than chemicals--a lot more. ...Because we can see it every day. It's cool to be able to understand what is going on. I think chemistry is just more complicated (and it) goes beyond what you can see to what you don't see so it's not so interesting (Interview, 11/1/93).

This seems to be a common comparison that these students make and they often brought their experiences in biology to our conversations. It makes sense because biology is the last science course they all had before they came to chemistry this fall and it would be natural to compare the two. What they say about how the two disciplines differ can offer insight into their own philosophy of science and chemistry in particular. For Brad, the hands and eyes-on nature of biology makes the discipline much easier to relate to. Chemistry is just much more abstract and removed from everyday experience. Who thinks about atoms and molecules and the behavior of chemicals as one can think and relate to animals and plants, things one can touch and see. He is not willing to make the jump to these abstract concepts of chemistry.

Although Carrie gradually came to like chemistry later in the year, she did not like it in the fall.

> I just don't like it. It's too different from biology. I love biology. Biology is awesome. I can relate more to biology than to chemistry. ...I can't see these compounds and elements and things like that. I can't really relate to them. ... And it was kinda like more--just more interesting (Interview, 11/19/93).

I asked her if it was the quantitative nature of chemistry that she didn't like, she said:

> No, its not the math. I love math-- it's my favorite subject. ...It's just not being able to see that atoms-- I guess I am a visual person because I can't understand it. And like even in the diagrams (of atoms), I don't understand the diagrams so I just don't like it. ... Maybe it's because if you show me a diagram of a heart or something like that or I can dissect it, and you can see a liver and everything else. If I can't see something, its boring to me. I can't take an interest. I don't care. I don't care what a reaction is you know (Interview, 11/19/93)?

Carrie later explains that in biology, a student merely has to memorize things like the names of animals or bones. "That's all it is. Well, except for when you do like genetics though." She then explains that in biology, she even used flash cards regularly in her study for tests. However, in chemistry,

> [Y]ou can't just memorize it because it is more understanding--not like biology. You can't just memorize it. ... (but) I like the process of learning chemistry better but I like what I learn in biology better. It's more tedious...but I really don't care about moles and whatever. I mean, biology is still cool to me. It's more interesting but it is more tedious to study (Interview, 5/11/94).

The process of learning chemistry is difficult for them to explain in terms of how it is different from learning biology. It has something to do with the satisfaction of getting a difficult problem correct on a test and knowing that it can be done.

> I just like to get the right answer and you know, there's a problem I love to have it just be right. Like to go through the huge problem and have it right is really cool. like just to understand it is cool. In

> chemistry, it's just the best feeling. In chemistry it's just like a mixture, kind of (pause) English and math or something because in math there is one right answer and in English, it's, you know, there are no boundaries. But with chemistry, it's like you have to understand this concept and once you understand a concept you have the right answer. But it is not like a certain problem, it's more like understanding concepts (Interview, 5/11/94).

She seems to be saying there is a mixture of the abstract and concrete and/or left- brained and right-brained activities in chemistry that is absent in biology. They say that biology is quite concrete and to help me understand, they compare it to mathematics. They explain that in mathematics, one usually just mindlessly does a "set of 40 problems" that are just like the sample problems. In biology, according to them, one merely goes through similar concrete operations. However, chemistry involves problem solving that includes challenge and rewards that seem to some, more rewarding than memorizing terms and concepts. Chemistry falls somewhere in the middle of the abstract English (she also mentioned poetry) mental activities and the concrete requirements in students' experiences with mathematics. To examine the nature of chemistry and student philosophy better, I turn to an examination of what students describe as "seeing and imagining."

- <u>Some students assert that real chemistry understanding involves struggles with ideas</u>

> Well, I think people are just not studying because all of those objectives are in the book and you know, what I do is just take each subject and write out about four sentences about it and then just memorize it and if that is what you want, if you just want the easy way out, you can just do that (Kyrsten, Interview, 11/22/93).

When Kyrsten was describing this process of success the easy way, she was explaining that this is a real temptation because it is efficient and makes sense. Andrea was part of this conversation and when she heard Kyrsten say this, she added her method. "I make flash cards--the basic objective on one side and on the other, like a definition." Kyrsten then went on to explain in more detail

> It's not like I just memorize. I don't just memorize it and forget it. I still understand it but I memorize exactly what they want for the objectives. Cause if you understand it you still have to know how to put it in words. When you get to the test, you have to know how to write it down. You have all the information but if you write it exactly down on a piece of paper, then you know, you have exactly the right information (Interview, 11/22/93).

Understanding is less secure and more uncertain of a reward. One needs just the right thing to write down as an answer to a test question. Andrea then went on to explain that it would probably be better if they did not just memorize. "In a way it will be bad because when we get to a high level, we'll be screwed. You know if we never understood" (Interview, 11/22/93). Therefore, it seems to these students that it might be better to be challenged to deeper understandings than are usually necessary for a good grade. This concept of challenge became very interesting in relation to this study because some students were describing something of success that seems to go beyond the required. This theme was addressed on many occasions in conversation. They described a struggle with ideas, concepts and in problem solving that is more rewarding than just doing the work required for a good grade. Jack Honderd often comments in his class about how it might be good for students to struggle with difficult concepts and learn difficult things. I asked Andrea if she knew why he said this. She said: "Because it is true. Otherwise you would give up."

Jeff entered the conversation by saying: "Yea, you learn more if you work hard to learn something. It will always stay in your mind." I wondered why struggle was somehow important to them and if chemistry is just difficult. All three of these students agreed that chemistry is not difficult but it does take a lot of concentration. "It's not something you can just sit there and watch TV and do homework." Jeff explained that it is really up to the student to see some value in working hard to understand chemistry.

> Well, when you read something and you don't understand it, you should work at learning it you know? So if there is something in chemistry that you don't understand, you should keep on working to understand it inside the book. But, I think most of the people in the class feel it should come easy and when it doesn't, they are just not going to get it. ...They just don't want to work hard. I mean, I don't even want to work hard. I've been trying to change my attitude and I have been trying to think of school in a different way. I think of school as a big waste. All of my homework, instead of just homework, I want to learn something (Interview, 11/22/93).

It is still not clear why it is important to work hard. In one sense, it seems that these students are saying that hard work in chemistry will teach them about hard work so that later in life, when they have a vocation or a job, they will know how to persevere in adverse conditions. Chemistry seems like a trial by fire and this hard work has little to do with actually wanting to learn chemistry. Andrea described this job-training function: "Those who don't work hard now--what are they going to do later in life... when your employer is going to know that you are working hard and there are no grades at all. It is going to be the person who works hardest that gains" (Interview, 11/22/93). On the other hand, some students make it quite clear that working hard to understand chemistry is part of being successful in learning chemistry itself. Kurt explains that he would rather think hard about mysterious things and wants to questions how and why.

> To know how things work, why they work, the way they are made and why they are that way. Just basically why. Why anything. ...Why does this thing work like this and why doesn't it work like that. Why can't we split an atom in half and keep the energy in light, take the energy

> and blow up, you know, this table. Which we can but not very well. Why can't we just put it in a little box and keep it there and take out a photon later? Mr. Honderd says it doesn't work that way. I don't like it when he says that-- I hate it when he says that:
> "It just doesn't work that way."
> It's kind of like: "Gee mom, can I have a cookie?"
> "No!"
> "Why?"
> "Just because" (Interview, 5/10/94).

Kurt went on to explain that it bothers him that his questions are most often put off and not dealt with. He seems to feel somewhat insulted. Yet he tries to understand and give his teacher the benefit of the doubt. He explained the teacher's attitude as "Don't bother me now." And that "I think he just wants to get out of here. I think he needs a vacation." Kurt would rather wonder about unseen things and real chemical properties and transformations than the on-paper tasks and rather rote performances he finds himself doing most often. I wondered if he felt that success would be more meaningful if he was challenged intellectually in his chemistry class. He links challenge to interest and constructing knowledge as opposed to rehashing old ideas.

> Well I was. I was interested in the bonding and all that other kind of junk like I said. But now in solids, you know, I know the three states of matter. I mean we learned those way back in IPS (Introductory Physical Science). And we learned why they were that way. You know, because of pressure, temperature and kinetic theory and all that other kind of stuff. So basically, this if kind of review from two years back and it is getting real boring. You're learning stuff you already know just more complicated terms. Terms which have no meaning practically. Isomorphic and all that other kinds of stuff. We already know about hydrated crystals but for some reason, we had to learn about them again. I mean, the only thing that might have been important was the polymorphic and isomorphic kind of stuff and that was the one substance has many crystal forms or many crystal forms, wait, many substances have the same crystal form. And that was the only maybe important part of the whole thing. All the other stuff was

> like review--get more technical and get more boring. I can tell I am going to like college a lot (Interview, 5/10/94).

Kurt does not have much patience for the mundane and review. When he explains that they are just getting more technical, I think he means that all they do is place more terms and names on things to make them more obscure. Mastery of these new terms are meant to pass for greater understandings. According to Kurt, in chemistry they are searching for deeper understandings. He explains that he wants what he learns to have practical meaning and not so removed from the real world around him. He enjoys wondering about bonding and "how things work, why they work, the way they are made and why they are that way." "Crystal forms" are still mysterious and his understanding is uncertain but it is this conceptual stretch or challenge that he seeks.

When Carrie was talking about whether or not there is a more meaningful success beyond the grade, she explained again that she is interested in a career in one of the sciences and therefore was very interested in understanding chemistry now. She explained that there were other options besides Jane Hatfield's class that would perhaps result in an easier grade and would also require less understanding.

> ...[I]f I was getting an A in another class it would not mean that I understand it. I mean I guess that she's easier and she's not a very good teacher so you don't have to ask any questions. I guess she doesn't give you (difficult assignments). This is just what I have heard.
>
> And so, if I was in her class and I was getting an A but didn't understand why I was getting an A or what I was doing, it wouldn't be the same. ...It's a bunch more satisfying to understand. Yet, I mean if I got an A and I didn't understand it, I would still work hard to try to understand it. Cause I don't think it is just the grade. I mean, if I'm getting a B and I don't understand it, then I'd be upset (Interview, 5/11/94).

Carrie is not the only person to discuss the idea that there is an easier teacher and an easier grade in another chemistry class at the hands of another chemistry teacher. In fact, Ryan, another student in Mrs. Hatfield's class made the switch at the semester break. When I asked him why he chose to move from Mrs. Hatfield's class, he confirmed what Carrie said above. He said he was mostly interested in his grade-point average and could receive a higher grade in this other chemistry class with less effort. I asked Hatfield if this happens more often. She answered by telling a story about Zack and his parents. According to Jane Hatfield, Zack's parents came in for a conference to discuss this option. She explained that they were very concerned by the fact that Hatfield "graded harder" and required more than the other chemistry teacher. Zack's parents advised him to make the switch. They left the decision up to Zack and he decided that it would be better for him to stay in Mrs. Hatfield's class. He explained that it is better for him in the long run to struggle and search for deeper understandings than just go for an easier grade. At the end of the year, he explained to me that he might even take a chemistry course at the local community college to catch up on some chemistry that he missed this year.

> I've done so bad in this class this year and I know I missed a lot of stuff. And for that, I actually thought about taking a chemistry class at (the community college) this summer just to kind of fill in the holes with what I missed and hopefully I'll do better at that... And you know, this is my first chemistry class and that explains it sort of. I guess I really did not have a good understanding of what chemistry was really like until I found myself asking what I am doing. I think if I do take a class, I'll kind of know where the class is going and I'll have an introduction into what's going on so that it's not such a mystery. ... I have no idea what I want to do when I get out of school, I want to keep my options open. ... It's (chemistry is) important (Interview, 5/5/94).

For Zack, then, it is important to know and understand chemistry and part of the process of understanding is a struggle with rather difficult things. Whether or not he takes a class this summer to "fill in the holes" of his knowledge, he is expressing a desire to know and understand chemistry, not just to understand what to do to earn a good grade in chemistry class. It seems that according to these students, success should involve this deeper understanding.

Chapter 5 Summary

In this chapter, I presented student voices about two planes of understanding in Chemistry. On one plane are the knowledge and skills understandings that are necessary for efficiently and quite painlessly earning success in school chemistry. On this plane, to succeed, one merely sets a personal standard, a grade that is good enough, and does what is necessary as efficiently as possible. Although students described complex pressures against success, there is a great deal of socio-cultural support for learning and performing in the realm of school chemistry. Positive support comes from peers, family, and institutions so that, weighing the alternatives, being a good student makes perfect sense to them in context. The teacher also plays an important and necessary part in making this school chemistry viable in the high schools in which they work. The teacher translates or transforms chemistry into school chemistry in the classroom to meet and in a sense, to conform to students' constructs and expectations for familiar, conventional schooling. Everyone seems satisfied and even happy with this arrangement most of the time.

However, on another plane, some students get glimpses of a mysterious world of real substances and their transformations. These glimpses usually involved students thinking about real things like tables and chairs and trying to imagine the "awesome" atomic structure of matter. Students on this plane begin to see what I call real chemistry or the understandings of the academic discipline that would enable them to comprehend specific chemical events in the natural world. The student realization that this plane exists sometimes makes success in school chemistry lose some of its flavor. Some students seem to feel that success is somehow not as sweet or meaningful if the "awesome" remains "out there" somewhere out of reach. Knowing deeply about the natural world is very real for these students and yet it is more elusive--part of imagination, creativity, and wonder. There is much less socio-cultural support for gaining understandings in real chemistry yet individuals also feel that if a student could operate on this plane, learning of chemistry might be more meaningful and even more practical.

It would be too simplistic to classify these focus students according to set perspectives such as those who struggle with real chemistry and those who don't. Instead, it might be useful to identify three varying perspectives in student voices with boundaries that are fluid and blur depending on the day, the mood and the time of the year. A few students never talked about the deeper understandings of chemical events in the real world and described only the traditional games of school chemistry. Their perspective is quite pragmatic and worry free. Other students consider deeper understandings optional for those others who might want them and that they hold some intriguing possibilities for them as individuals. However, some struggle with the nagging realization that "something awesome" exists in the real world and that success would be so much sweeter if one could only experience it. These students--Kurt, Trent, Carrie and Troy as examples--usually do the school chemistry that is required of them but at the same time see the rich possibilities in the wonderful world of deeper understandings of atomic and molecular theory. These students seem to worry about the quality of their chemistry education and know there could be something much better.

CHAPTER 6

Summary of Findings, Conclusions and Reflections

Introduction

The purpose of this research project has been to hear student voices in context about their lives in high school chemistry. Previous chapters presented the problem, framed the historical context, reviewed the literature and presented the analysis model which formed the framework and theoretical foundation for data analysis. In this final chapter, I will begin by presenting a brief abstract of the answers to the central research questions. I will then discuss the general research findings that support these answers. This analysis is organized around the same set of main assertions and supporting assertions that evolved with the data analysis as presented in the last chapter. Chart #4 lists these assertions with page references where the corresponding data and analyses are presented. The findings in *The Summary of Findings, Part 1* concerns the good students and their perspectives on "school chemistry," the chemistry consisting of understandings and performances required for getting a good grade in high school chemistry class. The *Summary of Findings, Part 2* concerns student perspectives on the nature and character on "real chemistry," the academic disciplinary understandings of real substances and their transformations. The *Summary of Findings, Part 3* concerns a dilemma some students face when considering school chemistry on the one hand, and real chemistry on the other.

After the general findings and supporting assertions are summarized, I will present my conclusions. I will then present my reflections on the findings which include some limitations of this study and some suggestions for further study. In reflection, I present two challenges for the educational community.

Abstract of Answers to the Central Research Questions

I. What does it mean to be successful in high school chemistry?

When I asked students this question, they usually described success in chemistry class as getting an acceptable grade and then having that grade appear on one's high school transcript and contribute to their overall grade-point averages. Successful completion of chemistry is described by students as a requirement for further study in the sciences, but more importantly and practically, it is believed to be a requirement for college admission. Therefore, students considered themselves successful if they passed chemistry with a good grade, have a good grade recorded on their transcript, and earn a good grade-point average so that they can gain admission to a college later in their academic career.

However, as conversations developed and they thought more about success and learning chemistry, several students began to describe a different form of success that they did not consider required or even expected of them. They seem to realize success might be sweeter and more meaningful when they glimpse "something awesome" in the world of molecules and atoms. They explained that if they knew chemistry in deeper ways, they might be better off in the long run. Realizing this second, almost haunting meaning of success exists is a source of conflict in the lives of some good students of chemistry.

II. What is required for a good student to be successful?

When I asked this question, I frequently received a simple answer. "You have to understand." However, when I probed into the possible meanings of the word "understanding," it became clear that they were describing two forms of understanding and held two related conceptions of success. First, they explained that a good student must understand how to do homework, listen in class, and go about the tasks related to getting good grades in chemistry. Not only do good students understand these things, they are willing and able to do them. The students who seemed satisfied with success in school chemistry didn't find being successful very difficult.

However, those who described the second understanding, an understanding of real chemistry (usually kinetic molecular theory) explained that success in school chemistry seemed to lose some of its flavor. In real chemistry, a good student must understand deeper things, struggle with ideas, and attempt to understand how real things exist and work in the real world. Although one success is not necessarily exclusive of the other, this second form of success was far more elusive, quite optional, voluntary and far more uncertain.

III. What is the nature of the cultural influence experienced by students of chemistry?

The Cultural Spheres of Influence Model conceptually represents the findings regarding student perspectives of the nature of the cultural influences in their lives. What it means and takes to be a good student in chemistry is socially constructed in context. The cultural milieu is an amalgam of subcultures with the individual in the center. Meaning and action are therefore formed in the context of this milieu. The model also conceptualizes the formation of the school chemistry construct as a product of the interaction and interrelationships of the first three subcultures: (in order of their apparent importance) peers, family and institutions. The chemistry student brings his/her own meaning of school and of doing school work to the classroom. The teacher also brings his/her own conceptions, expectations, and meaning of chemistry and chemistry learning to the classroom. The teacher metaphorically stands between the 5th cultural sphere, academic disciplinary chemistry (real chemistry), and the rest of the cultural milieu. He/she seems to translate or transform real chemistry into school chemistry in the classroom.

However, when some students get glimpses of real molecules and atoms moving and reacting, they seem to transcend the influences of the cultural milieu and at least for fleeting, almost spiritual moments, experience the chemistry of real things and how they work in the real world. They try to imagine real atoms and molecules moving and reacting in real substances. In thinking of these things, they begin to experience the chemistry of the 5th cultural sphere--they begin to gain some academic disciplinary understandings.

IV. How do these cultural influences affect student decisions regarding academic work?

Faced with the realization that success might be more meaningful if deeper understandings of real chemistry were realized, students are faced with a dilemma. On one side, there are the familiar, conventional performances and understandings of school chemistry and earning good grades. Although there are certainly cultural constraints that originate in each subculture, most of the cultural influences, incentives and rewards are positive for this form of success. On the other side, for some students, there is the almost nagging realization that real chemistry might involve knowing and understandings of real, almost unimaginable and awesome things. Although there appear to be few immediate incentives and rewards, these students consider this world of kinetic molecular theory more interesting, more worth while and even more practical in the long run.

Summary of Findings, Part 1: The Good Student and School Chemistry

(Part 1 contains three general assertions and four supporting assertions)

During this research, I found that most students in my study not only understand what is required for success in high school chemistry , but are willing to do the tasks and performances required. The Summary of Findings, Part 1 is about this understanding with its tasks and performances. This section summarizes the findings for Part 1 of Chapter 5 which deal with the good student perspectives regarding school chemistry. It is also about the student willingness to do the work necessary and why this willingness makes socio-cultural sense to participants. Although there are certainly constraints to success, there is also significant positive socio-cultural support for these students originating in all of the first four spheres of influence represented in the Cultural Spheres of Influence Model. I begin with three general assertions regarding the good student and school chemistry. These are followed by four other supporting assertions.

General Assertion 1-A. These students identify understanding as necessary for success in school chemistry

> We have a clearer sense now than we did ten years ago that successful participation in a school lesson, for example, requires not only "knowing" the subject matter, but "knowing" how to get a turn at speaking in the conversation and how to speak in ways that are appropriate and effective once one has the turn (Erickson, 1982, p.170).

As shown in Chapter 5, Part I, it was common in conversations for students to identify "understanding" as a necessary component for success. When I asked them what was required for success, the students explained that they needed to understand how to act, what to do and how to do it in order to earn an acceptable grade in chemistry. They explained that good students understand these things and those who have academic trouble often don't. Good grades are the driving force in making decisions to engage with course work and fulfill teacher expectations. In school chemistry, disciplinary understandings seem almost incidental and only loosely connected. To succeed, a student merely sets a personal standard, a grade that is good enough, and does the necessary tasks as efficiently as possible.

It is not a new idea in educational literature that there is a common sense knowledge that includes a set of culturally appropriate ways to act in school in order to succeed (Waller, 1967). The students of this study themselves describe how schools, as institutions, traditionally reward certain familiar tasks and performances. They not only own this common sense knowledge, but are also willing, able participants and co-constructors of it. What struck me was how they spoke of it as "just the way things are," the way things are done in school, and take it for granted as a matter of fact. It is so familiar to them, so safe, certain and reliable, and most often satisfying. To meet the established standards for success, the good reliable students, according to them, must understand how to prepare for tests, do homework well, do lab reports that meet standards, and own other varied strategies for doing work. These other strategies include understanding who to ask for help (parents, "A students" or AP Chemistry students), where to sit in the classroom (responsible students sit in the front of the room), and how to "give the teacher what she wants to hear." These are the common sense things all the participants understand and are able to do very well. They have been doing these things for many years and have found these understandings and task performances very reliable.

General Assertion 1-B. These students measure investments of time and effort against perceived rewards and decide to do what is required to succeed in school chemistry

Good students in this study described what it means to "understand" how to get a good grade in school chemistry but understanding what is required and how to fulfill expectations don't necessarily mean one is successful. The students explain that one must also be willing to do the work and spend the time that is necessary. This is a rational decision on their parts as they measure their investments of time and efforts against perceived rewards. But they are used to making this decision because they have been successful in school for many years and expect success in chemistry. They have already been members of the college bound track along with their peers for several years. However, they are not equally willing to do whatever it takes to succeed. For example, a few students explain that a B grade is adequate because an A grade would require a disproportionate amount of effort. These students sometimes seem to rationalize their decision by blaming the subject ("Its just too 'out there'" or "I just don't get it") or diminishing the worth of chemistry ("I'll never use it anyway" or "It has no value"). The social constraints of success (see pp. 51ff.) are perhaps the most revealing data as to the nature of these choices. These students are most often busy before and after school with social events, extracurricular commitments, and after-school jobs. They realize that these non-academic commitments take their time and energy so that there often is not much left for homework. Consequently, they are willing to do the work necessary as long as it doesn't require too much of them or interfere with these other social commitments.

This is a viable position to take in school chemistry because course work as they describe it, is actually designed to make life run smoothly in high school. There are several ways in which the situation is constructed in order to make things run smoothly. For example, the course expectations for success are made explicitly clear. Once students understand what is expected of them, each of them sets a personal standard or a grade that is good enough and then does the necessary tasks as efficiently as possible. Evidently these tasks and performances are intentionally traditional, familiar, safe, and not very difficult. They are reliable and very similar to the schooling students are used to. In addition, the tasks and performances required in school chemistry are very similar to those in the other academic courses they take at the same time. School English, mathematics, and history are usually characterized by remarkably similar homework tasks and cooperation in class. Under these conditions, all the focus students are usually very willing to do what is necessary to succeed in school chemistry. They complain only if and when chemistry work seems disproportionate to their other school work requirements.

General Assertion 1-C. Both student understanding and their willingness in school chemistry are constructed within the cultural spheres of influence

The Cultural Spheres of Influence Model serves to conceptually represent and pragmatically organize what I found out concerning student perspectives about what a person needs to know and be able to do to be a good student in high school chemistry. Assertion 1-C states that individual student understandings and their willingness to do what it takes to succeed are socio-cultural constructs that make sense in context. The theoretical underpinnings for this assertion are discussed in Chapter 2 and the evidence to support this claim presented throughout chapter 5, part 1. The following

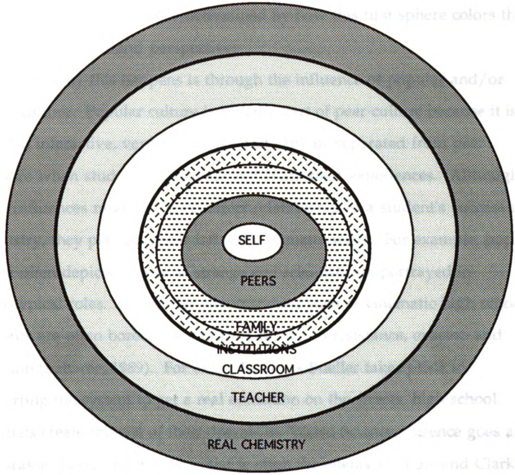


Figure 4. Cultural Spheres of Influence Model
(Repeated here for the reader's convenience. See also Chapter 2)

- Supporting Assertion 1a. The culture of high school chemistry provides a positive peer pressure for achievement supporting assertions summarize my research findings and explain not only that these student social constructs exist, but why and how they are formed in context.

The first sphere represents the influence within the peer subculture in each of these schools. It is the inner-most sphere of influence in the model because most of the social and cultural pressures that students described related to their peers. The nature of the influence of the other cultural spheres is therefore partially determined by how this first sphere colors the individual's vision and perspectives.

One way this happens is through the influence of popular and/or media culture. Popular culture is actually part of peer culture because it is integral, interactive, very persuasive and can't be separated from peer pressure when students interrelate and share their experiences. Although these influences might have no direct relationship to a student's success in chemistry, they play into peer influence in many ways. For example, popular media often depicts science as strange and scientists are portrayed in stereotypical roles. In popular circumstances such as cinematic high schools, students are often bored, demoralized, driven to resistance, evasion and rebellion (Labaree, 1989). For example, Ferris Bueller takes pride in subverting the system to get a real education on the streets, high school scientists create the girl of their dreams in "Weird Science," science goes awry in "Jurassic Park," the mad scientist is often the enemy of "Lois and Clark," and scientists are often portrayed in white lab coats, thick glasses and unruly hair. Students see these programs, read the books and bring associated conceptions of schooling and of science to chemistry class.

Popular culture doesn't always consider peer pressure negative. Folk wisdom suggests that individuals define themselves by the relationships they have with others so that "you are who you know" and care about. As Wong (1995, Draft) points out, it likely that if students know, spend their time with, and culture their reputations with successful or high achieving people, they are likely to think this of themselves. As Wittrock (1990, p.5-6) suggests, these affective processes merit much further study to determine their causes and more precisely how student beliefs actually affect their achievement.

The peer cultural sphere colors the individual's vision and perspectives in more direct negative and positive ways. Others have also shown interpretively that *negative* peer pressure often affects student achievement in school as well as a student's desire to stay in school (Fine, 1986; Okey, 1990; Sedlak, et al., 1986; Solomon, 1992; Willis, 1977). In addition, but certainly not less significantly in the lives of school students, folk psychology or common sense more often considers peer pressure a *negative* phenomenon instead of a positive one. Perhaps this explains why most of the research accounts of peer pressure on schools examine drop outs, forms of injustice and inequality, and student resistance.

In my study, students described negative peer pressures that constrain success. These social pressures fall into four categories, each closely related to a perceived limited amount of time. First, they explain that their time for chemistry is very limited because they all have other personal priorities that make demands on them. These demands include commitments to music practice, music lessons, drama organizations, sports, and other things. The second constraint relates to students' desires to have a rich social lives aside from academic work. Students explain that it is important to attend basketball and football games, and other social functions. Chemistry is also not at the top of anyone's priority list when compared to dating and other social events. The third constraint involves commitments to part-time jobs after school and on weekends. Some of these students work more than 20 hours each week. They explain that this work not only takes time but also energy so that they find it difficult to do their school work. The fourth constraint involves other school-related activities that also compete with academic work. Several students summarized these constraints by expressing a desire for personal freedom and autonomy so that they can enjoy and savor life in high school instead of just bowing to the demands of homework and academic requirements. Any decision to respond to chemistry as a discipline or succeed in school chemistry is measured against or taken in context of these peer-social factors first.

However, it is a much more significant finding of my research that most student talk about peer pressure is *positive* toward achievement. They describe how important their reputations as good students are and how simple things like where one sits in relation to others helps determine, identify or sustain that reputation. They describe very complex implicit and explicit social factors and attitudes. Some form and nurture social pretenses. Some describe important labels such as "A' student," "B' student," or "good student." Some students talk about how goals are congruent with peer goals and how they try to keep future options open, to gain admission to a college of choice, and to prove ability or competence to self and others. All of this serves to show that it is certainly a priority to these students to be known as good students. But it is especially important to note that this peer pressure is mainly about grades as a measure of good-student status and reputation. This means that most of the positive pressure from this subculture is about succeeding in school chemistry, not real chemistry. However, as I will explain in later, that when peers engage in conversations about real molecules and atoms acting in real things, they support each other to construct their meanings and understandings of much deeper things.

- Supporting Assertion 1b. Family members pressure students to succeed in high school chemistry

The family cultural sphere represents the influence of parents and other family members. Talk about families was frequent but the nature of the talk was different than other spheres of influence. Comments were usually brief and it seemed as if students were describing factors that they assumed everyone understood and took for granted. "Of course my parents are concerned about grades" or "my dad would kill me if I got an F on that test" or "it (a good grade) is just expected in our family." Consequently, with a few exceptions, it was difficult to get students to elaborate on home-generated influences in conversations. However, family influence is extremely important in reality even if not rich in detail in the data. Family pressure to succeed is a solid, on-going, foundational given ingrained in their lives, not a passing, temporary thing like basketball practice or play practice. Family influence begins at birth and will continue for most of these students' lives. This places family next in order of priority.

Waller (1965) describes the family as a "primary group" and a "starting point for all excursions" including excursions into school learning (p.178). He states that the home is the most important of the social groups because if forms the child before other groups have any influence and because it persists long after other influences fade out. According to Waller, there are only relatively short periods of time--the teen-age years is of course one of them--when others, such as peers, exhibit more influence on an individual. When the teens of this study did talk about family pressure, the explanations were quite consistent among participants. It seems that students not only consider family pressures very significant but also natural and expected. Much of the talk centered on family tradition and family expectations. "It is just expected that I take chemistry" or "I am expected to go to college and chemistry is a step in that direction" (interview transcriptions). According to students, parents consider successful completion of chemistry prerequisite to college admission. In addition, according to students, their parents took chemistry when they were young and assume their children should also. Chemistry students have been told that when their parents were young, chemistry was expected on one's transcript and parents are quite sure that the same is true today. For example, two student participants in this study, Jeff and Paul, both belong to families of engineers. They both feel very specific pressure from family to go on to a career in engineering, taking chemistry as one step along the way. Not only are individuals expected to take chemistry, they are also expected to be highly successful. In fact, students speak of consequences if they do not do well. When these consequences are described, they are usually linked to grades and privileges. Some parents threaten to take driving privileges away or hold the student's social life hostage in other ways.

It is important to note briefly that much of the literature about parental influence describes *negative* relationships or enmity between the home and school. For example, Okey (1991) and Fine (1986) and others found that one of the major reasons students drop out is because of a family history of antagonism between home and school. Others researchers describe conflict is associated with economic, ethnic and other factors (Sedlak, 1986; Clark, 1983 Waller, 1967, Willis, 1977, and many others). Generally, these studies were done in settings with different cultures, socio-economic standings, and generally, different social environments than in my study. It is significant that among my focus students, there is a lack of negative pressure for academic achievement from home. In my research, in these two suburban high schools, I found young people belonging to families who strongly support student achievement in school. Most of their parents have fond memories of school and most of them felt reasonably successful in school chemistry themselves. Perhaps there are other students in these schools who experience negative pressure for school learning from home who do not elect to take chemistry but these students would naturally not be represented in my research sample. It also must be remembered that the parents of my focus students probably remember school chemistry, not deep understandings of real things, and expect the chemistry their students experience to be similar and familiar. Therefore, as explained in chapter 5, the constraints to success that originate in family sphere of influence relate more to the type of chemistry and learning experienced. These students made it very clear that parental influence is all about getting good grades as efficiently and responsibly as possible and it has little to do with understanding difficult things deeply. Is this because parents only value grades and not learning to understand? Or, is it that parents just don't know that any chemistry other than school chemistry is possible in school? Do these parents remember a chemistry that had no relationship to reality and no practical use value and therefore see no use for real chemistry in the lives of their children? Are parents concerned that the learning of difficult things might impact grade-point averages and therefore limit opportunities?

- Supporting Assertion 1c. Institutions pressure students to succeed both in high school chemistry as a present reality and in (often assumed) future admission to college

The third cultural sphere, institutional culture, represents schools as institutions that influence a student's perceptions and decisions. There are some institutional incentives for real understandings in chemistry. As explained elsewhere, these teachers, as representatives of the institution, sometimes speak of conceptual understandings and make some attempts to move their students toward that end. For example, Jane Hatfield uses extra credit essay questions at the end of her tests to stimulate deeper thinking and problem solving. In addition, chemistry teachers by their title and position represent the awesome set of ideas about the natural world and in the Cultural Spheres of Influence Model, they stand between the classroom and the 5th cultural sphere. Teachers also have the institutional option of the ACS Chemistry outcomes test which is designed in part to test conceptual understandings. They also could bring real scientists, as representatives of the 56th sphere of influence, into the classroom either through historical accounts (see Jack Honderd's presentation of Mendeleev's work.) or by having scientists visit the class. There are other strategies teachers can use to orchestrate student experiences with real substances and kinetic molecular theory. However, the list of existing options is quite short and more importantly for this study, students do not talk about these potentially positive institutional pressures as significant in their lives. One significant exception is when a few of Jane Hatfield's students describe her "extra-credit" test questions and how they challenge deeper thinking.

Students more frequently describe institutional pressures that are based in the assumptions that college-bound students need credit for and a good grade in chemistry on their transcript for college admission. Although there actually is no official written policy to require chemistry on a college-bound student's transcript, counselors, teachers, other adults and peers told my focus students that they must take chemistry if they expect to go on to college. These students don't really question this and instead, take it as a matter of fact. When I asked them why they elected chemistry, they usually replied in a matter-of-fact tone: "Its required." According to them, chemistry is just one of those courses one should take in high school.

However, when I probed farther, they qualified this by stating that chemistry is not required for all high school students. One student explained: "its not really required but it is required for the college-bound path." They explain that there are non-college bound paths, or tracks, that do not require chemistry. When a student chooses a college-bound track, chemistry is part of the curricular package of courses to take. My sample of students were all, of course, in the college-bound track: "I think freshman year we got a packet and it said that route you can go through."

It is clear that American institutions officially or unofficially track students and that this policy sometimes has negative effects on self image and future possibilities of those in the "lower tracks" (Oakes, 1985). I, on the other hand, found that students in the "higher track," or college-bound track realize their advantage but also believe that this is an institutional phenomenon and that they have little control over it. Even though chemistry and other junior and senior-level courses are listed as electives in student handbooks, once the college-bound track is chosen by the students or chosen for them, there are actually few other subsequent choices available to them. "We are on a sequence. Chemistry is next." "You can go through the normal (freshman) science, Biology and then Chemistry. We can choose our senior year what we can take." They feel their schedule in science is a given, at least until the senior year. Even in their senior year, many of these students feel the only course choices open to serious college-bound students are AP science courses and/or physics.

It is also very clear that this institutional pressure is focused on the grade earned and merely taking the course, not on the chemistry learned. They understand that there are more people associated with the school who have vested interests in whether or not a student does well in chemistry. They also know that doing well means getting good grades to these people. They know they are the "good students" in the system and that in a very real sense, the reputation of the institution and the pride of the educators associated with it hold a stake in their success. Parents, students, teachers, administrators and other "overlapping collectivities" (Cusick, 1992) can point to these students and say how successful their educational system is. Thus the character of school life is greatly influenced and determined by overlapping collectivities of people who care about the school for various reasons, who pressure all the participants in schools in various ways.

However, these students also know that the focus on grades as a measure of success is not ideal. As Troy explained, "they put too much emphasis on getting a good grade." When I asked him who "they" were, he said: "The teachers, the school board, everyone" (Interview, 10/19/93). According to Troy, everyone associated with the institution put various pressures on students to get good grades and thereby achieve success in high school chemistry.

Since the institutional emphasis is on taking chemistry and getting good grades, it makes sense for students to seek good grades as efficiently and effectively as possible. It also makes sense for the institution to make the path to chemistry and success in chemistry quite clear and straightforward. Therefore, according to many of these students, a good grade is quite easily earned. "That's just the way things are." They understand that it is not a mistake that school chemistry is familiar ground, relatively safe, and certain with its conventional understandings and performances. From the institutional perspective, the stakes are quite high because these good students are living proof of the effectiveness of the educational system. Institutions have a vested interest in keeping students successful. If success is measured in grades, and good grades are quite easily earned in traditional ways, things tend to run smoothly. Everyone is happy with the success of these students--students who understand what is required of them, do their homework and cooperate in class. However, since the major institutional emphasis is on taking the course and getting good grades, there are few incentives for learning real chemistry that is inherently difficult, non-traditional and much more uncertain. Many of my focus students are very aware of all of this and apply this knowledge in their daily lives in chemistry class. Consequently, there is little felt support of struggling for deeper understandings of difficult things. Instead, the reward system is built around an institutionalized form of school learning.

According to Waller in his classic treatment of *The Sociology of Teaching* first published in 1932, (Waller, 1967) it is the requirement system in American public schools that forces students to learn but to learn in what he called a strange, institutionalized way.

> Certain tasks are laid out, students are graded numerically on the manner in which they perform these tasks; advancement in the social machine, and ultimately liberation from it, depend upon the accumulation of satisfactory grades for tasks performed (355).

One of the most troubling themes in the more recent literature is that this institutionalized learning is quite common in the majority of American schools, not just the middle-class suburban schools similar to those in this study. It seems to cut across all walks of life and all social and economic levels. Even those in the achievement-oriented schools like those in this study, are quite uninvolved in the acquisition of challenging academic knowledge (Cusick, 1983; Goodlad, 1984; Peshkin, 1978; Sizer, 1984). Young people are implicitly encouraged to seek the "credential," the high school diploma instead of seeking deep understandings of subjects (Sedlak, 1986). This starts early in a student's educational career where completing worksheets, completing simple assignments and doing school tasks willingly and well is the goal and is connected to the rewards. The result is often procedures and incentives for "Proxies for learning" (Sedlak, 1986, p.182) that quite intentionally grease the students' path toward graduation (Labaree, 1989; Labaree, 1983). All of this does not encourage or reward the learning of difficult things. Waller, in 1935, explained that most of the social incentives for teaching and learning in institutional schooling lie with lifeless facts, content and task performances.

> Dead matter makes the best courses. It can be taught best, and learned best, within the learning situation peculiar to school.
> Bulk too, is essential. Most teachers would rather teach big books than small ones, for the ultimate tragedy of the classroom teacher is to run out of something to teach (Waller, 1967, p357).

Likewise, in high school chemistry today, instruction and learning is often quite focused on the symbols which actually become the reality. Traditional performances provide a path toward students success. As high schools encourage "proxies for learning", so does the typical American chemistry class. Barrow (1991) states that this common chemistry of grade consciousness and conventional school performances is not chemistry at all. As if to make Barrow's point, all of the students in this study manage to do what is required to earn a good grade, are considered successful, but few describe a sense of enjoyment and satisfaction of basic understandings, inquiry and discovery in the discipline. It is also understandable that students fail to see how chemistry can apply to their real lives and world.

As Schwab (1978b) states, educators and their students are drawn in schools toward a curriculum based in a sort of folk wisdom or common sense "which is formed by consulting existing wants and needs, social, personal, and economic... the know-hows, information, skills, and attitudes most relevant to our existing problems" (p.266). For our focus students, the pressing practical problem is knowing and doing what it takes to succeed in school chemistry whether or not it requires any deeper disciplinary understandings. This is consistent with previous studies of science education in schools where it was found that even if teachers have deep understandings of the structure of their discipline, those understandings do not necessarily get translated into classroom practice (Brickhouse, 1989b; 1990; 1992a; 1992b; Lederman, 1992). If teachers do not translate their deeper understandings into practice, most chemistry students are not likely to experience it. "If the structure of teaching and learning is alien to the structure of what we propose to teach, the outcome will inevitably be a corruption of that content" (Schwab, 1978b, p. 242).

- Supporting Assertion 1d. Students hold multiple viewpoints on how teachers pressure them to succeed in high school chemistry

Aside from peer culture, the teacher's influence on students is the most significant and complex of all. The subcultural influence of the teacher is fundamentally different from the other spheres of influence and therefore is represented differently in the model. The classroom stands between the other spheres and the teacher because the students bring their constructs of schooling and learning to the classroom as they enter it from the hallways. The teacher also brings his/her own beliefs and expectations about schooling to the classroom. However, the teacher represents authority and institutional expectations. Students are influenced by the subculture in the institution (see descriptions of the institutional sphere) but the teacher is the face-to-face authority who sets the tone, the norms and context within the classroom. This gives the teacher incredible power.

From the conversations with students, participant observations, and other sources of data, it is quite evident that the teachers' power exists at least on two levels as they set the stage for success in their classes. First, the teacher is ultimately in control of the grade students receive and the requirements and expectations necessary for attaining that grade. In the settings of this study, the teachers set what they consider high expectations and standards. I found that teachers say they deliberately set the stage for success by helping students understand what behaviors, attitudes, and task performances are necessary to succeed and help students understand chemical concepts and applications. Students explained that "it (success) really depends on the teacher." They explain that it is the teacher's responsibility to set appropriate and clear standards so that students can respond with cooperation and willingness to meet those set standards. Waller (1967, p. 357) explains that it is typical of teachers to "display an extravagant devotion to academic standards." My students add that not only should the teacher set academic standards, they also must make sure standards are reachable, make expectations clear, and in many ways, pave the student's path toward success.

The second way the teacher holds power in the classroom is by fulfilling the role of resident chemistry expert who controls the information presented and made available to students in chemistry class. The teacher comes to the classroom, stands in front to teach chemistry to these students and therefore not only represents the authority, acts as gatekeeper (power of the grade giver), holder and translator of knowledge in the discipline. The teacher is therefore the resident chemistry expert and it is the teacher who represents the discipline (Dewey, 1938; Schwab, 1978b; Shulman, 1986b, 1987). This is why the Cultural Spheres of Influence Model places the teacher's sphere outside the classroom and just inside academic chemistry. Teachers present personal versions of chemistry to students so that the only chemistry most of the students can relate to is that which is interpreted, transformed and delivered by the teacher. The student experience with chemistry is mainly orchestrated by the teacher and it is almost impossible for most of these students to think about chemistry apart from their teacher's influence.

One way to control knowledge in the classroom is through the use of the textbook. In both of the settings for my research, each teacher made it very clear on several occasions that the text should only be considered a resource, not the curriculum. In fact, each teacher occasionally pointed out errors and/or inadequacies in the text to the class thereby effectively usurping much of the authority it may have had. None of the students considered the textbook the source of instruction or resource for deep understandings of chemical concepts and ideas. Instead, according to them, it only provides chapter objectives, reading assignments, charts, graphs, and handy problems for them to do as homework. Few of the students actually read it.

As shown on the Spheres of Influence Model, the space labeled "classroom" represents the contextual space to which students bring their constructs of schooling and to which the teacher brings his/her conceptions of chemistry. The result is schooling with required understandings for success in the every-day life of chemistry class. As Gardner (1991) explains, it is common in schools to sacrifice "risks for understandings" for "correct answer compromises." It doesn't often pay for teachers or students to pose challenging problems in learning and for teachers to force students to stretch in new ways that will risk failures that might make both students and their teachers look bad.

> ...both teachers and students consider education to be a success if students are able to provide answers that have been sanctioned as correct. Of course, in the long run, such a compromise is not a happy one, for genuine understandings cannot come about so long as one accepts ritualized, rote, or conventionalized performances (p.150).

The cultural influence of the teacher, because of its importance and significance, is examined further and in more detail in the my reflections later in this chapter.

Summary of Findings, Part 2: Glimpses of Real Chemistry--Chemistry as a Way of Comprehending Selected Events in the Natural World

(Part II contains three general assertions and two supporting assertions)

Some students get glimpses of real chemistry that potentially change the rules of schooling and the meaning of success in high school chemistry. They find themselves faced with a dilemma. On one hand, they know that the easiest, most familiar path to becoming a good student is through school chemistry. On the other hand, there is a nagging realization that success would be sweeter if they gained deeper understandings of real things in the real world. This process of deciding between school chemistry and what I have defined as real chemistry is very complex as students attempt to make sense of their world in and around high school. The glimpses of real substances, real atoms and molecules in everyday objects, and the related student decision process is examined in this section. This section begins with three general assertions that deal with student perspectives. First, they describe glimpses of real things (General Assertion 2-A) and understandings of real chemistry suggest to them that there is a more meaningful form of success (General Assertion 2-B). The third general assertion (General Assertion 2-C) states that both glimpses of real things and the realization of this more meaningful kind of success are constructed within the cultural spheres of influence. Following these three general assertions, I summarize in more specific detail what I found concerning student perspectives on real chemistry (Supporting Assertions 2-a and 2-b).

General Assertion 2-A. Some students get glimpses of chemistry as a means of comprehending the natural world

"There must be something awesome out there!"

When students describe real, wonderful atoms and molecules, they go beyond what is instructed, expected and required and move into personal discovery and invention--"that is invention of new terms in which to frame new kinds of hypotheses which embody the possibility of obtaining new forms of knowledge of things..." (Schwab, 1978b, p.336) --that is new to the individual learner. As Troy, one of the focus students, explained, although school chemistry doesn't require it, there is knowledge and comprehension possible that go beyond requirements and expectations: "You just study and do homework and you'll get an A, but you don't have to go beyond to the knowledge and comprehending stuff... . " On these occasions, they seem to inquire above and beyond the call of classroom duty. Troy further explained that "There are some students who learn it (knowledge and comprehending stuff), but they take it on themselves to learn it." For these focus students who are able to glimpse some of this theoretical, academic knowledge, knowing chemistry deeply is very real and yet elusive, related to imagination, creativity, and wonder. To these students, this level exists just out of reach. "I can't really grasp it." Yet they also seem to feel that if real chemical understandings were gained, their learning of chemistry would be much more meaningful and even more practical for the future. "Hence, theoretical or disciplined knowledge is practical knowledge virtual: a massive potential of capacities to do, to make, to alter, and to modify" (Schwab, 1978b, p.267). Our students talk of this academic disciplinary knowledge as more valuable in the long run but having little practical value in preparation for the next test or doing one's homework. "She bases her class on what you need to know for the tests. She doesn't expect us to know it any differently than that."

When students described their glimpses of invisible things in terms of wonder and awesome reality, it reminded me of how Waller (1967) describes a most significant event in the life of the learner. According to Waller, mental life develops by a series of "Aha moments" (p.105) or moments of insight.

> The little round glass backed with mercury is for the very young child something to pound with; a little later it is a mystery, and later yet a thing with which to play a prank upon a teacher; at one time it is a thing that is slightly disgraceful to be caught looking into; for an adult, it is just a pocket mirror (p.105).

To Waller, it is the difference in mentality which determines the different perspectives through which one sees and uses an object. Likewise some chemistry students get exciting, intriguing glimpses of real objects and events--real atoms and electrons in tables and chairs. This glimpses are almost moments of epiphany.

> ...Then felt I like some watcher of the skies
> When a new planet swims into his ken;
> Or like stout Cortez, when with eagle eyes
> He stared at the Pacific-- and all his men
> Looked at each other with a wild surmise--
> Silent, upon a peak in Darien.
>
> John Keats

Experiencing "something awesome out there" is an emotional event: "with wild surmise--silently" awestruck. There are many mundane, even trying moments to behold along the way, and there are frequent small moments of delight, but once in a long while all our patience and perseverance pays off with a moment of triumph which should hold us, the watchers, spell bound, awe struck, and speechless. The "watcher of the skies" watches patiently and intensely in anticipation for something great to happen. "Stout Cortez" through great hardship, struggle, and perseverance plodded on patiently until all of a sudden, there it was--The Pacific--too wonderful to believe.

Students' descriptions seem epiphanic and almost a spiritual awakening for them. Atoms and molecules and real things "moving around in tables and chairs" are almost too "awesome" to be explained by scientific means. This might be partly why they seem to consider thinking about these things as extra-classroom, outside the realm of mental requirements in school science. This isn't too far removed from the way many scientists treat ideas that are outside the predominant paradigm. Scientists delving into spiritual or supernatural forces to explain unexplainable things are sometimes called mavericks. In a recent profile of Fred Hoyle, Horgan (1995) briefly describes Hoyle "the maverick's" "quasi-steady state" theory and his ideas that life on earth might have arrived from outer space to give evolution a sudden (compared to the apparent age of the universe) start and goes on to say that Hoyle's universe is governed by purpose.

> He has long felt that natural selection alone could not account for the appearance and rapid evolution of life on the earth. Some supernatural intelligence must be directing the evolution of life and indeed of the entire cosmos--although to what end Hoyle does not know (p.47).

Physicists and astronomers have of course been struggling with ideas of an awesome reality since the beginning of science. In the context of this historical struggle, it doesn't seem so strange that thinking students would consider these almost impossible things to require a spiritual or metaphysical character. As Hoyle himself stated: "There are too many things that look accidental that are not" (p.47).

General Assertion 2-B. Glimpses of chemistry as a means of comprehending the natural world suggest a different, more meaningful kind of success

> "You can understand in order to do the tests...
> (but that is) not understanding for our well being."

Some students also describe a second understanding in chemistry that is not usually required but in many ways, in their perspectives, a higher calling. According to these students who glimpse real chemistry and talk of atoms and molecules moving and reacting, success could be much sweeter and much more meaningful. Students describe a success that would involve a different, more difficult knowing and understanding--a different way of knowing that involves deeper understandings, visions of real things and how they act and work in the real world. This success would involve knowing a chemistry that includes things that are unseen, mysterious, difficult, and involve struggles for understanding. It would involve understandings that exist in a different world of real chemistry that is encountered almost in spite of conventional schooling. As Andrea explained, students realize that if they go through high school without deep understandings of things, "...when we get to a high level (college), we will be screwed."

Under this other definition of success, students begin to develop a different, deeper and better way of knowing theoretical or disciplined chemistry. In our discussions of understanding at this level, success through the first understanding, understanding of school chemistry, loses some of its flavor. Some of these students explained in different ways that they are not really satisfied with merely doing the typical work that is required for a good grade. As Jeff said: "I want to learn something." When they talk like this, it reminded me that learning to understand can be practical in the long run and that students are often aware of this. "Its a bunch more satisfying to understand" (Carrie). As Schwab (1978) explains, the "pursuit of science--of systematic knowledge of the subject matter--is more practical than the practical" (p.266). "The practical" for Schwab stands in opposition to "the academic." Schwab, in "The Practical: Arts of the Eclectic," (Schwab, 1978, pp.322-364) the methods used to solve problems associated with complications of theory and practice are *arts* because they must be modified and adjusted to every situation. The practical, as opposed to theoretical academic, consists of "richly endowed and variable particulars" (p.324). The problem for those who wish to study them is to see them. "This is difficult because we normally see only what we are instructed to look for..." (p.324). It seems that the focus students are limited by the fact that they are instructed to see certain particulars and not others. Kurt explained this in his own way when he described how his teacher puts off what he considers deeper, more interesting questions about real things. He says his teacher's attitude is "don't bother me now" because "you don't need to know this now."

General Assertion 2-C. Both glimpses of chemistry as a means of comprehending the natural world and a realization of a success related to deeper understandings are constructed within the cultural spheres of influence

As several students explain, really comprehending events in the natural world is optional or even an individual endeavor loosely linked if at all to school chemistry. In addition, there are actually few incentives for learning real chemistry because most of the cultural influences reward the first kind of understanding--the understanding of school chemistry. As stated above, some students feel that it is really up to them to somehow muster intrinsic desire to go beyond the grade to learn "how things work, why they work, the way they are made and why they are made that way" (Kurt).

Even though Kurt and others describe this process of going beyond school chemistry as an individual endeavor, their inquiry and understandings are actually collective and socially formed. Danziger (1990), explains that a person's knowledge in the disciplines is always socially derived: "epistemic access to the world is always collective--it is always mediated by the social conditions under which groups of investigators work" (p.195). It is not merely a product of an individual's interaction with the natural world. Kurt struggles with ideas that interest him and deeper understandings in context. For example, our group conversations seemed to give him a chance to wonder freely with a receptive, interested and responding group of peers and me. During our conversations, he did not feel the frustration of being "put off" by a teacher with a different agenda and a time schedule. In this way, the social situation seemed to free him to play with ideas and the social interaction seemed to bring out the discovery of this wonderful world of real things. Most often when students wondered aloud in conversation groups it was quite clear to me that sense making evolved. My questions and probing certainly instigated discussions about ideas and subjects that often went beyond class expectations and requirements and in turn influenced student thinking. Students occasionally said that they appreciated "talking about these things" partly because their daily lives in chemistry seemed to be filled with more traditional tasks and performances. This is another example of positive peer pressure in that this sense making happens in the context of these peer gatherings, conversations, and cooperative efforts.

This student awareness of things beyond school chemistry experience seems to involve a passion for deeper understandings. Put this way, it is understandable that students consider success that involves these deeper understandings more potentially rewarding and valuable. Dewey (1916) explained that it is the passions and emotional dispositions which give study in the disciplines excitement and energy. Students of the discipline have a spark, an electricity, a playfulness, and a cultivation of imagination (Tom, 1984)-- a wonder and delight that comes from the soul. For example, Shulman (1986, p.13) describes a teacher whose subject matter is clothed with emotion and an active, vigorous interaction with ideas which are "grasped, probed, and comprehended by a teacher, who then must turn it about in his or her mind, seeing many sides of it" (p. 13). Students of this teacher at first witnesses of the grasping, probing, and comprehending, soon partake in the wonder and delight in the playing with ideas. It is the subject matter being rediscovered, reenacted, and resolved in the classroom. Cohen (1988) describes this process as intellectual exploration and embarkation on a guided tour from adventure to adventure. On this tour, the participants, wide-eyed and intrigued by inquiry and how all things fit together, are involved in an active and interactive relationship with both the subject matter and each other. The relationship is one of intellectual stresses and stretches, pushes and pulls on ideas. Wilson and Wineburg (1988) provide another example when they describe teaching as "artistry' and "choreography." They are talking about teaching but if we think about the students who are there with them, the disciplinary learning must be interesting and exciting. They explain that learning in these classrooms involves puzzle solving and a living, active, changing and growing endeavor. Optimally, the focus is on the substance of the discipline and curiosity-driven inquiry.

The examples given in the last paragraph are about "dazzling teachers" but they are also about students who catch the teacher's vision, cooperate and learn with them (Cohen, 1988). In my research, it is the students who began to wonder and delight in knowing deeper things of chemistry sometimes in spite of classroom instruction. When students talked about "something awesome out there," I was almost shocked by something different, something exciting, something causing electricity in the air. The image Jackson (1986)gives of students suddenly "seeing the light", waking up, becoming "uncorked", and seeing the beauty in the discovery of the world are described as miracles and thrills. Younger children have a wonder that comes quite naturally and it is insatiable in its need to be filled with experiences. It is wonderful to hold an image is of a child with a new discovery at his fingertip studying it, observing it, and then running to share it with someone she loves. This is not a conservative view of learning. When describing these passions, the focus students seem to be like naive, novice adventurers in the discipline, natural inquirers into the mysteries of the natural world (Cohen, 1988, p. 38).

But again, these experiences students described were rare, fleeting moments, small glimpses of real molecules and atoms among the day-to-day life in school chemistry. I order to understand why and how this works in socio-cultural context, I now turn to the main research questions, a description of the findings of this research and then on to the conclusions, challenges and implications.

Two Assertions that Support the Idea That Some Students Experience Real Chemistry

As explained above, the fifth cultural sphere represents the real chemistry as knowledge and action within the academic discipline before it is interpreted, transformed or affected by any of the other cultural spheres of influence. Some students try to go beyond conventional performances in attempts to understand real atoms, molecules and how they work in the real world. As we have seen, this is quite rare and seems to exist in fleeting moments of student awareness and interest. Some students know that deep conceptions of real things in chemistry do exist though, even though they sometimes seems quite removed and are seen quite dimly through the filters of the other cultural spheres of influence.

These students describe a struggle to understand the almost unimaginable, awesome things like real atoms and moving electrons in tables and chairs (their examples). In this way, they describe chemistry as almost mystical, very difficult to imagine and to understand. When they talked this way, they usually struggled with trying to visualize actual events in the natural world, the particulate nature of matter and how real things like tables and chairs can possibly contain invisible moving things and space between them. I was puzzled at first because sometimes these students would barely finish describing chemistry as very difficult and then they would begin to explain how easy it was to succeed in it. Gradually, it became quite clear that the apparent contradiction didn't really exist because they were making distinctions between a chemistry of conventional performances and another, deeper chemistry that was aside from or different from the first. The following assertions evolved as students described deep and awesome mysteries of real substances that were quite different from the chemistry of everyday, traditional performances.

- Supporting Assertion 2-a. Some students assert that understanding involves "seeing" and imagining real things or events in the natural world

Students often used sight or picture metaphors for describing their struggles to understand real chemistry. They describe "picturing" or "seeing" atoms, molecules and reactions in their minds, in a world of imagination and yet in real things like tables and chairs. Much of the student talk about the difficulties in visualizing the things of chemistry deal with the particulate level of matter, the essence of theoretical chemistry. We know that chemistry students have difficulty with concepts that deal with the particulate level (Williamson, 1995) and there have several studies of students' inability to visualize particulate behavior (Gabel, 1987; Larkin, 1983; Novick, 1981).

Several other focus students stated that although molecules and atoms must exist in the real world, they can't seem to picture or see electrons, protons, and other such things in their minds. Most of these students made distinctions between believing that these unseen, unimaginable things really exist and picturing or visualizing these things moving, reacting and behaving in the real world. The latter is much more difficult and harder to believe even though understandings that relate to them would seem better and more useful in life than simpler understandings. But the reality of it seems almost too amazing and too "out there." But this "out there" chemistry is wonderful to those who describe it and it inspires awe in them even though it is not really necessary for success in chemistry class.

This was evident even in the beginning of the school year when I asked students if chemistry is different in any way from other sciences they had experienced before. Several focus students immediately began to compare chemistry to biology. One possible reason is that biology was their most recent experience with school science and in the beginning of the school year, it was quite fresh in their memories. Most of them enjoyed and felt successful in biology but because this was in the beginning of the school year, they were just beginning to make judgments about chemistry. At this time, chemistry seemed different and a little uncertain in comparison. They did not seem quite sure that conventional school performances and traditional understandings that earned them success in biology would work in chemistry. This makes these comparisons to biology most intriguing if we focus on what students said about chemistry. They usually brought up the subject of biology during conversations about imagining and "seeing" atoms and molecules in real things. For example, students explained that one can see most animals and plants, touch them and understand how they interrelate and interact. They explained that knowing biology involves memorizing terms and concepts and this makes biology much more straightforward and rational. To them, atoms and subatomic particles seem far too removed from reality and the senses. They explained that the particulate nature of matter seems much more mysterious and difficult to study and to know than living things. It seemed to me that during these conversations, they were describing something very different and more difficult to understand than the familiar school performances and expectations in school chemistry. Later in the school year, they still struggled with "seeing" and imagining real things but they no longer seemed to wonder if conventional task performances would get them through chemistry as they did in biology.

- Supporting Assertion 2-b. Some students assert that understanding chemistry involves struggles with ideas

Students described a process of struggling with ideas, concepts, and problems that go beyond the traditional performances required for success in school chemistry. This seems congruent with much of the research and rhetoric about what is required for conceptual change (Posner, 1982; Strike, 1992), constructivism in general and deeper conceptual understandings in the chemistry discipline (Ausubel and Piaget are often cited in the Journal of Chemical Education). There is also evidence that students tend to rely on algorithmic problem solving instead of conceptual approaches that require theoretical understandings of underlying chemical principles and processes (Bodner, 1992; Fortman, 1993; Gabel, 1993; Nakhleh, 1993; Reif, 1983; Rowe, 1983). However, some focus students talked of something deeper than traditional strategies and performances associated with school chemistry--a success that is more rewarding than that won through school chemistry. Some students were talking about working hard for its own sake. In this sense, struggling with difficult things is a process of learning, developing and practicing a kind of work ethic they considered potentially useful in their later vocations. They seemed to think that working hard in their chosen vocation will help them succeed in their future careers. This described struggle was a form of job training or trial by fire. Once completed, one could say that "I did something difficult so now I am prepared for more difficult things." Conventional strategies performances can do this for a person if there is enough information to memorize or if assignments are long enough. Plodding on, making it through a thick stack of flash cards, setting different priorities, or giving up a basketball game to study for a test are certainly struggles and difficult things to do. However, others talked of different, valuable struggles with difficult ideas and concepts which relate to real chemistry instead of school chemistry. These students explained that thinking hard about mysterious things has lasting value. They explained that it is important and enjoyable to wonder about how things work, why they work, and to personally accept the challenges of learning deeper, more difficult things.

Summary of Findings, Part 3: A Student Dilemma
(Part 3 contains two general assertions)

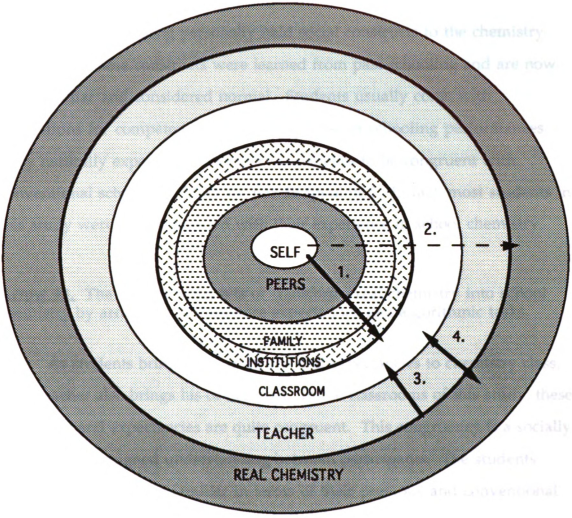
General Assertion 3-A. Some students face a decision between different chemistries, each with its own definition of success

I found that some students struggle to choose between school chemistry with its socio-culturally supported conventional performances on the one hand and the less supported real chemistry with its deeper understandings on the other. When they choose the success that is primarily linked to getting good grades in school chemistry, they act as conventional performers. Here, students are on familiar and safe ground because life in school chemistry involves only academic work they are comfortable with and very good at. Most students, their peers, parents and teachers are comfortable, pleased and safe with this decision and students can consider themselves good, successful students under this definition.

If they choose the other option, success as knowing and understanding real chemistry, they think and act quite differently. These are the students in search of deeper understandings of real and difficult things. This decision is quite infrequent and often tentative because, according to most students, there are few incentives in chemistry class to understand in deeper ways. Those who choose real chemistry consider it better to go beyond the requirements for good grades to something more rewarding.

General Assertion 3-B: Student decisions are made in socio-cultural context

An extension of the Cultural Spheres of Influence Model can help conceptualize and explain the research findings about student decisions regarding school chemistry and real chemistry. I first add three arrows to the model, #1, #2 and #3, to represent student meaning and action. Arrows #1 and #3 together represent the cooperative efforts of students and teachers in shaping life in school chemistry in the classroom. Arrow #2 represents those glimpses of real chemistry that occur almost in spite of what goes on in the classroom. Each of these arrows are described in greater detail below. Arrow #4 represents a recommendation and will be discussed in the Reflections section at the end of this chapter. Arrow #4 represents what should be; what the teacher should do to bring real chemistry into student experience.



KEY TO ARROWS:
1. Students bring constructs to chemistry classroom.
2. A few students glimpse real chemistry.
3. The teacher translates chemistry into school chemistry.
4. The teacher mediates students & real chemistry.

CULTURAL SPHERES OF INFLUENCE MODEL

Figure 5. Student Meaning and Action

Arrow #1. Students bring their own history of success and constructs of schooling to chemistry class.

Individuals bring personally held social constructs to the chemistry classroom. These constructs were learned from past schooling and are now very familiar and considered normal. Students usually come with reputations for competence and with expertise in schooling performances. They naturally expect their chemistry experience to be congruent with conventional schooling. Most are not disappointed. In fact, most students in this study were highly satisfied with their experience in school chemistry.

Arrow #3. The teacher interprets or transforms real chemistry into school chemistry by arranging performance expectations and algorithmic tasks.

As students bring their constructs and expectancies to chemistry class, their teacher also brings his or her own. In the classrooms of this study, these constructs and expectancies are quite congruent. This congruency is a socially derived and designed understanding between participants. The students expect chemistry to be familiar in terms of their previous and conventional performances and the teacher basically gives them what they expect. The result is school chemistry, a cooperative effort and socially constructed phenomenon.

One possible reason it comes so naturally to the teacher is that it is likely the same chemistry the teacher learned in high school and in college chemistry classes. Teachers naturally tend to teach the chemistry they were taught and have come to know (NCRTL, 1994, p.26). Even if the teacher knows chemistry in deeper ways, traditions of schooling are so strong, cultural influences so influential that what they actually bring to the classroom is quite conventional and familiar. Most of the participants seem quite satisfied, even happy with this arrangement. In requiring and rewarding conventional school performances it is comfortable and non-threatening, and is not unduly difficult. The teachers in this study make expectations clear, pave the way for student success with school chemistry, and are understandably known for their good teaching. They are very good at producing good, successful and satisfied students of school chemistry.

Arrow #2. Conflict is apparent when students get visions of real chemistry.

As discussed above, although most of these students are quite satisfied with their success in school chemistry, some get alluring, disturbing glimpses of something better. Arrow #2 is a dashed line to signify the character of these encounters with these deeper and better understandings. The students who have had this vision of something better, know that somehow success would be sweeter if deeper understandings of real things and their transformations were somehow achieved. Personal conflict occurs when the student becomes aware of a way of knowing chemistry that somehow goes beyond what is required for a good grade; it is considered "extra credit," above and beyond the call of duty in chemistry classroom. On the one hand, there is the success of school chemistry that is earned by paying attention, taking tests, doing lab reports and assignments well. On the other hand, there is an almost mysterious chemistry that perhaps would help them in their future or even help them understand the real world better, lurking somewhere, as one student put it, for a select few who "understand", who "like thinking about this kind of stuff", or are not satisfied with just doing what it takes to get good grades.

Conclusion

If we listen to the media, everyday conversations, and read much of the educational literature about the condition of American education we are tempted to think schools are just filled with lazy students subject to negative peer pressure and ineffective teachers who don't know their stuff. Instead, I found intelligent young men and women who do their school work willingly, benefit from positive peer pressure and learn from teachers who not only know their chemistry very well, but also teach it effectively. These students take pride in their accomplishments and value their reputations as good students. I also found that they make rational, intelligent decisions that make perfect sense to them in context. But the school chemistry they describe, that which is supported so well by the socio-cultural influences and the social structure around them, is really a surrogate form of chemistry which will not make them scientifically literate. Because a surrogate form of chemistry is learned, so too is the related success a surrogate form. These students explained this very well. School chemistry is not really about science literacy, it is about traditional strategies and task performances that become a rite of passage. In school chemistry, the goal, the prize to win, is a good grade on a transcript.

However the same positive, well established socio-cultural support system is perhaps our best source of hope for improving chemistry education in the future. This same complex system which so effectively supports students in their efforts and investments in school chemistry has the potential for supporting real chemistry equally well. The same students who described school chemistry to me also described what they consider a higher calling, a chemistry that would involve deeper understandings of real things and their transformations that are much closer to the substantive content and process in the academic discipline. They considered this real chemistry "something awesome" which fills them with wonder. They spoke of it with affect and passion and told me, sometimes indirectly, sometimes explicitly, that this is what they really wanted to count for success. In their perspective, comprehending real events in the natural world should be required in schools if only it were possible, if it would only make sense in their world to pursue it. School chemistry could become real chemistry and could contribute to real scientific literacy if the incentives, expectancies and norms of the cultural milieu supported it. This potentiality naturally leads us to consider how we might change American high schools so that real chemistry learning is supported and encouraged.

Reflections

The vision of teaching represented by Arrow #4 of the Cultural Spheres of Influence Model is different from traditional transformations or interpretations of real chemistry into school chemistry that is represented by Arrow #3. The arrow is double-ended in order to suggest a mediation metaphor for teaching (Lakoff, 1980, Roth, 1993). A teacher-mediator takes an intermediate position between two very different worlds both of which the mediator understands deeply. Understandings between these worlds are not easily facilitated or gained, neither are they often rewarded in conventional schooling. Mediation of scientific knowledge construction with student constructs of schooling is an extremely complicated endeavor (Grimellini-Tomasini, 1995). Whether or not real chemistry is encountered in the classroom will depend on whether the teacher is able to bring this world into the experience of the student. If mediation is successful, an individual student would increasingly become a student of the discipline able to quite independently (of mediation) culture and nourish his/her relationship with the real thing instead of a school version of it. Herein lies challenges for the educational community. How can we provide the teachers who can mediate and then empower them to do so? A mediator would bring the student closer in personal relationship with real chemistry instead of a translated or transformed school version of it. Reshaping teacher education is a viable recommendation provided, as my research shows, learning real chemistry makes sense to students in context.

Implications and Recommendations: For Educational Researchers, Teacher Educators, Teachers and Their Students

This research has been an attempt to hear student voices and to understand their perspectives of success in high school chemistry within the context of school culture. One of the most significant findings of this research is that there is incredibly powerful positive peer pressure, nested in other cultural influences, that supports good students in the business of doing school chemistry well, as efficiently and painlessly as possible, and earning a good grade. They know what is expected of them, do it, and maintain their good- student reputations. The gamesmanship of doing school their way usually makes perfect sense in context of their lives. On the other hand, some more thoughtful students are faced with the realization there is "something awesome out there" in the real world of real things that would challenge them on a different level of understanding and rather unique ways of comprehending the events of the natural world. This realization presents them with a paradox. Grand thoughts of unseen, almost unimaginable things in real chemistry make success in the status quo with its school chemistry lose some of its flavor and meaning.

Reflecting on the results of this research, I believe it is possible to provide more positive support, better reward systems and to turn the powerful positive peer pressure, the first and most significant sphere if influence identified here, so that students and their teachers are encouraged to seek out real chemistry understandings. This is a view filled with optimism for chemical education in American high schools. However, the task is complicated, multifaceted, difficult, and far reaching.

Implications for Educational Researchers

It is time to realize again that it is the actual teachers in actual classrooms with their students who will either make or break any efforts to significantly improve chemistry education in the future (McLaughlin, 1976; Weiss, 1989; Welch, 1979). There has been a tendency for the educational community to blame the teachers for opting out of any significant and far reaching reforms to improve education in America (NRC, 1990; Ravitch, 1984; Silberman, 1970; Stake, 1978). Blaming the teachers is far too simple an explanation for the resilience of the status quo in science education. The character of teaching and learning depends on the nature of the cooperative efforts (or lack of it) of all the players in schools and in school communities. This makes teaching and learning a socio-cultural phenomenon. Because of this, educational researchers should carefully examine the socio-cultural context in and around American schools in order to better understand how the players there make sense of their situations. How can educational research help teachers, with their administrations, change the rules, rewards and expectancies of school learning? How can a common-sense psychology that includes the often difficult struggles for deeper understandings of real chemistry be developed in American schools? How can the results of research help the communities, teachers, parents, and peers reshape their influence in order to support the learning of real chemistry for the 21st century? It is unrealistic to think that the current reform initiatives in science education will change things without the cooperation and support of teachers, students and the other cultural spheres of influences. Therefore, we need to understand the cultural milieu and the individual self nested in that milieu much better than we do now. For example, I found that the peer cultural influence in these schools strongly supports good students in their efforts to "understand" school chemistry and to be successful. It seems clear that if this important positive peer influence could support real chemistry instead, not only will teachers will be challenged to reform chemistry education, but students, their friends and their parents will demand it. My focus students described understandings of the awesome reality as a higher calling that would make success much more meaningful. They said they would prefer it now and in preparation for the future if there were only social incentives and immediate rewards.

Therefore, because the viability of efforts to improve science education in America depends on these socio-cultural relationships, there is a great need for more research into the voices of high school students and their teachers in order to find out more about the culture of success and the culture of schools and schooling. We need to know more about why and how the decisions they make in daily life make sense to them. For example, there is much more to learn about the socio-cultural barriers that stand firmly in the way of teachers like Jane Hatfield in her efforts to get students to think deeply about atoms and molecules and how they behave in real things.

In addition to hearing more of the voices of students like those in this study, we also need to know more about other groups and subgroups in similar schools. How do non-college bound students make sense of self within their cultural spheres of influence and how should the Cultural Spheres of Influence Model change to fit their situations? What are their views of science and their conceptions of success? For a different set of perspectives, are chemistry student attitudes, beliefs and spheres of influence different in different schools in different neighborhoods? How should the Cultural Spheres of Influence Model be adapted or changed to represent the socio-cultural structure in different places and times?

In addition, several of the students in this study; Kurt, Paul, Jeff, Jessie, and others were understandably very interested in use value of what they learned. What long-range value, along with having a good grade appear on one's transcript, does chemistry have for artists and musicians like Troy and Trent? For a poet like Andrea? What can a future engineer like Jeff learn in high school chemistry that will help him in the future? How can we convince Jeff that spending his intellectual energies and his time on learning difficult things like chemistry is important when it is difficult for him to take his mind off his children and the pressures of his family life? We need to get better at answering these questions in ways that are honest, which cut to the point and have the potential of convincing students like those in this study. We are good at saying that subjects like chemistry are important in themselves and important in providing a liberal education. We are not very good at forming or articulating honest reasons or incentives for learning difficult things like real chemistry--those which will convince our students.

Another suggestion for further research is to learn more about what "understanding" in the disciplines means in the context of schooling and school learning. Although all teachers claim to teach for understanding, this research clearly shows that there are many different meanings and uses for the term that fit different situations and contexts. Educational research can help us better understand understanding in context. In the beginning of this thesis, Gandalf offers an adventure but finds it's very difficult to find any takers in these parts. Bilbo Baggins replies: "I think so-- in these parts! We are plain quiet folk and have no use for adventures, nasty, disturbing, uncomfortable things! Make you late for dinner! I can't think what anybody sees in them"(Tolkein, 1966, p.18). Learning can and should be adventurous. However, adventurous learning is potentially disturbing and uncomfortable because the search for deeper understandings has no end. A personal search for deeper understandings not only identifies the often disturbing limits of what we think we know about the world, but also points us to the complexity of that aspect of the world. When we reach this stage, we are much closer to the understandings we seek.

> At root, understanding is a true paradox: the more one learns about some aspect of the world, the more aware one is likely to become of the depth of one's ignorance of it. That does not necessarily mean that as a consequence of learning, one's understanding actually decreases, but simply that one's appreciation of the complexity of that aspect of the world is likely to increase--which may be, after all, a better understanding of a fundamental sort (Nickerson, 1985)

There are no pat answers and no final point when one can say "Ah, I've got it." When is one's understanding of the atomic structure of matter good enough or complete enough? Teaching for understanding therefore focuses our attentions on this paradox and messes with the safe and secure ways of doing school. Adventurous science learning is therefore uncertain and risky, and it might shake conceptions of self in relation to the cultural influences around us. On the other hand, it is also an adventure filled with wonder, delight and meaningful successes.

Implications for Teacher Educators: A call for teacher education in a new epistemology.

This set of implications presents a need to examine ways to develop teacher education programs which will give prospective teachers a working knowledge of real chemistry. Shulman (1987) suggests that if the conception of pedagogical reasoning places emphasis on the intellectual basis for teaching performance rather on their performance behavior, "an emphasis on pedagogical content knowledge would permeate the teacher preparation curriculum."(p.20) However, both prospective and practicing teachers often have little knowledge of the history and philosophy of science because they have very few opportunities to study these fields. Therefore, it is very difficult for teacher educators and their students to concentrate on the intellectual basis for teaching when prospective teachers have deficiencies or limitations in how they experience and know their discipline. In particular, prospective teachers often have a distorted understanding of the nature of science because of several deficiencies in their academic preparation. By the time they graduate and begin to teach, they have little knowledge of the way scientific knowledge is developed and validated. Because of the disconnected, lifeless nature of the science they know, they also are very limited in their ability to apply their knowledge to the real world in which they live and relate. It is understandable that high school students are presented with the school science their teachers have come to know and understand: science that is facts and procedures to memorize and then recall on examinations. This chemistry, when taught as well as the teachers in this study teach it, is familiar, expected, quite safe, certain, viable and self perpetuating. It is also not necessarily interesting, enjoyable, practical, useful or important. As a consequence, as we have seen above, the study of chemistry often becomes symbolic, the tools self referential, and processes ritualistic.

Most of the social pressures these students feel support safe and familiar school chemistry. Institutions, in many ways make it clear to students that having chemistry on one's transcript and getting a good grade are expected. Parents ask them what grades they earn instead of what they are learning. Teachers set standards for success by establishing rules, expectations and procedures in order to provide student pathways for success. For practical reasons, they often focus on work ethic and getting things in on time instead of requiring more uncertain, often messy, and more difficult deeper understandings of real chemistry. Students support each other and describe their responsibility to meet set standards for success. "I'm good at being a robot you know." Good students do what is expected of them. Most of the social and cultural incentives are for things to run smoothly, efficiently, and traditionally.

One viable way to break this cycle, is to prepare of a new generation of science teachers. It is not enough to change the high school curriculum or produce more skillful pedagogues. Teachers most often know the chemistry they teach and they teach it very well. However, in order for teachers to teach a different and ideal chemistry, they first need to come to know their subject differently.

Chemistry teachers have come to know science gradually throughout their own educational history. Through their elementary, middle and high school years, they have learned science with their peers from teachers who also taught as they were taught. Since conceptions of science develop gradually through the years of education, the preparation of teachers should be considered a lifelong process beginning at a very young age through a more formal education in the discipline. In other words, we need a more holistic, long-range view of science instruction for all throughout the educational continuum in order to produce the best teachers for the future. The logical and useful place to start is in the academic preparation of the next generation of science teachers who will in turn, bring a different science into the schools.

At present, the greatest deficiencies in science education lie at the philosophical or epistemological levels. Among other deficiencies in the academic preparation of science teachers, is a lack of study of the nature of science and the fact that students never develop a personal philosophy of science. Even most secondary science teachers who have a vocabulary of facts, terms and skills lack the connected, integrated, inspired understandings needed to make their discipline come alive for themselves and their students. According to the new American Association for the Advancement of Science (Project 2061) blueprint for teacher education (NCRTL, 1994), future science teachers need to know science and their discipline in deeper ways than they typically do. According to this blueprint, the scientifically literate teacher (or anyone else) is one who (1) has integrated knowledge of the different disciplines of science, mathematics, and technology, (2) has a deep conceptual understanding of scientific concepts and ideas, and (3) appreciates that both the knowledge and the practice of science are dynamic and constructed (p.3). All of these characteristics and abilities involve deep understandings of the nature of science and conceptual understandings of the history and social construction of scientific knowledge; a different epistemology.

Much more work needs to be done in developing teacher education programs which include the study of the philosophy and the history of science, in the social development of scientific knowledge, and more generally in the nature of science and the scientific enterprise. Therefore, I suggest that an academic major for prospective secondary chemistry teachers should include at least one course in each of the following areas:

1) the philosophy of science

2) the history of science and the development of scientific methods

3) the social construction of scientific knowledge which includes a study of socio-cultural perspectives of science.

One of the more important goals should be that the individual develops a personal relationship with a personal way of knowing the discipline. Teachers need to own real chemistry themselves, to practice it with passion and wonder, and to appreciate continual inquiry, discovery and learning. Teachers need an epistemology which serves as an underpinning framework which flavors and feeds every aspect of their teaching. Only then will they with their students be challenged and able to lift their eyes off paper and focus on real, inspired scientific understandings.

Although teachers, in order to teach a different and ideal chemistry, first need to come to know their subject differently, they also need to teach their chemistry to real students in the real world of schools. Although national policy initiatives consistently call for educating *ALL* students equally, it is becoming increasingly difficult achieve equity in a climate of diversity and cultural complexity. Consequently, teacher education programs should also concentrate on the socio-cultural issues as they apply to high schools and specifically to science and science education. Teachers need to know their students better in terms of cultural norms, expectancies and ways of knowing the world. They need to understand family expectations and values, ethnicity, gender issues, and other levels of culture.

For these reasons, teacher education programs should also require at least one course that explores issues of society and culture that present themselves in schools and other social institutions in the United States. It should include in-depth readings and discussions that challenge prospective high school science teachers to examine different and strange (to them) cultures and ways of making sense of the world. It should include an intense field component that requires hearing the voices of high school students and their teachers in places and contexts like where they might teach some day. Especially if this course includes this field component, students can learn experientially about how individuals make sense of the world around them. They should also learn about the increasing human diversity, multiethnicity and multiculturalism that increasingly characterizes American schools and further complicates the social structure of schools. As explained above, they need at least "150 ways of knowing" (Wilson, 1987) every day. Teachers need to learn to find efficient and appropriate ways of knowing how individuals make sense of their world and how they will likely respond to the chemistry teacher's efforts to teach. Then, they need to think hard about potential curricular solutions to the social problems and complexities in schools. What are appropriate and empowering institutional responses to cultural diversity and what are some current and past efforts to reshape and improve education to better meet the needs of American citizens?

It seems impossible to attend to so many different ways of knowing and yet "[m]elding these different domains of knowledge is at the heart of teaching" (McDiarmid, Ball, & Anderson, 1989). Shulman and others speak to the complexity of teaching and have called what teachers need to know and be able to do "pedagogical content knowledge"(Shulman, 1986, 1987; Wilson, 1987, 1988). Shulman (1987) defines this knowledge as the kinds of knowledge and skill needed to teach difficult subjects well. "It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction"(p.8). He also states that pedagogical content knowledge is the category of knowledge most likely to distinguish the knowledge of the expert in the discipline, the content specialist, with that of the pedagogue. According to this perspective, the teacher who owns this pedagogical content knowledge is able to accurately transform what they know about their discipline, (and what content specialists know) into "something meaningful to students" (Prawat, 1989). In fact, a teacher really needs to be able to translate the subject matter for each individual student, so that if he or she teaches 150 different students in one day's work, in effect there are 150 translations, 150 different and required ways of knowing one's subject (Wilson, 1987).

My research, in identifying the complexity and power of the cultural milieu and students' positioning of self, provides another level of complexity to what is usually considered "pedagogical content knowledge." It is quite clear that under the incredibly powerful influence of the cultural milieu, the translation of subject matter into "something meaningful to students" too often results in the translation of real chemistry into school chemistry (Arrow #3 of the Cultural Spheres of Influence Model). Doing chemistry too often becomes conventional school performance because it seems quite safe, certain and familiar to teachers and their students. Therefore, it is too simple to say that teachers need the knowledge to transform subject matter. Instead, I have suggested that teachers mediate the relationship between their students and the real discipline. Mediation seems a better metaphor for what is needed to address the paradox presented when conventional school performances conflict with "something awesome out there." I believe the substance of the chemistry discipline can be experienced in an honest form by the high school student without the teacher translating it into something less than substantive even though it might be more familiar and safe for students and teachers (Schwab, 1964, 1978a, 1978b).

Because of the age in which we live, the world is getting metaphorically smaller, the students of today will eventually relate to others in this world in ways that are hard for us to imagine. Prospective teachers should also think more globally and examine the attitudes, values, and beliefs of different young people in different cultural settings and backgrounds. What is the character of cultural influences and barriers as they form in the social institutions of other countries? How do these cultural barriers and areas of cultural dissonance in relation to schooling affect the teacher of chemistry in other places?

Too often, prospective teachers are sent out into the complex world of high schools with very little preparation and few experientially-derived conceptions of the diversity and different cultural spheres of influence they will meet there let alone how to deal appropriately and effectively with them. It is understandable why so many of them, in spite of the optimism and enthusiasm of youth, soon retreat into the familiar and safe world of tradition, conventional performances of school chemistry.

Implications for Chemistry Teachers and Their Students

There is much for us, as teachers, to learn from this study of the culture of success in high school chemistry for improving our own practice and for school learning in the disciplines in general. It is clear that as we work within the institutional and socio-cultural context of our schools, we have significant and powerful influence with our students. I have described the teacher's influence on at least two levels: as ultimately in control of the institutional requirements and expectations necessary for attaining a grade; and in control of the subject matter, the information and processes presented as chemistry. The wide range of activities we do are essentially designed to help others understand. We explain, ask questions, assign homework, create hands-on experiences in the laboratory, and attempt to accurately and fairly assess student understanding. But we are not alone in the classroom. Our students actively participate in determining the character of their learning experience. Instead of passive receivers, students are active agents in their own learning as they position self and help construct their experiences in high school. Because we and our students bring socially constructed expectations to chemistry class, things run more smoothly, with less conflict and misunderstandings, when our constructs and expectancies are not only clearly understood, but also congruent with what it traditionally means to do school. Everyone seems happy most of the time in school chemistry because it meets most of our expectations.

It is therefore understandable that traditional schooling is persistent and resistant to change. By the time students reach a course like chemistry, they are good at doing school and have developed deeply entrenched expectations of what school and school work should be like. They are quite content with the way things are. And, as my research shows so clearly, there is a well-seated socio-cultural support system around chemistry students that includes strong positive peer pressures to perform, succeed, and to maintain their reputations as good students. Many chemistry teachers are also quite content with the way things are. Traditional schooling is the way it is for good reasons. It seems to provide a common ground in the midst of diversity and complexity of individual needs and desires. It keeps everyone happy and everything running smoothly.

It is important to notice that only when talking about the deeper, "awesome reality" did the students become emotionally engaged. During these conversations, chemical concepts and the atomic structure of matter came alive for them. In an almost spiritual way, they described how it would be exciting to really think hard and try to understand what was happening in real things around them. When they spoke of these things, they explained that deeper understandings would be better because they would be more practical now and in the long run. They explained that if they really understood, they would be able to transfer their understandings in meaningful ways to other subjects, daily life, and also to college chemistry. Instead, most of the time, for practical reasons they just went about the business of doing what it takes to get a good grade in what they described as rather dull and lifeless daily work. They were actually quite satisfied with doing school because this is what good, college-bound students do. Everyone--peers, parents, and others--supported them and exerted positive pressure to get good grades as efficiently as possible. Students knew they were not really learning to understand science and that the value their work held was quite temporal and linked only to their present and future school lives. They explained that what they learned would have little value in the real world.

We, and the chemistry teachers before us, have transformed or translated our subject, real chemistry, into more meaningful or understandable forms for our students (Prawatt, 1989, p.319-320). In fact, we have been taught that it is important to translate subject matter for each individual student so that each requires of us, a different way of knowing one's subject (Wilson, 1987). However, in spite of these good intentions, we too often try to find a common ground in this diversity and end up with a surrogate form of the real thing (Barrow, 1991). School chemistry lacks life and doesn't require understandings of difficult concepts and ideas. Although we can identify practical reasons why this has come about, in truth, a concern for practicality should push us toward teaching real chemistry. It can take some of the mystery out of daily things like atmospheric ozone, a burning marshmallow, a rusting car, efficiency ratings on a water heater, and how plants make their own food. Also, deep understandings of real chemical concepts form a solid foundation for transferring knowledge to other subjects, other ways of thinking, and real-world applications as well as further study in the academic discipline.

Why is this education, the kind that got most of us to where we are now, not good enough for our students? First of all it is not good enough because it is not the best we have to offer. There is a serious ethical and moral issue involved in telling our students it is important that they should learn and know chemistry and then not offer them the real thing. Second, it is not good enough because it is essentially a waste of their time. It is not rewarding and has no use value now or in the future except for preparing them to perform other equally conventional school tasks. It doesn't help take the mystery out of what happens in real life and it doesn't help them understand how their world works. It is not good enough because school chemistry does not expect or require deep understandings that are so important in transferring knowledge to other subjects, real-life applications and further study in the discipline. It is not good enough because it does not represent chemistry as one of the great creations of the human minds. Chemistry, as we know it today is the product of a long history of scientific discovery and inspired human genius so that it has become a wonderful, efficient and practical way of comprehending the natural world. Finally, it isn't good enough because they are not challenged to develop a sense of wonder, curiosity, inquiry, quantitative reasoning, communication and the other habits of mind so important in scientific literacy.

Before we try to change things and bring the real academic discipline into our classrooms, we need to seriously rethink our own knowledge and relationship with the discipline. It is probably safe to say that the chemistry most of us have come to know in our preparation to teach is more like the school chemistry my focus students describe than real, authentic chemistry. Our high school and college chemistry courses were probably quite similar to the ones we teach ourselves. Life experience might have pushed us beyond this, but few of us have done academic research in chemistry or have experience in industry beyond work as technicians. We are tempted to say if it was good enough for us and it got us where we are now, it is good enough for our students. The first challenge in making chemistry more real, rewarding and practical for our students is to confront this question head-on for ourselves. Unless we have a clear sense of what chemistry is and should be in our own lives and minds, change will be impossible. We need changes of mind and different ways of knowing our discipline that inevitably will cause us to change our practice. Each of us should honestly and regularly examine our own understandings of chemistry and our own goals as chemistry teachers. Is real chemistry alive in our own minds and in our practice? Are we thinking about the reality of atoms, molecules and molecular transformations when we teach about moles and periodicity? In what ways is science alive, functional and important for us in our everyday lives? How do we "practice" chemical understandings in daily life? What scientific habits of mind have we developed as individuals and as professionals? Are we active and excited about our own continual learning in the discipline?

Change is always difficult, always time consuming and guaranteed to upset our lives and the lives of our students. From my personal experience, when I tried to change my own conceptions of teaching and learning in the sciences, I felt alone, beleaguered and at risk. This is at least in part because most of the social pressures and professional rewards for me as teacher were linked to conventional school performances and traditional schooling. It is easy for me to be empathic with other teachers who are hesitant to push on conventional conceptions of schooling and reluctant to expose students to the excitement and challenges of real chemistry. There are personal, professional and psychological risks with grass-roots change that challenge the norm--change that takes time and energy and can threaten the otherwise orderly "doing of school." Efforts to change take time, sap our energy and may even endanger our professional security. Parents and administrators become distressed when students who always have accomplished school tasks easily are forced to grapple with hard ideas and find the process difficult and disconcerting. Parents question why the chemistry they had when they were in high school is no longer good enough today. Change requires us to educate administrations and parents who want the best for students but no longer understand what is going on in our classroom.

It is clear that we can't just place chemistry as a means of comprehending the natural world in front of students and expect them to rise to the challenge automatically. The incentives and rewards for conventional schooling are too established and too deeply entrenched. We need to address the dilemma students face when conventional school performances conflict with "something awesome out there." Students need the clear realization that chemistry is a viable means of understanding the natural world. That it is a wonderful creation of brilliant and inspired human minds throughout centuries of scientific development. Remember that the wonder and delight in this awesome reality came in student voices and their stories. Those who talked this way explained that they were willing and able to struggle for deeper understandings if only there were significant incentives and if their culture would support it. The cultural influence of peers offers strong positive support for success in conventional school chemistry. We must find ways to turn this positive peer pressure to support the learning of real chemistry instead. We must find the inspiration to improve our own relationship to our discipline along with the courage and wisdom to make the authentic learning of chemistry make sense in the classroom, school, and life.

There are also implications for the chemistry students of these classroom reformers. Students are active agents in their own learning experiences in chemistry and in understanding difficult things. They do school and some strive for deep understandings sometimes in spite of the social pressures around them. Using cues and values of their teacher to appropriate acceptable behavior and expectations, they will respond to the teacher of real chemistry if given the chance. But student response and cooperation is necessary if any significant changes are to be made in chemical education. The message from the literature is clear that good, revolutionary teachers need the support and active cooperation of good students who are willing and strong enough to stand alone and become leaders among peers in efforts to learn real chemistry. Standing alone because this will involve standing up against peer pressure and all the other spheres of influence which so effectively support school chemistry. One of the most important lessons of this research is that these students experience very significant and powerful positive peer pressure for success in school. This same positive pressure could and should support real chemistry learning instead of school chemistry. It is a shame that trying hard and struggling with difficult ideas is such a lonely endeavor in today's schools. Good students need to support their peers in their efforts to learn. Students like Troy, Trent, Kyrsten and Kurt-- who see the value and excitement in the wonder and awesomeness in real things need the freedom and positive support to pursue these things. The alternative, as Jeff explains, is the monotony of the same daily plodding on through requirements and meaningless assignments and daily work.

Exemplary teachers who try to make improvements in their own practice teach in real high schools with real students and real cultural spheres of influence. Students, in their academic lives are often like Bilbo--"plain quiet folk and have no use for adventures, nasty, disturbing, uncomfortable things!" Adventurous learning in chemistry classes is often a hard sell for teachers to make. The student perspectives examined in this research suggest that there are significant, extremely powerful and varied cultural influences which support, reward and enforce the status quo. The cultural milieu is so powerful in participant lives that any efforts for change at the classroom level will be held hostage to it. It will not do to deplore lazy students and/or shallow and ignorant teachers. As the participants in this study were, chemistry students and their teachers are intelligent people making sensible decisions. Therefore, considering the nature of these cultural influences and participant perspectives of them is a great challenge which must be undertaken. This challenge is to further examine the socio-cultural influences at work in schools and develop ways to encourage a new ethos and a new student epistemology so that real chemistry, indeed real learning in all the disciplines is encouraged, rewarded, and eventually can become the cultural norm. It is time for teachers in classrooms to more carefully examine the cultural context in and around their own school in order to understand how to change the rules, rewards and expectancies that are the norm there. The high school should be a learning place for students and teachers as they, together, try to learn difficult things (Marshall, 1990; McRobbie, 1995b). "Doing school," the patterns of conventional interactions in classrooms have a long and deep history. How can a common sense psychology that includes struggles for deeper understandings of real chemistry be developed in a school? The interactions and expectations of communities, teachers, parents, peers --all the other spheres of influence--will have to be significantly reshaped if they are to support the learning of real chemistry.

BIBLIOGRAPHY

Bibliography

AAAS (1989). Science for all Americans: A project 2061 report on literacy goals in science, mathematics, and technology. Washington D.C.: American Association for the Advancement of Science.

Abraham, M.R. (1994). A cross-age study of the understanding of five chemistry concepts. Journal of Research in Science Teaching, 31 (2), 147-165.

Allen, B. (1978). Personal experience narratives: Use and meaning in interaction. Folklore and Methodology Studies, 2, 5-7.

Atkinson, J.W. (1964). An introduction to motivation. Princeton, NJ: Van Nostrand.

Ausubel, D.P. ; Novak, J.D., J.D.; Hanesian, H. (1978). Educational psychology: A cognitive view. (2nd. ed.). New York: Holt, Rinehart, & Winston.

Barrow, G.M. (1991). Intellectual integrity or mental servility. Journal of Chemical Education, 68 (6), 449-453.

Belenky, M.F.; Clinchy, B.M.; Goldberger, N.R. & Tarule, J.M. (1986). Women's ways of knowing: The development of self, voice and mind. New York: Basic Books, Inc. Publishers.

Bodner, G. (1992). Why changing the curriculum may not be enough. Journal of Chemical Education, 69 (3), 186-190.

Brickhouse, N.W. (1989). The teaching of the philosophy of science in secondary classrooms: Case studies of teachers' personal theories. International Journal of Science Education, 11 (4), 437-449.

Brickhouse, N.W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. Journal of Teacher Education, 41 (3), 53-62.

Brickhouse, N.W. (1992a). Bringing in the outsiders: Reshaping the sciences of the future. Educational Development: University of Delaware.

Brickhouse, N.W. (1992b). The beginning science teacher: Classroom narratives of convictions and constraints. Journal of Research in Science Teaching, 29 (5), 471-485.

Bruner, J.S. (1960). The process of education. Cambridge, MA: Harvard University Press.

Bruner, J.S. (1966). Toward a theory of instruction. Cambridge, MA: Harvard University Press.

Bruner, J.S. (1986). Actual minds, possible worlds. Cambridge, MA: Harvard University Press.

Bruner, J.S. (1990). Acts of meaning. Cambridge, Mass: Harvard University Press.

Camitta, M. (1990). Gender and method in folklore fieldwork. Southern Folklore, 47 (1), 21-31.

Clark, R.M. (1983). Family life and school achievement: Why poor black children succeed or fail. Chicago: The University of Chicago Press.

Cohen, D.K. (1988). Teaching practice: Plus ça change. Issue Paper No. 88-33 National Center for Research in Teacher Education: East Lansing

Coleman, J.S. & Hoffer, T. (1987). Public and private schools: The impact of communities. New York: Basic Books.

Cusick, P.A. (1973). Inside high school: The students' world. New York: Holt, Rinehart, & Winston.

Cusick, P.A. (1983). The egalitarian ideal and the American high school. New York: Longman.

Cusick, P.A. (1992). The educational system: Its nature and logic. New York: McGraw Hill.

Danziger, K. (1990). Constructing the subject: Historical origins of psychological research. Cambridge: Cambridge University Press.

Delgado-Gaitan, C. (1988). The value of conformity: Learning to stay in school. Anthropology and Education Quarterly, 19, 354-379.

Dewey, J. (1916). Democracy and Education. New York: The Free Press.

Dewey, J. (1938). Experience and Education. New York: Collier.

Doyle, W. (1980). Student mediation responses in teaching effectiveness. Denton, Texas: North Texas State University.

Dweck, C.S. (1986). Motivational processes affecting learning. American Psychologist., 41 (10), 1040-1048.

Ealy, J. & Ealy, J. (1994). View from my classroom: Frustration + cleverness ≠ learning. Journal of Chemical Education, 71 (2), 148-149.

Edwards, B. (1979). Drawing on the right side of the brain. Los Angeles: Tarcher.

Erickson, F. (1982). Taught cognitive learning in its immediate environments: A neglected topic in the anthropology of education. Anthropology & Education Quarterly. XIII, (3), 149-179.

Erickson, F. (1986). Qualitative Methods in Research on Teaching. In M. Wittrock (Ed.), *Handbook of Research on teaching* New York: Macmillan Publishing Company.

Erickson, F. (1990). Qualitative methods. In Shulman, L.S. (Ed.) Research in Teaching and Learning. (pp. 77-194). New York: Macmillan.

Fine, M. (1986). Why urban adolescents drop into and out of public high school. Teachers College Record., 87, 393-409.

Forgas, J.P. (1981). What is social about social cognition? In J. P. Forgas (Ed.), Social Cognition (pp. 1-26). New York: Academic Press.

Fortman, J.J. (1993). Pictorial analogies I: States of matter. Journal of Chemical Education, 70 (1), 56-58.

Gabel, D.L.; Samuel, K.V. & Hunn, D. (1987). Understanding the particulate nature of matter. Journal of Chemical Education, 64, 695-697.

Gabel, D.L. (1993). Use of the particle nature of matter in developing conceptual understanding. Journal of Chemical Education, 70 (3), 193-194.

Gallagher, J. (1989). Research on secondary science teachers' practices, knowledge, and beliefs: A basis for restructuring. In Tobin, K.; Butler-

Kahle, J.; Fraser, B.J. (Eds.), Looking into Classrooms: Problems associated with higher-level cognitive learning. London: Falmer Press.

Gallagher, J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. Science Education, 71 (1), 121-133.

Gardner, H. (1991). The unschooled mind: How children think and how schools should teach. Basic Books.

Gee, J.P. (1992). The social mind: Language, ideology, and social practice. New York: Bergin & Garvey.

Geertz, C. (1973a). Deep play: Notes on the Balinese Cockfight. In C. Geertz (Ed.), The Interpretations of Cultures (pp. 412-453). New York: Basic Books.

Geertz, C. (1973b). Interpretations of cultures. New York: Basic Books.

Geertz, C. (1983). Local knowledge: Further essays in interpretive anthropology. New York: Basic Books.

Geertz, C. (1992). Common sense as a cultural system. The Antioch Review, 50 (1-2), 221.

Glaser, B.G., & Strauss, A.L. (1970). Theoretical sampling. Chicago, IL.: Aldine.

Glaser, B.G., & Strauss, A.L. (1965). Discovery of substantive theory: A basic strategy underlying qualitative research. The American Behavioral Scientist. VIII (6), 5-12.

Goetz, J.P. & LeCompte, M.D. (1984). Evaluating ethnographic design. In J.P. Goetz, (Ed.), Ethnography and qualitative design in educational research. Orlando, FL: Academic Press, Inc.

Gold, K. (1990). Get thee to the laboratory. New Scientist, 126 (1712), 41-45.

Goodenough, W.H. (1963). Cooperation in change. New York: Russel Sage Foundation.

Goodenough, W.H. (1964). Cultural anthropology and linguistics. In D. Hymes (Ed.), Language in Culture and Society. New York: Harper & Row.

Goodenough, W. (1976). Multiculturalism as the normal human experience. Anthropology and Education Quarterly, 7 (4), 4-6.

Goodenough, W.H. (1981). Culture, language, and society. Menlo Park, CA.: The Benjamin/Cummings Publishing Company, Inc.

Goodlad, J.I. (1984). A place called school: Prospects for the future. New York: McGraw-Hill.

Gordon, R.L. (1987). Interviewing: Strategy, techniques, and tactics. Homewood, Il: The Dorsey Press.

Grant, G. (1988). The world we created at Hamilton High. Cambridge, MA: Harvard University Press.

Grimellini-Tomasini, N. & Pecori-Balandi, B. (1995). Teaching with students' ideas in mind. Paper presented at annual meeting of the NARST: San Francisco.

Harre, R., & Gillett, G. (1994). The discursive mind. Thousand Oaks, CA: Sage.

Hawkes, S.J. (1992). Why should they know that? Journal of Chemical Education, 69 (3), 178-181.

Hawkins, D. (1974). The informed vision: Essays on learning and human nature, especially "I, Thou, and It" and "Messing Around in Science". New York: Agathon Press.

Herron, D.J. (1983). What can science educators teach chemists about teaching chemistry?--A symposium. Journal of Chemical Education., 60 (11).

Horgan, J. (1995). Profile: Fred Hoyle. The return of the maverick. Scientific American. March, 46-47.

Ives, E.D. (1974). The tape recorded interview: A manual for field workers in folklore and oral history. Knoxville: University of Tennessee.

Jackson, J.E. (1990). "I am a fieldnote": Fieldnotes as symbol of professional identity. In R. Sanjek (Ed.), Fieldnotes: The makings of anthropology (pp. 3-33). Ithaca: Cornell University Press.

Jackson, P. (1986). The practice of teaching. New York: Teachers College Press.

Kirshenblatt-Gimblett, B. (1989). Authoring lives. Journal of Folklore Research, 26 (2), 123-149.

Labaree, D.F. (1983). Setting the standard: Alternative policies for student promotion. Harvard Educational Review, 54 (February), 67-87.

Labaree, D.F. (1989). The making of an American high school. New Haven: Yale University Press.

Lakoff, G. & Johnson, M. (1980). Metaphors we live by. Chicago: University of Chicago Press.

Larkin, J.H. (1983). The role of problem representations in physics. In Genter D. & Stevens, A.L. (Eds.), Mental Models (pp. 75-98). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. Journal of Research in Science Teaching, 29 (4), 331-359.

Lin, H.S. & Lawrenz, F. (1992). Teaching beliefs and practices: A survey of high school chemistry teachers. Journal of Chemical Education, 69 (11), 904-907.

Marshall, H. (1990). Beyond the workplace metaphor: The classroom as a learning setting. Theory into Practice, 29, 94-101.

McDiarmid, G.W.; Ball, D.L.; & Anderson, C.W. (1989) Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. Issue Paper 88-6, NCRTE: East Lansing

McLaughlin, M.W. (1976). Implementation as mutual adaptation: Change in classroom organization. Teachers' College Record, 77 (2), 339-351.

McNeil, L. (1986). Contradictions of control. Boston: RKP.

McRobbie, C. & Tobin, K. (1995a). Restraints to reform: The congruence of teacher and student actions in a chemistry classroom. Journal of Research in Science Teaching, 32 (4), 373-385.

McRobbie, C.J. & Tobin, K. (1995b). The school learning environment: Places for teacher learning or a busy workplace. In Annual conference of the NARST, . San Francisco

Mehan (1980). The competent student. Anthropology and Education Quarterly, 11 (3), 131-152.

NCRTL (1994). A Blueprint for the education of Project 2061 science teachers. Draft Paper: MSU.

NRC (1990). Fulfilling the promise: Biology education in the nation's schools. Washington, DC: National Academy Press.

NRC (1996). National science education standards. Washington, DC: National Academy Press.

Nakhleh, M.B. & Mitchell, R.C. (1993). Concept learning versus problem solving. Journal of Chemical Education, 70 (3), 190-192.

Nickerson, R.S. (1985). Understanding understanding. American Journal of Education, 93 (2), 201-239.

Noddings, N. & Witherell, C. (1991). Stories lives tell: Narrative and dialogue in education. New York: Teachers College Press.

Novick, S. & Nussbaum, J. (1981). Pupils' understanding of the particulate nature of matter: An interview study. Science Education, 65, 187-196.

Oakes, J. (1985). Keeping track: How schools structure inequality. New Haven: Yale University Press.

Okey, T. (1990). The family perspective on the individual's decision to drop out of high school. dissertation, MSU.

Parsons, T. (1963). Societies: Evolutionary and comparative perspectives. Englewood Cliffs, NJ.: Prentice Hall.

Peshkin, A. (1978). Growing up American: Schooling and the survival of community. Chicago: The University of Chicago Press.

Peshkin, A. (1982). The researcher and subjectivity: Reflections of an ethnography of schooling. In G. Spindler (Ed.), Doing the ethnography of schooling (pp. 48-67). New York: Holt, Rinehart, & Winston.

Peshkin, A. (1985). From title to title: The evolution of perspective in naturalistic inquiry. Anthropology and Education Quarterly, 16 (3), 214-224.

Peshkin, A. (1986). God's choice: The total world of a fundamentalist Christian school. Chicago: University of Chicago Press.

Posner, G.; Strike, K.A.; Hewson, P.W. & Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66 (2), 211-227.

Powell, A.; Farrar, E., & Cohen, D. (1985). The shopping mall high school: Winners and losers in the educational marketplace. Boston: Houghton Mifflin.

Prawatt, R.S. (1989). Teaching for understanding: Three key attributes. Teaching and Teacher Education, 5(4), 315-328.

Quine, W.V.O. (1953). From a logical point of view. Cambridge: Harvard University Press.

Rappoport, R.N. (1977). Family influence and the school learner: A propositional inventory. Oxford Review of Education., 3 (3), 247-256.

Ravitch, D. (1984). The troubled crusade. New York: Basic Books

Reif, F. (1983). How can chemists teach problem solving? Journal of Chemical Education, 60 (11), 948-953.

Rose, M. (1989). Lives on the boundary. New York: Penquin Books.

Roth, W. & Roychoudbury, A. (1994). Physics students' epistemologies and views about knowing and learning. Journal of Research in Science Teaching., 31 (1), 5-30.

Roth, W-M. (1993). Metaphors and conversational analysis as tools in reflection on teaching practice: Two perspectives on teacher-student interactions in open-inquiry science. Science Education, 77 (4), 351-73.

Rowe, M. (1983). Getting chemistry off the killer course list. Journal of Chemical Education, 60 (11), 954-956.

Sarason, S.B. (1982). The culture of the school and the problem of change. Boston: Allyn and Bacon.

Schwab, J.J. (1964). The structure of the disciplines: Meanings and significances. In G.W. Ford & L. Pugno (Eds.), The structure of knowledge and the curriculum Chicago: Rand McNally.

Schwab, J.J. (1978a). Interview with Lee Shulman: A conversation on curriculum. IRT: Michigan State University.

Schwab, J.J. (1978b). Science, curriculum and liberal education. Westbury, I. & N.J. Wilkof (Eds) Chicago: University of Chicago Press.

Sedlak, M.; Wheeler, C.; Pullin, D. & Cusick, P. (1986). Selling students short: Classroom bargains and academic reform in the American high school. New York: Teachers College Press.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 4-14.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57 (1), 1-22.

Shumba, O. & Glass, L.W. (1994). Perceptions of coordinators of college freshman chemistry regarding selected goals and outcomes of high school chemistry. Journal of Research in Science Teaching, 31 (4), 381-392.

Silberman, C.E. (1970) Crisis in the classroom: The remaking of American education. New York: Random House.

Singer, E.A. (1988). What is cultural congruence and why are they saying such terrible things about it? (IRT Occasional Paper No. 120). MSU.

Sizer, T.R. (1984). Horace's compromise: The dilemma of the American high school. Boston: Houghton Mifflin.

Smoot, R.C.; Price, J. & Smith, R.G. (1987). Merrill chemistry: A modern course. Columbus, Ohio: Merrill Publishing Co.

Solomon, R.P. (1992). Black resistance in high school: Forging a separatist culture. Albany, New York: State University of New York Press.

Stake, R.E. & Easley, J.A. (1978). Case studies in science education. University of Illinois.

Strike, K.A. & Posner, G.J. (1992). A revisionist theory of conceptual change. Albany: State University of New York Press.

Tannen, D. (1990). You just don't understand: Women and men in conversation. New York: Ballantine Books.

Tobin, K., & McRobbie, C.J. (1994). Epistemological fit and the hegemony of learning environments. American Educational Research Association.

Tolkien, J.R.R. (1966). The hobbit. New York: Ballantine Books.

Tom, A. (1984). Teaching is a moral craft. New York: Longman.

Waller, W. (1967). The sociology of teaching. (3rd Ed.) New York: Wiley & Sons.

Weber, M. (1949). Methodology of the social sciences. Glencoe, IL: Free Press.

Weiner, B. (1986). An attribution theory of motivation and emotion. New York: Springer-Verlag.

Weiss, I.R. (1989). Report of the 1985-1986 National Survey of Science and Mathematics Education. Research Triangle Park, North Carolina.: Research Triangle Institute.

Welch, W.W. (1979). Twenty years of science curriculum development: A look back.

Wertsch, J.V. (1985). Vygotsky and the social formation of mind. Cambridge, MA: Harvard University Press.

Williamson, V.M. & Abraham, M.R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. Journal of Research in Science Teaching, 32 (5), 521-534.

Willis, P. (1977). Learning to labour: How working class kids get working class jobs. Farnbourough: Saxton House.

Wilson, S.M.; Shulman,L.S. & Richert, A.E. (1987). "150 different ways" of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), Exploring teacher's thinking (pp. 104-124). London: Cassell.

Wilson, S.M. & Wineburg, S.S. (1988). Peering at history through different lenses: The role of disciplinary perspectives in teaching history. Teachers College Record, 89, 525-539.

Wittrock, M.C. (1990). Student's thought processes. New York: Macmillan Publishing.

Wong, D.E. (1995 (Draft)). Scientific reasoning as adaptation. Paper presented at NARST, San Francisco.

Yager, R.E. (1986). What kind of school science leads to college success? The Science Teacher, 53 (9), 21-25.