Students' Chemical Knowledge Construction In Microcomputer Based Laboratories

by
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A thesis
submitted in partial fulfillment
of the requirements for the degree of Master of Education
in the Department of Mathematics and Natural Sciences
The University of Manitoba
August 1992

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ABSTRACT

This study examined Grade Eight students' chemical knowledge construction in microcomputer-based laboratories (MBL). The three major questions that were explored were:

1) What were the influences of teacher strategies and behaviors on Grade Eight students' knowledge constructions of endothermic and exothermic reactions in the MBL environment?

2) What understandings of chemical principles do students construct about endothermic and exothermic reactions?

3) How do Grade Eight students use computer -generated data to understand endothermic and exothermic reactions?

Questionnaires, laboratory reports, teacher and "critical friend" observations, and tests were used to assess the understanding of the 25 students in the class. The students were then categorized into three groups - Naive, Transitional and Chemist's understanding. Qualitative case studies were done of the most articulate student from each category. The data were then related to the constructivist theory and implications were made in terms of children's conceptualizations, learning as a social/mediation process and teacher reflections on the whole process.

Acknowledgements

I would like to express my sincere thanks and appreciation to my research advisor, Dr. Harvey Williams, and my committee members, Dr. Barbara Nelson and Wayne Serebrin for their intellectual and moral support during the development and implementation of this research study. Through their different perspectives on education and shared concerns about the development of children's conceptualizations and the teacher's practice in the classroom, they have helped develop my insight as a teacher and researcher.

I would also like to thank Leslie Mesman who assisted me in my observations. Her interest and encouragement in this study reflected both her professionalism and her generous and loving nature.

My thanks to Raymond Padua, my laboratory assistant and to Patricia Magsino for transcribing my tapes.

I would like to acknowledge the following individuals for taking the time to read parts of the dissertation and for offering constructive suggestions: Dr. Jazlin Ebeneezer and Dr. Harold Grunau. I am also grateful to Dr. Eric MacPherson for his words of advice and encouragement.

My thanks to my friends and colleagues who offered their support: Natalie Dupont, Mark Chizzy, Contessa Mendoza, Mona Lynn Howden, Alison Kapalka, Susan Mark and my principal, Claire Painchaud.

Finally, I express my love and gratitude to my family: my husband, Jim Stoeber, my parents, Evelyn and Rodolfo Padua and my brothers, Ronald, Rodolfo, Raymond and Rodel who have always been there for me. I also thank Tegan for her comforting presence in my life.

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CHAPTER ONE

INTRODUCTION

Background to the Problem

The focus of many teachers seems to be the product rather than the process of learning. Indeed, it is easier for teachers to use student marks as an evaluation of student comprehension; to use the same lesson repeatedly year after year; and to blame the students for their lack of success. We often classify students based on their grades as being weak, average or strong students and then treat them as such. We assume that students come to class with no previous ideas about a concept, are able to immediately enter into our realm of meaning and can passively absorb knowledge as it is transmitted to them. When we do the above, are students really learning? Are we sacrificing student comprehension for the completion of all the curriculum objectives? Are we teaching for marks or for the develoment of student conceptualizations? Research into student learning has revealed that students have their own ways of constructing meaning which may be different or similar to our own. It is not enough to transmit the same information, the same way, and hope that all the students will comprehend. Wheatley (1991), believes that

> ...knowledge is not passively received, but is actively built up by the cognizing subject. Ideas and thoughts cannot be communicated in the sense that meaning is packaged into words and "sent" to another who unpacks the meaning from the sentences. That is, as much as we would like to, we cannot put ideas in students' heads, they will and must construct their own meanings." (p.10)

Indeed, although we as teachers cannot reach into a student's head and put ideas into it, we can provide the mediating activities that make the concepts that we wish to convey more meaningful to the student. Computer activities, books, notes, laboratories, and lectures are sources that students can use to mediate or make sense of the the scientific concepts. Student dialogue with the teacher, with other students and other adults enable them to organize their thoughts and confirm or dispute their personal knowledge. Students construct their own realities using different means and sources. Learning becomes not only a personal matter but a social one as well and in order to help students reach the conclusions that we wish them to make, teachers need to try to see the world as students do.

"The teacher (should be) viewed as a valuable resource, as a person who facilitates learning rather than the authority who sets production quotas. In a learning place the goal is learning, not completing tasks." (Wheatley,1991,p.13) Emphasis therefore, needs to be not only on the transmission of scientific concepts but on the student's individual constructions that enables him or her to make sense of these concepts. Memorization should not be the ultimate goal in science instruction, but rather, the objective should be the development of a scientist's awareness, curiosity and approach to a perceived problem.

This study can be thought of as a journey through my development as researcher and teacher. Although I was aware of the constructivist view of teaching and learning where the emphasis is more on the process than on the product of learning, I was not sure of the application of this approach in my classroom. I felt that I needed to examine my own teaching and the students' thinking in response to my instruction before I could make any changes. I was also interested in incorporating the computer in the laboratory and I wanted to examine how this instrument could be used to mediate student's understanding of the concept that I wanted them to learn. This study was therefore conceived with the idea of reflecting and improving upon my own teaching through an analysis of student responses on questionnaires, laboratory reports and interviews as well as my own personal teaching strategies. I decided that using such qualitative techniques would give me more insight into how students processed the information. I attempted to research students' thoughts and ideas during a chemistry unit in response to the mediating activities which I provided.

Research Questions

My first research question derived from the need to examine my role as a teacher and mediator of student comprehension. I did not make any drastic changes in my teaching style during the study since my objective was to study my regular classroom procedures and behaviors and their effect on student learning.

My second question addressed the development of the students' conceptualizations. I wanted to explore how students thought about endothermic and exothermic reactions and what experiences helped them to shape their ideas.

My last question was developed from my interest in the computer as a tool for learning in the laboratory. I wished to determine if the computer could be used to mediate students' ideas about the scientific concept.

Thus, the major questions that were explored in this study include:

1. What were the influences of teacher strategies and behaviors on Grade Eight students' knowledge constructions of endothermic and exothermic reactions in the microcomputer - based laboratory (MBL) environment?

2. What understandings of chemical principles do students construct about endothermic and exothermic reactions?

3. How do grade eight students use computer - generated data to understand endothermic and exothermic reactions?

This study was inductive in that the purpose here was not to prove or disprove hypotheses held before entering the study. Rather, this study was of a descriptive nature and the data collected served to provide evidence to understand the problems that I as a teacher felt I needed to focus on in my teaching. This study also helped me to develop my personal philosophy of science teaching and come to a better understanding of my students as active participants in the learning process.

Overview of Methodology

Within a classroom, it is difficult to assess the conceptualizations of every student for every scientific principle. Accordingly, I chose to examine the way I taught the concepts and principles relating to endothermic and exothermic reactions and to explore in some detail the conceptualizations of three students using a case study method. Merriam (1988) defines the qualitative case study as "an intensive, holistic description and analysis of a single entity, phenomena or social unit. Case studies are particularistic, descriptive and heuristic and rely heavily on inductive reasoning in handling multiple data sources" (p.16). She defines particularistic as meaning that "case studies focus on a particular situation, event, program or phenomenon"; descriptive as being that "the end product of a case study is a rich, "thick" description of the phenomenon under study" and heuristic meaning that "case studies illuminate the reader's understanding of the phenomenon under study. They can bring about the discovery of new meaning, extend the reader's experience, or confirm what is known" (pp.12-13).

By using this approach, I became an "inside observer" who was familiar with both the situation and the students. This is in contrast to an outside observer who would have to take the time to familiarize himself or herself with the situation and the individuals involved. I used qualitative techniques such as student interviews, student questionnaires, teacher notes and observations, field notes and student laboratories and tests to describe events and student conceptualizations. I reflected upon the results of these techniques in order to define my role in the student learning of the scientific concept. By doing this, I was able to step back from my instruction and come to a better understanding of how I could integrate the cognitive theories that I had read about and studied in my courses and apply them to the practice of teaching. Thus,

> The data collected was in the form of words or pictures rather than numbers. The written results of the research contain quotations from the data to illustrate and substantiate the presentation...(one tries) to analyze it (the data) with all its richness as closely as possible to the form it was recorded or transcribed (Bogdan & Biklen,1982,p.28).

I chose the students to interview based upon their responses on the student questionnaires, their marks and my observations of their behavior in class. Like many teachers, I tended to put students into categories of weak, average and strong, so using Hesse's categories (1987) where students were categorized as being naive, transitional or having the chemist's understanding appealed to me. (Although I had read about constructivism, at this point in my study, I was still developmentally oriented in my practice.) I then analyzed the results by organizing student conceptualizations into a hierarchy of understanding. This hierarchy was constucted from my assumptions about the students' thought processes as they learned about endothermic and exothermic reactions (see definition of terms). The hierarchy was then matched to student responses during and after the experiments. The implications of these results were also related to my personal teaching strategies. I was able to determine which strategies helped to mediate student thinking and where improvements could be made which would foster better student conceptualization of endothermic and exothermic reactions.

Justification for the Study

This study is intended to provide a background for further study and to identify questions that can be examined in future research. It is by no means intended to be conclusive since it is limited to the experiences of one teacher, one class and one school. The value of my study is that it

1. provides some insight into the teaching and learning of chemical concepts, specifically, endothermic and exothermic reactions to which other teachers may relate as they read this study;

2. reveals my journey to understanding myself as a teacher and my struggle to understand how students process information using the computer and other mediating activies. It also highlights the conflict within myself as I try to reconcile the different views of teaching to my practice; and

3. highlights the need for more studies where a teacher's own observations and self reflections can be used to improve his or her instruction. Moreover, while there have been many studies done on student conceptions at the elementary level, more needs to be done at the adolescent level if a teacher accepts the premise that the development of conceptualizations is a continuous process. Also, many previous studies using quantitative techniques, focused on the before and after results of teaching but did not reveal the processes that students go through to arrive at their conclusions.

In order to maximize learning of scientific concepts in the MBL environment, it is important for the teacher to have as complete a picture of what is going on in the students' minds as possible. Teachers can then plan for interesting, motivating lessons that take into account students' conceptualizations and backgrounds.

Description of Terms

The meanings of the most commonly found terms in this study are listed below in alphabetical order.

- **Concept:** "A concept is a combination of things...it is the synthesis of many examples or things that exemplify the concept...a concept involves rules or descriptions (although some concepts do not have convenient rules or definitions)...concepts also have titles." (Smith,1978)

- **Endothermic Reaction:** A process that absorbs heat. Example: The boiling of water on a stove where water ceases to boil if there is not a constant source of heat.

- **Exothermic Reaction:** A process that liberates heat. Example: The burning of wood.

- **Hesse's Categories** (1987):

a) **The Naive Students** (naive understanding) - Students who cling to naive theories or alternate conceptions of the nature of change in the physical world. These conceptions almost always contain elements that would be considered unacceptable by the chemist.

b) **The Transitional Students** (transitional understanding) - Students who are between the stages of naive understanding and the chemist's understanding. While they possess some understanding of chemical concepts, they may revert back to the use of everyday materials (analogies) to explain events.

c) **The Goal Conception Students** (chemist's understanding) - These students are able to explain chemical changes at the atomic - molecular level and use chemical substances in their explanations.

- **Mediating activity** - an action with an object or individual(s) that students utilize to try to make sense of (conceptualize) a scientific principle. Wertsch (1991) believes that "a defining property of higher mental functioning, one that is unique to humans, is the fact that it is mediated by tools and by sign systems such as natural language."

- **Microcomputer-based Laboratory:** Probes are connected to a computer which help the student to measure, record and graph quantities like temperature, light intensity, and relative velocity. The measurements are taken by a probe and are displayed directly on the computer monitor in real time. These measurements can be saved, further analyzed in diverse ways or printed out (Stein, Nachmias & Friedler, 1990).

Transmission model - The translation (or "encoding") of an idea into a signal by a sender, the transmission of this signal to a receiver, and the "decoding" of the signal into a message by the receiver. (Wertsch,1991)

CHAPTER TWO

RELATED RESEARCH

Children's Conceptions in Science

I began the study with the belief that teaching for understanding does not mean bombarding students with scientific theories, hoping that they eventually understand but rather, to create an environment conducive to the structuring and restructuring of student ideas. Being that learning is an active process in which the child constructs meaning from new experiences, the teacher needs to be a mediator between the learner and the knowledge. However, being a teacher whose views were based on the transmission model of learning, knowing about constructivism and applying it were two different things. I needed to determine for myself if students would benefit from a change in my philosophy by examining my regular teaching practice in relation to their learning. I would then be in a better position to determine where constructivism would apply in my teaching situation. What follows are the highlights of my readings that have led me to consider a change in my viewpont on teaching and learning.

The teacher as a mediator between knowledge and the learner needs to be understood from the view that

> ...meaningful learning occurs as a result of active student engagement during learning activities. Learning and growth of understanding always involves learners in the construction of personal understandings. Because learning is a personal endeavor, each student needs to have a set of experiences that takes into account of his/her current knowledge and the way he/she can make sense of science content (Tobin, Espinet, Byrd & Adams,1988,pp.434-435).

Moreover, according to Linn (1987),

> Recent research suggests that students' intuitive ideas about a discipline overshadow the potential influence of general reasoning patterns, such as those characterizing the scientific method or critical thinking. These findings emphasize the importance of identifying and articulating the learner's ideas and thinking skills within a subject matter domain as a basis for designing instruction (p.197).

Indeed, a student's ideas are very much content dependent. Students have their own world view and actively construct an understanding of scientific phenomena according to this view. Duschl (1989) states from his own readings that "a learner's knowledge base is organized into conceptual schema and such schema include both declarative knowledge and procedural knowledge" (p.381). Linn (1988) supports this idea when she observes that

> ...students do not so much reject incomplete or inaccurate ideas as embrace more powerful ideas about science ... research confirms that students develop mental models of scientific phenomena and that powerful models help students learn. Mental models include factual details or declarative knowledge, procedures and plans that combine declarative knowledge and procedures to yield problem solutions (p.3).

Linn also identifies two types of understandings that students require in the comprehension of scientific principles and concepts. The first, "robust understanding", refers to knowledge that can be applied to new but related problems. She claims that students entering science classes for the first time have fragile knowledge that applies to one small problem. The second type of understanding involves the knowledge required to capture the nuances that differentiate problem solutions. This she calls "cohesive understanding". Students entering science classes often cannot determine which science ideas apply to which problems. One wonders if and when students achieve these understandings and whether the strategies teachers use make any difference.

Staver and Jacks (1988) took these ideas further in their study which examined the influence of cognitive reasoning level, cognitive restructuring ability, working memory capacity and prior knowledge on eighty - three high school students' performance on balancing chemical equations by inspection. Piagetian cognitive level was measured using the Test of Logical Thinking which assessed four reasoning schema, proportions, variable control, probabilities, and correlations as well as combinations. Cognitive restructuring ability was based upon students' ability to visually rotate objects. Disembedding ability was assessed by the Find-A-Shape Puzzle where students must find and shade a simple figure in five complex figures on a page. Working memory was determined by the Reading Span Test. Students wrote the last word of each sentence after each set of five sets of two, three, four, and five; and three sets of six sentences were read aloud. Prior knowledge was assessed using a pretest on chemical formulas.

Although Staver and Jacks's study was specifically about the balancing of equations, their results may have some significance for this study. Their findings revealed that:

1. When prior knowledge alone is considered, students' understanding of chemical formulas significantly influences overall equation balancing performance.

2. When prior knowledge, restructuring and working memory are considered, only restructuring ability significantly influences overall performance.

3. Working memory capacity does not significantly influence overall performance but does on certain posttest items.

4. Prior knowledge and restructuring ability also significantly influence performance on certain posttest items (p.763).

Because the study's design was pretest-posttest and ex-post facto, there was little information on students' cognitive processing between the pretest and posttests. The authors propose that " It may well be that increased restructuring allows students to connect apparently unrelated facts, concepts and rules, thereby forming a small number of chunks and not overloading working memory" (Staver & Jacks, 1988,p.774). In order to better confirm this claim, qualitative techniques such as student interviews may be more effective in determining what connections and what kind of cognitive restructuring may be occuring in students' minds. My teaching emphasised building prior knowledge of chemical bonding as a background for the next grade level. Prior to my readings, I did not really consider the importance of knowing how students restructure their ideas.

One investigation that targeted students in the same grade level to be examined in this study used student interviews to determine students' conceptions of changes in the state of matter from liquid or solid to gas, as well as their understanding of the reversibility of this process. Stavy (1990) found that the concept of matter as being composed of particles and the state of matter as explained according to the arrangement of these particles, was only noted in 15% of grade 8 and 9 students although this concept is supposed to be taught in the seventh and eighth grades. She discovered that

> There were rare cases in which the students mentioned particles, although they claimed that dense particles are heavier than rare (lighter) particles. The children had in fact adapted the particulate theory to their own conception according to which solids weigh more than gases. In other words, the particulate theory is not internalized and does not become useful for most of the students even though they have learned it in school (Stavy,1990,p.279).

This observation may have important ramifications in the analysis of this study on exothermic and endothermic reactions since particulate theory is of significance in the explanation of what is occuring in the experiment. Students who have not internalized this concept and do not deem it useful may have difficulties explaining their results in the scientific language required by the teacher.

Indeed, even if students do understand the conceptualization, they may not be able to interpret experimental data (observations) in terms of the model. They may even have conflicting ideas about what is happening in an experiment despite what they have learned. That is, they may have learned the concept but are unsure of its application. Hashweh (1988), conjectures that

> ...(students') beliefs can persist after instruction; students can compartmentalize their knowledge, using preconceptions under certain contexts and scientifically accepted conceptions under other contexts...Students can assimilate orthodox knowledge that seems contradictory to their preconceptions into their existing cognitive structure (p.125).

Thus, it is possible for students to internalize conflicting ideas and to apply them to whichever situation seems to merit the idea be it scientific or not. Duckworth

(1987) observes that rule bound children will search their memory for a learned rule that may apply to the situation whether they understood the rule or not. She also notes that

> ...children's understanding is not infinitely malleable. At certain levels, the children do not even see the conflicts that exist in their own thinking. Conflicting notions are simply compartmentalized, and no need is felt to reconcile them. Only if children recognized and were bothered by a conflict did they sometimes manage to construct a more adequate notion to coordinate the two conflicting ones (Duckworth,1987,p.39).

The use of analogy by students exemplifies this discrepancy. "The approach of learners, and in particular novice learners, to understanding a new situation appears to depend much more on reasoning by analogy with other known situations that are judged to be similar than on the application of general rules of procedure" (Millar & Driver,1987,p.51). The meaning that students attribute to a given situation is very much context and content dependent. The use of analogy may or may not be the transitional stage between the "naive " understanding of a concept and the chemist's understanding of the same concept.

Hesse (1987) in his thesis on **Student Conceptions Of Chemical Change**, examined the written responses of 100 first year high school chemistry students who explained the phenomena of the rusting of an iron nail, the heating of copper in air and the burning of a wood splint. From these students, he chose 11 for clinical interviews and then did an in-depth analysis of the respnses of three of the students. Analysis focused upon the students' chemical knowledge, their conservation reasoning and explanatory ideals (standards by which the acceptibility of scientific explanations is judged). In his study, Hesse interprets the choice of the analogy as the "need for something familiar when explaining scientific phenomena..."(p.108). Hesse also noted that

> The use of analogies, similes, metaphors and models in scientific explanation can be treated as a useful step in the development of a scientific explanation. In some cases, analogies actually pinpoint the underlying mechanism in a complex system...the analogies used ...do not focus upon the underlying mechanism, but upon surface similarities between the familiar and the unfamiliar (p.142).

Hesse's three case studies were categorized as "naive", "transitional", and "chemist's understanding". Through the use of interviews with the three students, he found that the student that he claimed as being "naive" was seen as possessing little chemical knowledge, very seldom conserved mass or substance and seemed oblivious to the notion that atoms/molecules and their interactions formed the basis of an acceptable explanation of chemical change. The student preferred to use the homespun analogies. The "transition" student tended to struggle over the choice of explanation. Although the student possessed some chemical knowledge and could apply it to some situations, in areas where she was unsure of her explanations, she reverted to the use of analogies. The student possessing a "chemist's understanding" indicated a preference for the atomic - molecular theory to explain the changes occuring before him and could quickly detect and correct minor errors in his conservation reasoning.

These categories based upon developmental theory seem reasonable to the author and to many teachers. However, problems may arise with labelling students in this fashion. The knowledge and usage of chemical concepts by students depends upon the context and the ideas that they bring to the situation.

Thus, student conceptualizations in science are often dependent on the context. Students bring their own ideas and past experiences into their interpretation of scientific data and while they may be able to internalize a scientific concept and apply it to a single event, they may have difficulty applying it to different situations. If they have not been exposed to a concept, they may try to find analogies to help them understand it. These analogies, however, tend to be superficial, that is, based on the observable event and do not take into account the underlying concept.

Thus, a teacher needs to adopt an insider's view, that is, to seek to understand the sense that students will bring to a situation, help students develop their understandings, meanings and assist them to appropriate the official science language to explain their concepts.

With the above ideas in mind, I attempted to examine my students' thinking in response to my teaching in order to determine how they made sense of endothermic and exothermic reactions and what my role was in their learning.

The Teacher as Mediator of Student Reasoning in Science

To ensure learning of scientific processes, teachers need to be aware of students' familiarity with the scientific skills and concepts to be attained and provide students with settings that challenge and enable them to structure and/or restructure their own reasoning. In my study, I wished to examine whether my teaching techniques were enabling students to make sense of the scientific principles. One way that teachers mediate students' ideas is through language be it with the teacher, other students or even other adults. Lemke (1990) in his book Talking Science states that

> The job of science education is, at the very least to teach students how to use language according to the thematic patterns of science, flexibly and for their own purposes. This means, at least, teaching them to "talk science" in class, on tests, in talking their way through to the solution of a problem (aloud or to themselves) and in writing or speaking about issues to which science is relevant (p.100).

Language in this case refers to the written as well as verbal aspects. Students, however, do not get enough practice "talking science" in the classroom. Lemke also expresses some concern about the use of scientific language in the laboratory. He claims that

> In the laboratory students talk science to each other to guide themselves through prescribed experimental procedures, to decide what to do when something goes wrong... Unfortunately, too often, students do not seem to have enough command of the language they need to be able to figure out what's really going on in the laboratory while it's happening. At best some reconstruct it later (Lemke,1990,pp.156-157).

Lemke also offers some advice for teachers to develop commonality of language with their students. He suggests that teachers should

1. Give students more practice talking science.
2. Teach students how to combine science terms in complex sentences.
3. Discuss students' commonsense theories on each topic.
4. Teach students the minor or major genres of science writing.

Ziedler and Lederman (1989) in their study on the extent high school biology teachers' language may influence tenth grade students' conceptions of natural science researched the teacher's role in student comprehension. They state that

> Without precise language on the teacher's behalf, without forethought about the manner in which teachers present subject matter to their students, it is quite possible that the "common" perceptions that students envision may at best lead to a misunderstanding of physical laws, theories, or phenomena, or at worst a distorted caricature of the theoretical foundations of all scientific endeavors (p.77).

Ebenezer (personal communication) also observed discrepancies in teacher language and student comprehension. She examined the classroom discourse that occured between a chemistry teacher and his students. Her study indicated that although the establishment of common knowledge (definitions and meanings that are the same for the teacher and the student) is important to enhance communication and learning in science, teachers often do not take the time to establish common knowledge in class. She claims that

> ...common knowledge is not established due to constraints of externally imposed curriculum, time, types of knowledge, and the students' unpreparedness to enter into the teacher's world of meaning...teacher power, control, and authority relationships with

students are knotted into the web of communication. The teacher is accepted as the possesor of power and control. It appears only those students who enter into the teacher's realm of meaning would experience success. It follows, that the teacher in his efforts can reach only a handful of students. (pp.26,27).

These constraints are both internal as well as external, however. Teachers have to be made aware of the value of researching and understanding students' viewpoints and ideas and their implications in the instruction of scientific concepts.

Thus, teachers need to make more of an effort to understand and assess a student's realm of understanding in order to provide the type of learning environment in which students can attain the teacher's realm of understanding. Teachers also need to research their own attitudes and how they mediate learning in the science classroom. A teacher who is a mediator of student learning will have a different role from the teacher who transmits information to a passive audience.

Often, a teacher may not be aware of his/her role in the classroom and how he/she is perceived by students. As long as students have the information and are achieving good marks, the teacher is satisfied. Like students, teachers must perceive a need to change before change will occur. The need for the teacher to be a researcher in his or her classroom is exemplified in the study by Tobin, Espinet, Byrd and Adams (1988). Their research focused on the actions of a supposedly exemplary chemistry teacher. They used an interpretive research methodology to investigate his actions in science classrooms. According to these researchers, this teacher had a perspective on science teaching which differed from their own perspectives. They made the following assertions:

1. The teacher emphasized getting the work done in the scheduled time rather than learning.

2. The assessment schedule influenced the nature of the academic work. This implied that students had few opportunities to practice skills and concepts in a formal sense without the threat of a grade.

3. Teachers and students adopted strategies that reduced the cognitive demands of the academic work in science classes.

4. A relatively small number of target students dominated whole - class interactions and laboratory activities.

5. Differential teacher expectations for classes and students influenced the nature of the academic work.

However, when confronted with the results of the study, the teacher was defensive of his actions and regarded the results as an example of "ivory tower" views of the research team. In order for a teacher to come to these conclusions and make changes in his/her instruction, he/she should feel the need to observe and reflect on student learning in response to his/her instructional strategies. Indeed, like students, teachers cannot be forced to think a certain way but must come to their own realizations. My own readings have led me to the realization that my instruction could be more directed towards children's conceptualizations, however, it is only by examining my own teaching that I could determine where and how I could reconcile the above ideas with my practice.

Thus, the teacher has an active role in promoting a classroom environment that facilitates the development of scientific concepts and skills in students.
The language that he/she uses, the examples and activities, and his/her expectations, all play an important role in how students process information. Unfortunately, teachers may find it difficult to teach for the construction of student conceptualizations because of constraints such as the time it takes to assess student understanding, large class sizes and the covering of a diverse curriculum which promote

memorization as an essential tool for students. Moreover, teachers may not have the skills and insights to implement qualitative research methods and the constructivist approaches of teaching and learning.

MBL in the Science Instruction

This section of the literature review describes the use of the computer as a mediating device in children's learning. Many researchers have studied the value of a MBL (microcomputer - based laboratory) in the science laboratory in relation to student conceptualizations. While **PIMMS'** (Project to Increase Mastery of Mathematics and Science, 1987) research revealed that there are some disadvantages and cautions about the use of MBL, they believe that its many advantages compensate for its disadvantages and suggest that MBLs can be effective learning tools.

The researchers for **PIMMS** in its "Guide to Computer Use by the Science Teacher" assert that

> The combination of computers and probes provides the teacher and student with a tool that has three major effects. First, it reduces the tedium involved in the

collection of data and allows students to devote more time to an understanding of the concepts...the new technologies open the classroom to a host of different types of investigations...these technologies can unleash student creativity by providing new experiences that generate questions the students themselves can answer (p.6).

PIMMS also identified some real problems that inhibit MBL usage in science instruction. These included the teacher's lack of confidence in using MBL and misconceptions about computer usage (such as the computer replacing teachers as instructors); the need for increased teacher preparation time; the lack of resources (hardware and software) and the lack of finances. They also noted that "Beyond anecdotal evidence there is a lack of published data on the impact of MBL on student attitudes and student learning, except for graphing skills" but concluded that problems are "more than offset by MBL's performance in gathering and analyzing data and its ability to excite and motivate students" (p.8).

Baird (1989) on the basis of his own studies asserts that the advantage of using a computer in scientific experiments: "With MBL, science becomes truly interactive...Science becomes more realistic...Learning becomes more concrete and intimately connected to observable phenomena...Teaching science as process skills becomes easier for teachers" (20). However, he is not specific as to how the MBL accomplishes this nor does he provide researched support.

Evidently, there is a need for more study of student reasoning and MBL if teachers are to be convinced of its worth. A study by Baird, Ellis and Kuerbis (1989) showed that only 33% of teachers reported using computers one year after the training.

MBL and Student Cognitive Ability

According to several researchers, MBLs may help students understand an observable event in relation to the abstract scientific theory. Researchers such as Staver and Jacks, 1988, (mentioned earlier - p.15 of this study) believe that working memory may be important in the understanding of the balancing of chemical equations. Friedler, Nachmias and Linn (1990), from their study of the impact of enhanced observation or enhanced prediction on scientific reasoning, relate memory to the use of MBL when they hypothesize that

> Using the computer as a tool to collect experimental data might reduce the burden on students' working

> memory and enable them to observe more carefully. When students do not need to process information concerned with logistics, they can focus their limited STM (short term memory) on information gained from their observations (p.175).

They also claim that

> Using MBL, in contrast to traditional laboratory techniques, reduces the memory load required for understanding the relationship between the experiment and the graph. It also provides a dynamic representation of a complex relationship. Thus students understand the graphic representation (p.176).

The focus of the study which used written tests, classroom observations and interviews, was the enhancement of observational and predictive skills through the use of MBL. The study did not explore the effect of teacher interactions on student cognition nor the reasoning that students use to make sense of the experimental data.

Adams and Shrum (1990) in their study of the effects of MBL on the level of cognitive development in 10th grade biology students suggest that the MBL may provide "...a concrete example of the abstract representation (that) may be useful. It may be of some use in bridging the gap between formal and concrete operations" (p.778).

On the basis of their own research and their readings from secondary sources, Linn, Layman and Nachmias (1987) propose that because

> The graph displays in microcomputer-based laboratories are generated in real time and thus permit learners to comprehend the underlying principle of the laboratory lesson without the delays that the conventional, piecemeal, manual graphing methods entail...
> The graphs in MBL are formed as the experiment is carried out and are immediately related to an experiment that the students may have designed or set up for themselves. Thus they are less likely to be seen as static pictures and more likely to be seen as dynamic relationships (p.244-245).

Porter (1989) suggests that "students are involved in the data collection, but they do not need to laboriously write and plot each individual data point. Student time is spent analyzing and interpreting - reasoning skills we want our students to develop" (p.17). She does not however, mention sources to support her statement. A qualitative study depicting students thoughts and reasoning could enhance understanding of these ideas about student cognition and MBL.

Furthermore, Nachmias and Linn (1987) in another study found that MBL enabled some students to see that scientific data are affected by many variables, some known in advance, other, detected as knowledge is gained. They state that a weakness of their study however, is that their

> ...interview revealed glimpses of how students follow their ideas for awhile and then revise them, but these interviews do not provide enough information...to accurately determine how individuals select the ideas they retain, or what conditions support conceptual change (p.503).

Stein (1987), based on one year of classroom experience with one year of microcomputer-based laboratory use concluded that the computer and laboratory learning environment helps to develop higher cognitive skills, especially the procedural skills of planning, testing and revision. She claims that

> Using the computer to forge a strong and immediate link between the process of doing a laboratory and the analysis of the results should give students an unprecedented opportunity to keep the underlying goal of a lab investigation in sight, to receive and respond to results in terms of that goal and to modify experimental procedures accordingly. Thus, the

> emphasis in the laboratory may shift from record - keeping and rote procedures to the procedural tasks of planning, testing and revising hypotheses which underlie all problem solving (p.227).

Thus, MBL may facilitate comprehension by reducing cognitive load and short term memory demands. Because students do not need to concentrate on data collection, they can observe what is going on in the experiment and concentrate on the link between the scientific principle and the experiment.

In this study, this "link" between the process of doing the experiment and the analysis of the results will be explored. What sense do students make of computer-generated data? What is the influence of teacher's strategies on the development of students understanding of scientific concepts? This present study should provide more insight into how students think about computer-generated data. Through the study of my teaching in relation to student learning, I hoped to discover which activities influenced students' thinking and why as well as other significant mediating influences. Teachers need to be aware of this since "teaching correct scientific ideas requires restructuring the concepts that children have, rather than simply supplying correct concepts" (Linn,1987).

Moreover, Martin and Szabo (1990) observe the need for more research when they note that "...we are still in a primitive state of knowledge about how to employ the computer to optimize cognitive restructuring" (p.41).

CHAPTER THREE

PROCEDURE

Because I wished to get an "insider's" view of students' thinking, as well as a view of my teaching from the students' vantage point, I chose qualitative procedures that would give me more data about their conceptualizations than simply test results would have. Furthermore, I tried not to deviate from my regular classroom procedures since I wished to examine my regular instruction in terms of students' conceptualizations. The procedures used proved to be a good vehicle for studying the computer as a mediating device for student ideas.

Furthermore, since I was developmentally oriented in my practice at the beginning of my study, I used Hesse's categories in order to group my students. This was in keeping with my perception of my teacher role as the giver of marks and the expert to which the students could refer. Despite what I knew and read about constructivism, I was not yet at the point of reconciling my practice with the theory at the start of the study. I was not even convinced that I needed to change my teaching practices since many of my students seemed to be getting good marks. Yet, I was worried whether I was enabling students to think like scientists or producing memorizers who viewed the language of science as being elite and incomprehensible.

In the section that follows, I describe my procedures in terms of the participants, setting, experiments, and the qualitative techniques that I used to collect my information.

a) **Selection of Participants**

The individuals for the study were selected from a class of grade eight late French Immersion students. This class was chosen because I wished to minimize possible distractions to student concentration on the endothermic and exothermic reactions. Thus I:

1) selected a class with computer experience,

2) conducted the interviews, journals and questionnaires in English,

3) used a class that I taught the year before.

I reasoned that a class that had already used the computer and was familiar waith my teaching would be comfortable with myself and my procedures.

The students were categorized according to Hesse's (1989) categories (see definition of terms in chapter 1) as naive, transitional and with the chemist's understanding.

Three of the students were selected to be interviewed based on my analysis of the journals and questionnaires as well as my own observations. The most articulate student from each category was chosen in order to better understand the scientific thinking of students in each of these categories. I identified the most articulate on the basis of the accuracy of the information and the amount written in the questionnaires and my own observations of the students in class.

An example of an answer of a student whom I would perceive as being at the naive level of understanding would be as follows:

Question: What were the major observations of your experiment?

Answer: "My observations were that whenever you added baking soda to anything, it would bubble and when you added it to viniger [sic] it practilly [sic] exploded."

Question: How would you explain your observations?

Answer: " The baking soda and vinagar [sic] exploded because of a chemical reaction. I not sure how it works but I do know that when you add baking soda to vinegar it explodes."

The "naive" students focused mainly on the physical aspects of the reactions.

An example of the transitional student's responses to the same questions would be:

Answer: "In the experiment the major observations are how much the temperature of the water goes down with the different proportions of water and baking soda."

Answer: " The observations are the more baking soda that you add the less the temperature goes down."

This student discussed the reaction in terms of the temperature changes as seen on the computer screen and was able to relate the temperature change to the proportions of the substances.

The students whom I considered close to having a chemist's knowledge gave reponses similar to this one:

Answer: "I observed that the temperature went up, stayed constant for awhile, then fell."

Answer: "Heat is used to break the forces between the molecules and when the forces break more heat is let out than was used in the first place. When the reaction is finished the temperature stays the same until it falls to room temperature."

This student not only notes the temperature changes but also discusses what has occured in terms of molecular theory.

b) Setting

The science laboratory was equipped with sixteen Apple II computer systems, each computer having 128K memory, one or two disk drives and a monochrome monitor. Students used **Science Toolkit** (ST) by Broderbund. Like the majority of MBLs, ST consists of an interface unit and two transducers sensitive to light and temperature. In this study the students worked only with the temperature probes.

c) **Experiments**

Previous to the experiment on endothermic and exothermic reactions, the students performed two experiments not using MBLs on the mass and volume of a solution and the different types of solutions, the results of which were used to classify students. In the first one, the students measured the mass and volume of a mixture of colored alcohol and water before and after it was stirred. The mass before and after should not change since mass is the measure of the amount of matter in a substance. The total volume of the mixture of water and alcohol should be less than the sum of the volumes of the two liquids separately.

In the second experiment which explored the concepts of saturated, non-saturated and supersaturated solutions, the students made up sugar and water solutions. They used a certain amount of water and added sugar until the water could hold no more without leaving a residue. They measured the mass of the sugar that they had put into the water. They then put the solution into a hot water bath and determined how much sugar could be dissolved in the solution at a higher temperature. The students were supposed to learn that a non - saturated solution could still have more solute (sugar) added to it and no residue would be left over; a saturated solution contains the maximum amount of solute at a given temperature and a supersaturated solution contains more solute at a higher temperature.

The endothermic and exothermic experiment consisted of three parts. In the first part, students measured the water temperature using the temperature probe. They then measured the temperature of the water as varying amounts of baking soda were added. As the students varied the proportions of water and baking soda, the computer recorded and graphed the temperature changes over time for student observation.

For the second part of the experiment, the method of the first part was repeated but this time varying proportions of baking soda and lemon juice and baking soda and vinegar were used.

For the third part, the temperature change of the water over time was measured before and after the addition of a fixed amount of calcium chloride.

The students worked from teacher - prepared worksheets and notes for the experiments. I expanded the definition of endothermic and exothermic that was provided in the textbook by explaining about the role of chemical bonding in the reactions. I did this on the premise that this would provide a background for the students when they reached grade nine and would study covalent and ionic bonding. They had already been exposed to the idea of chemical bonding in grade seven and in grade eight, I felt that they needed to be provided with settings that would help nurture their understanding of this concept.

The MBL experiments were taken from the Broderbund laboratory manual. These were translated and distributed to the students.

d) **Research Procedures**

The students began the chemistry unit in September and completed the unit mid December, 1991. The students were instructed in the chemical principles and concepts as per the Manitoba curriculum guide. In the past years, my concern was that the students could memorize and regurgitate the definitions that I gave them on a test. However, because of my readings on students conceptualizations, my focus changed to providing students with another instance of chemical bonding (continued from grade 7) in order to help facilitate the learning of covalent and ionic bonds in grade 9. Staver and Jack's study (see p.15) emphasize the importance of prior knowledge in the learning of chemical concepts.

Two of the chemistry experiments were videotaped beforehand so that students would be comfortable with the camera during the research experiments. During the experiments, the students were put into groups of two or three and kept the same partners for the entire unit. I also kept my own personal records of the learning taking place during this chemistry unit. A "critical friend" (Leslie) and the laboratory asssistant were present during three of the experiments in this unit so as to help students become comfortable with their presence. The role of the "critical friend" was as another information source of what was occuring during the laboratory and as a mediator for student comprehension. Leslie was asked to observe the students, ask them about the experiment and note anything of importance during the laboratories. Previous to this, we had discussed the purpose of her observations and she had read the proposal for this study. By asking the students about the experiment in English, students were able to explain what they thought was occuring and the reasons for their observations in their mother language while the experiment was occuring. This would have been difficult for me to do since I am supposed to discourse with the students only in French. Talking science with Leslie allowed students to construct their ideas during the experiment rather than after as Lemke (see p. 24) noted that students were apt to do.

The role of the laboratory assistant was to videotape the laboratory session.

e) **Records**

The data were collected via Leslie's field notes during observation periods, my personal notes and observations, student questionnaires, laboratory reports and tests and videotapes of the class as they worked on the computers.

Student questionnaires - After each experiment, students were given teacher-made questionnaires to assess their learning and to group them according to Hesse's (1987) categories: naive, transitional and chemist's understanding.

In an effort to uncover student ideas, I asked questions that were open-ended and non - specific. The questionnaires themselves also reflect the transition in my thinking. In the first questionnaire, the question was posed so that it seemed that the scientific principle was something external to the students' world. "What theory did you learn in this part of the chemistry unit?" The second question emphasized the importance of a right answer and that the objective of an experiment was to prove the theory. The second version of the questionnaire seemed to be more relevant to student comprehension and reasoning since it asked for student observations and an explanation for their observations. One student from each category was then chosen for interviews. (see Appendix I for examples of questionnaires)

Student interview - Three students were interviewed. They were asked open-ended questions pertaining to their understanding of the laboratory experience and the comprehension of the theory behind the activity. The interviews were tape recorded for subsequent transcription purposes.

Teacher notes and observations - In these notes, I wrote about the purpose of each activity; the way in which each activity was implemented, including all copies of teacher - prepared materials used; comments and impressions about what the students were doing; questions that I had about the students' ways of learning and what I could have done to improve my instruction. I also noted any other classroom events (equipment problems, visits by other personnel, etc.) The results of these notes were to be used to help me assess my teaching strategies in relation to the development of student ideas. (see Appendix II for example of notes),

Field notes - These were made by Leslie, my "critical friend" and included such things as teacher procedures; student and teacher interactions with the labware; student progress and problems during the activity. Both she and I discussed my objectives for this study and what I expected of her as observer. She became another source of information from which I was able to better gauge the instructional settings that I had provided the students in terms of their understanding of the concepts. She circulated around the laboratory and asked students what they were doing and why. Through her interaction with the students in English rather than French, students had the opportunity to "talk science" and explain their ideas to someone who they may have perceived as non threatening. They did not feel that they needed to have the **right** answer with her. We then discussed her observations and impressions of the students' comprehension of the laboratory experience and what activities helped foster their ideas.

Videotapes of the laboratory periods - A laboratory assistant videotaped the experiments for future reference during the analysis of the data. For the first half of the class, she mainly focused the camera on one group and the second half she scanned the class. From these videotapes, I was able to better observe student interactions with each other and the computer as well as Leslie's interactions with the students during the laboratory sessions. I was also able to observe what my role was to the students during the laboratory session.

e) **Data Transformation**

An inductive analysis of the data was attempted in order to find patterns of student reasoning and student conceptions as they tried to reconcile the observed data with the abstract scientific concept. A hierarchy of student understanding for endothermic and exothermic reactions was developed and discussed in terms of students' conceptualizations. Teacher strategies and interventions were also discussed in relation to their importance to the development of student comprehension through analysis of my own observations and impressions as well as the responses from the student questionnaires, tests, laboratory reports and interviews. This study attempted to discover what sense students made of computer - generated data of endothermic and exothermic reactions. The role of the teacher and the learner when using MBL was also explored.

CHAPTER FOUR

RESULTS

This chapter describes the results of the qualitative procedures that I used to collect my data. From my personal notes, observations and the videotapes of the laboratory sessions, I was able to reflect on my teaching strategies and the mediating activities that affected students' conceptualizations of endothermic and exothermic reactions. I was able to monitor these conceptualizations through the use of the student questionnaires, laboratory reports, tests and interviews. Leslie's observations provided further insight into student thinking since her observations were taken during the laboratory sessions. These observations and the student interviews probably provided me with the best data of student comprehension since it was possible to pose questions that could provide me with insights into what activities or persons affected their reasoning. The tests provided me with information on what they remembered or memorized, that is, what information about the reactions that they deemed important to know. The laboratory reports and questionnaires provided some clues into students' conceptualizations but I would not consider these to be totally reliable as students may have copied from each other, used their notes or did not understand the questions.

The first section of this chapter discusses my "intellectual autobiography" where I explore the development of the perceptions of my role as a teacher and the student as controllers of their learning. The next section describes my teaching strategies as mediating activities of student thinking. The next part deals with my original ideas about how student thinking about endothermic and exothermic reactions would occur. I arranged these processes in a hierararchy of understanding. I then describe the results of the laboratory reports, tests, Leslie's observations and interviews with my hierarachy in mind. The case studies then describe the responses of three students, Kristy, Jerome and Erin whom I had assessed using Hesse's categories, in more detail.

Intellectual Autobiography

In this section, I wish to reveal how my thinking changed as I progressed from the initial planning of the study, through the early stages of data collection and analysis, to the advanced stages and finally to report writing.

Prior to the study, although I was aware of the complexity of student conceptualizations from my coursework and readings, I was unsure if I was taking these into account in my teaching practice. I tended to present the material in the form of notes and readings and then the students would read and memorize the material. Laboratories were given in order to prove the theories that they had learned in class. They would then regurgitate the material that they had "learned" on tests that were very factual and procedural in nature. The important thing was that I covered all the concepts of the curriculum rather than ensuring that students were doing more than memorizing. My teacher role was perceived by both myself and my students as being "the provider of information and the giver of marks" rather than the facilitator of student thinking. With time, I realized that students had not really internalized the concepts and that science was perceived as a boring, rote subject that was incomprehensible to many students. Students did not see the value of science - "Why do I need to know this? When am I going to use this in real life?" Thus, they did not feel the need to reach the "chemist's understanding" of scientific theories. As long as they got the necessary marks that they needed to pass, many students were satisfied.

I noted that because scientific principles can build upon each other, it is important to provide students with instructional settings that motivate them to learn, stimulate their curiousity and enable them to develop connections with past experiences that lead to long term rather than short term memories. Using the computer as a tool in the science laboratory thus seemed like a promising option because I had already noticed that many students enjoyed using it. However, I wondered whether it would better enhance the development of student conceptualizations in science as the literature had claimed.

At the start of my study, I had the following objectives:

1. To map the processes by which a learner translates new data into conceptualizations and to examine to what degree using microcomputer-based laboratories encourages this process.

2. To reveal teacher expectations and the effect of these expectations upon instruction and thus upon student reasoning.

As the study progressed, I tried to further refine my focus. My questions became:

1. What were the influences of teacher strategies on Grade Eight students' knowledge constructions of endothermic

and exothermic reactions in the microcomputer-based laboratory (MBL) environment?

2. What understandings of chemical principles do students construct about endothermic and exothermic reactions?

3. How do Grade Eight students use computer-generated data to understand endothermic and exothermic reactions?

My emphasis became not so much the effectiveness of the computer in helping the students learn about endothermic and exothermic reactions, but rather, what sense the students made of the graphs that they saw on the computer screen. I wondered whether students were able to go beyond what they saw on the screen to what was occuring in the reaction that they could not see, that is, whether the computer helped them to mediate their ideas.

Furthermore, I wanted to determine whether the students could explain the reaction using the scientific explanation related to the molecular kinetic theory or whether their thinking would be at a more "naive" level. As a teacher, I felt that I needed to assess students' levels of comprehension in order to provide the kind of instruction that would be appropriate to their level of understanding. At this point, I still saw the students' understanding as being organized in neat little compartments where students would move from one level to the other in a linear fashion. As I analyzed and reflected upon the results of my procedures, I found that this is not necessarily so and that students' ideas are not so neatly organized and easy to decipher.

When I first started the study, I did not foresee many of the problems nor anticipate the amount of time and energy that it would take to plan and collect the data. During the first stages of my study, I planned the experiments and activities that the students would do, debated over how I would present the concepts and theories, made up the questionnaires, and talked with the English teacher about giving the students time to write in their journals during English class. Because students express themselves better in their native language, I believed that I would get more accurate results if they wrote their journals in English rather than in French. The students did not, however, continue with the journals. The process of journal writing had not been taught and the objectives for writing the journal were not clear to them. Students also forgot their journals at home.

During the planning of my lessons, I could already perceive a change in my teaching perspective. Although I still tended to give students information through notes and lectures, I also let them participate actively in their learning. (see section to follow). Most of the activities were teacher - directed rather than student directed.

Teaching Strategies and Personal Observations

I introduced the concepts of exothermic and endothermic reactions in the same manner that I have always done. Normally, I have the students copy the definitions which include one or two examples of each reaction, read over the definition with them and then try to explain it in more detail. I assumed that students needed to be given the scientific vocabulary and objectives at the outset before so that they could use them in discussions later. I also believed that if they had the vocabulary and the definitions they should be able to enter my realm of meaning right away. I ask students if there are any questions and then give them an assignment or have them prepare an experiment about the concept or theory. I felt that doing doing an experiment would strengthen the concept in the students' minds.

Reflecting upon the above strategy in terms of constructivism theory, I realized that I had been providing the students with information and assuming that they understood. I was also reinforcing the idea that the only purpose of school laboratory experiments was to support theory. Accordingly, I provided a mediating activity intended to assist students in making sense of the theory. The students "acted out" the reactions by portraying molecules and their joined hands represented the forces holding the atoms in molecules. Groups of students were molecules of baking soda and other were water. Other students were heat energy that broke the "bonds" by separating the clasped hands. New "bonds" were then created. I also used diagrams to explain the reactions.

Subsequently, we reviewed the experiments and how the probes and computer programs were used. I gave them handouts that describing the experiment. Usually, I give them just a general outline of the experiment and it is for them to determine the variables (independent, dependent and controlled variables), and the hypothesis. They also rewrite and organize any method given in numbered steps. However, I felt that the experiment would proceed faster if it were given to them. All they had to do was to follow the instructions and answer the questions as they did the experiment rather than afterwards as they were used to doing. The need to proceed faster and to cover all aspects of the curriculum was always at the back of my mind as I decided upon this strategy. Later, I would discover that it takes time for students to internalize a concept and that making time for the development of conceptualizations would have been a better option than repeating the same experiment.

The students then did the experiment in groups of two or three. These groups were assigned by myself according to my perceptions of their abilities and social behavior in the laboratory. That is, I tried to put the weaker and stronger students together. I reasoned that the stronger students would enter into discourse with the weaker ones and help them to construct and organize their ideas. However, there was always the risk that the weaker ones would simply copy from the stronger students. I also tried to avoid putting students together who would be disruptive.

During the laboratory session, I found that much of my time was spent explaining procedures and assisting students with computer problems in the hardware or software. It was difficult to monitor the students' learning but I noted that the majority of students seemed to be performing the procedures of the experiment. Several students asked me about the questions on the laboratory reports and about the data that they saw on the computer screen. They wanted to know if they had the "right" answer or the "right" data. I tried to ask them about what they thought and to encourage them to make hypotheses about the data that they saw.

Students perceived me as the expert and wanted me to give them the answer rather than take the time to really think for themselves. Some students either found it difficult to verbalize their thoughts, did not have a clue, or drew upon the theory that that they had been exposed to in class. Most students realized that the rise or fall in the curve of the graph indicated a temperature change based on the type and proportion of the chemicals used. Most were also able to name the reaction that they saw. However, when the temperature rose instead of fell as they had expected, they immediately asked me why and were frustrated when I told them to think about some possible reasons. I think that while some students made an effort to try to reconcile the discrepancies to what they already knew or had learned in class, others gave up and decided that I would probably give them the answer in class anyway.

Afterwards, I corrected the laboratory reports according to the answer key provided in the laboratory manual and then we discussed the results. However, many of the students did not make a data table for third part of the experiment (the observations) although they did attempt to answer the questions. This was confirmed from my interview with Jerome, who stated that his group did not get to the last part of the experiment and from my observations during the laboratory session. While the majority of students attempted to answer the questions, probably after the experiment, they did not have any data to support their responses in their report. It became evident to me that I had rushed the students to finish the laboratory by the end of the class, therefore making it hard for them to do little more than perform the procedures rather than thinking about the data. Thus, I had the students redo this part of the experiment - writing it out, defining the variables and numbering the steps to be followed. I felt that defining the variables on their own would make them think about what they were looking for in the experiment and numbering and writing out the steps would help them be better prepared for the experiment instead of depending on me during the laboratory session to guide them at each step.

The experiment progressed much better this time. Instead of worrying about finishing the experiment on time, I noted that the students were talking more about the results that they were seeing on screen, that is, how fast the temperature was rising in comparison with their previous experiment and why the temperature would be going up rather than down. While it seemed that students were discussing more amongst themselves, certain students found the experiment redundant and wanted to know, "What's the point of doing this again when we've done it already and we know what's going to happen?" I told them because their data were not complete. Reflecting upon the adequacy of this response, I realized that I had missed a "teachable moment", that I could have emphasized that science experimentation is not about getting the "right" answer, rather it is a meaning making process. Thinking about why a certain result occurs is what is important. We then discussed these results. I found that most of the students could describe an endothermic or exothermic reaction by the direction of the curve of the graph, though a few students confused the terms. They also seemed to know that heat energy was used during the reaction and was used to break bonds. They did not seem to be able to make the link between the change in temperature and the change in chemical bonding. They may not have had enough experience with this scientific principle or may not have internalized the scientific terminology to explain it.

During the review for the final test of this unit (about two weeks later), we again examined the experiments and the results. Students remembered that the way that the graphs curved indicated which reaction was taking place, a few students stated that heat was being used to break the forces between the molecules, and some still mixed up the terms endothermic and exothermic.

Selecting Students for Interview

In order to choose the students for interviews, I grouped the students using the categories that Hesse (1987) had used in his study and then chose the most articulate from each group. These categories were naive understanding, transitional understanding and the chemist's understanding (see description of terms, p.10). This categorization reflects my developmental viewpoint at the beginning of the study.

The results of the questionnaires from the two experiments on the mass and volume of a solution and the types of solutions were surprising. Although I felt that I had satisfactorily covered the concept in class, for the experiment on mass and volume, out of the twenty - three questionnaires that were filled out, only eight students were at "transitional" level of understanding (according to my own standards) while only four were at the chemist's level of understanding. Examples of student responses at each level of understanding are as follows:

Questions: 1. What theory did you learn in this part of the chemistry unit?

2. How do you know if the theory is right or wrong?

Naive: 1."We learned the theory about molecules and how they react with other molecules"

2. "By preforming [sic] the experiment we did in science class with the alcool [sic] and if you pour the alcool [sic] and water and the mass rised.[sic]"

Transitional: 1. "That if you poured alcohol over water (slowly) the alcoohol [sic] would stay on top. Water molecules are bigger than alcool [sic] molecules (mass & volume)."

2. "We did an experiment with coloured alcoohol and we poured it onto water, the alcoolhol [sic] stayed on top but when you stir it the alcoolhol [sic] mixes in with the water and becomes more dense but there's less liquid."

Chemist's understanding: 1. "We learned a theory about molicules [sic] and how they mix together by going in the spaces between."

2. " I know the theory is right because in the lab the volume of the mixture went down alot because the molicules [sic] of the alcool

went between the molicules [sic] of the water."

The student that I had identified as naive understanding noted that the mass "rised" and did not give any scientific explanation for his claim. The transitional student attempted to give a more scientific explanation for her observations but her explanation was not totally correct. The student who I identified as being close to having a more chemist's understanding supported her observations with an acceptable (to me) scientific explanation.

For the second experiment, out of the twenty - one students that answered, only four were at the level of naive understanding while the others were at a more advanced level. An example of each of the level of responses would be: (The same questions as before were used.)

Naive: 1. "We learned the theories on saturee, sur-saturee and non-saturee.[sic]"

2. "Because we did the experiment and it proved to be right."

Transitional: 1."How to determine the amount of residue in a substance."

2. "We did an experience. First we added a little sugar to water then mixed and if there

was none left on the bottom you kept doing that till some was left."

Chemist's understanding: 1. "We learned that there are spaces between the molecules that can hold dissovible [sic] substances"

2. "We know the theory is right because we did an experiment. We had 10 ml of water and kept adding sugar until it dissolved."

The naive student seemed to simply parrot the scientific terms without providing any meanings. However, it is possible that this student may have known more than he had written down. The transitional student used the less formal definitions and noted that the formation of a "residue" was an important part of the experiment. The student with more of a chemist's understanding attempted to explain her results using the molecular concept of spaces existing between particules of a substance. She may have memorized this without any meaning attributed to it.

I also used the results of the questionnaires from the experiments on endothermic and exothermic reactions to aid me in selecting the students for interviews. I again grouped the students into the naive, transitional and chemist's understanding. (see pp. 38-39 for examples)

I found that it was not easy to group students this way. The students that I placed in the naive category tended not to write very much, therefore making it difficult to asssess what they knew. Students may not have understood the questions or what a "theory" was and may not have had the language to express what they understood. The students were not used to thinking about their own conceptualizations and may have been uneasy about revealing what they thought in case it was wrong. They may have been simply repeating what they had learned in class at a superficial level. I hoped that the interviews would give me more information on how students thought about scientific data , specifically the computer-generated data.

Personal Hierarchy of Student Conceptualizations

I outlined my expectations carefully and came up with a hierarchy of understanding that I thought the students would go through as they attempted to grasp the concepts of endothermic and exothermic reactions. I thought that this hierarchy would help me assess their comprehension. It also revealed to me how I perceived students' thinking to proceed in a linear fashion.

I thought that the most basic understanding of the experiment would be evidenced by a description of concrete/observable events. The second would be the interpretation of the graphs on the computer screen where, if the line goes up, the temperature rises; if the line goes down, the temperature drops; and if the line does not change, the temperature is constant. The third level was the concept that heat can be absorbed or liberated during a chemical reaction. The fourth level was if the student could provide explanations of events at the molecular level, that is, that chemical bonds are being broken and reformed during the reactions. The final level was the use of the scientific terminology (exothermic and endothermic) in the explanation of events. I saw these levels as moving from lower or less complete understanding to higher or more complete understanding.

Upon examination of the twenty - two student questionnaires that I received after the first run of the whole experiment (both types of reactions) and the twenty - three questionnaires that I got after the second run of the experiment (exothermic reactions), I discovered the following:

HIERARCHY OF UNDERSTANDING

Level	% of Students (Frequency) First Run	Second Run
1. Observable/concrete	14	0
2. Interpretation of Graphs	82	91
3. Concept of Absorption or Liberation of Heat	14	22
4. Molecular Level: Changing of Chemical Bonds	18	17
5. Terminology: Endothermic and Exothermic	55	52

Examples of student responses from each level are as follows:

1. **Observable/concrete** - "My major observations were that whenever you added baking soda to anything it would bubble, and when you added it to vineger it practilly (sic) exploded."

2. **Interpretation of the graphs** - "In the experiment the major observations are how much the temperature of the water goes down wtih different preportions of water and baking soda."

3. **Concept of Absorption or Liberation of Heat** - " The temperature rises because the heat from the environment

breaks the forces between the molecules, but between the molecules is energy which forms heat which causes the temperature of the environment to rise."

4. **Molecular Level: Changing of Chemical Bonds** - "The calcium de chlorure raised the temperature because there is alot of action in the molecule and when the forces between the molecules are broken the heat goes in to the environment (water). The bicarbonate de soude lowers the temperature because all the heat in the water is used to break the forces between the molecules."

5. **Terminology: Endothermic and Exothermic** - "When it was exothermique temperature went up endothermic temperature went down."

The results of the questionnaires showed that there my hierarachy did not match the students' actual levels of conceptualization. This will be discussed in more detail in chapter 5.

Laboratory Reports

In this section, I will report on the students' answers in terms of the hierarchy of understanding specified earlier.

1. Observable/Concrete - Students noted that:

- there is "action in the baking soda."

- "the mixture feels colder."

- "there is a greater amount of movement in the lemon juice than water."

- "there is more baking soda for water and water is soaked up in the baking soda..."

- "when you have a lot of lemon juice/vinegar because it overcomes the baking soda."

- " the only reaction is that the temperature drops."

- "it was different because we used different substances."

- " the first mixture was a fast reaction, it maybe bubbled a bit and after it was calm."

- "The baking soda and water because it's "fizzy" and bubbles alot."

- "more baking soda, the water is more thick. More water, the solution has more liquid."

2. Interpretation Of Graphs - Some of the students comments included the following:

- "The temperature decreases when you put more water."

- "The temperature increases when you put more baking soda."

- "An endothermic reaction is when the temperature drops"

- " You know that the reaction is exothermic or endothermic when the graph goes higher it's exothermic and when the graph goes lower it's an endothermic reaction."

- " When the proportions have more baking soda the temperature decreases."

- " The strip chart says if the reaction is fast or slow."

According to the laboratory reports, most students noted that if the graph's curve went up, the reaction was exothermic and if the curve went down, it was endothermic. Moreover, from their observations of the graph while the reaction was occuring, some students noted right away the change in the rate of reaction using the different substances.

<u>Absorption or Liberation of Heat During the Reaction</u>

Some students associated the rise or fall of the temperature curve with the absorption or liberation of heat energy. Others realized that heat was of importance in an endothermic/exothermic reaction but did not associate this with the breaking and reforming of chemical bonds:

- "...when the baking soda uses the heat it just uses all it can, not more."

- "The dissolving is finished and all the heat is used that is needed to be used."

- "An endothermic reaction is when the chemistry takes the heat from the environment."

- "An endothermic reaction takes the heat and the environment becomes colder."

- "... there is alot of energy and you don't use a lot of energy and there is heat left in the environment."

- " The vinegar creates the greatest drop in temperature because the heat is used up faster."

- "In the endothermic reaction, the heat is liberated and in the exothermic reaction, the heat is absorbed."

- " We saw that when we did this experiment, the temperature of the mixture dropped because all the heat of the environment which surround the mixture was used."

- " A chemical reaction is when the reaction takes the heat from the environment."

It seems to me that the majority of students have associated the rise or fall of the temperature curve on a graph as being related to an increase or decrease in the amount of heat in the water. From their statements, some of the students realized that the heat energy had to go somewhere if it was not in the water and reasoned that it had to do with the dissolving of the baking soda.

Molecular Level - Chemical Bonds are Broken and Reformed

Not many students attributed the changes in temperature to the breaking and reformation of chemical bonds. Those that did wrote that:

- " The heat is used to break the forces between the molecules."

- "...when the water breaks the molecules, the heat goes into the environment."

- "When you add the salt to ice cream, it makes a reaction and the heat in the liquid and uses it to break the forces and the temperature drops past zero degrees and it is solid."

- " Because the forces between the molecules are stronger and the solution uses more heat in order to break the forces than in the first experiment."

- " There are more bonds to break and the mixture is colder."

- " The molecules aren't broken very fast in the other experiment."

- " An endothermic reaction is when the liquid uses more heat to break the molecules than is in the molecules."

The students were taught last year that chemical bonds exist between the atoms that make up the molecules substances. This was again examined in the discussion of endothermic and exothermic reactions in class. It seems that the few students who were able to internalize the concept of the existence of chemical bonds were more apt to use them in their explanations. I think that it made sense to these students that the heat energy was used to break the bonds in the baking soda. It is also possible that the students were only repeating what they learned in class. However, we did not discuss the rate of reaction in class. It seems, then, that the student who noted that " The molecules aren't broken very fast in the other experiment" seemed to be using the concept of the breaking of chemical bonds to account for the change of the rate of reaction. The theory made sense to him in relation to what he saw on the computer screen. The student who noted that " There are more bonds to break and the mixture is colder" also seemed to be relating the theory to the data. If there are more bonds, more energy is needed to break them and so more heat is taken from the water.

Scientific Terminology - Endothermic and Exothermic

In their laboratory reports, students used the scientific terminology correctly. This was probably because the questions asked referred specifically to a reaction as part of the question. Their usage was also emphasized in class by me. I think that the students were "parroting" my words rather than really understanding their meanings. While they seemed to comprehend the relationship of the temperature curve to the amount of heat in the water (the computer-generated data), the identification of the graphs as being endothermic or exothermic was probably done strictly through memorization.

Student Responses From The Unit Test

There were two questions on endothermic and exothermic reactions on the test. These were:

1. What is the difference between an endothermic and exothermic reaction? Give an example for each one.

2. Draw and explain the graphs for the endothermic and exothermic reactions.

Out of the 25 students that wrote the test, 84% (21/25) of the students explained the reactions according to the graphic interpretation, that is, that the temperature changes according to the graph's curve. 48% (12/25) of the students talked about the absorption or liberation of heat in their explanations while only 24% (6/25) mentioned the breaking and reformation of chemical bonds. Only eight of the 25 students (32%) gave examples of each reaction. Not all of the examples given were appropriate. Only two (8%) students answered the question using all four categories.

For the second question, 92% of the students were able to represent the reactions graphically. These graphs however, were not the graphs taken from their experiments but those that were given in their notes as examples.

Observations of the "Critical" Friend (Leslie)

As was mentioned earlier, the role of the "critical" friend was to provide another information source or student comprehension for me. I had informal meetings with her prior to the commencement of her observations to discuss my study its objectives. She was very enthusiastic. To prepare herself as well as the students for the observations, Leslie was also present at one of the experiments prior to the experiment on endothermic and exothermic reactions. After she had completed her observations of the experiments she would write down comments on the procedure and the activities of the students during the explanations. The first time the students did the experiment on endothermic and exothermic reactions she observed that:

"Most students were paying attention, except for one who fiddled with his books, until his seatmate finally helped him find the pages in his book. After that, his eyes wandered all over the room, and he seemed not to be paying attention."

She had been at the back of the room as I explained the procedures again so she had a good view of what the students were doing. After the explanation, she circulated amongst students and asked questions about their experiments, asking them to explain what was occuring in English, claiming that she was an English teacher and did not understand what was happening. She stated that:

"I had some very interesting responses from, "I dunno" to "cause she (teacher) said so", to "the temperature is <u>supposed</u> to go up (or down), but it didn't ... maybe we didn't measure correctly..." and " it gives off heat because the changing of the molecules takes energy" and "because she (teacher) made us be molecules... and we held on to each other..."

She concluded this observation session by noting that:

"There was very obviously a lot of thinking going on... a lot were uncertain of what the computer experiment was supposed to show...but most seemed to understand the exchange of molecular energy/heat in chemical reactions. They were able to guess why their experiments weren't working as they expected them to do (when that happened) with thought if not necessarily accuracy. It seemed to help the students "explain" what was happening to tell someone who they thought had no notion of what was going on, nor understood the language (how could an L.A. teacher know Science or French???). They were very patient and very precise in their explanations."

As part of her second observations, she tried to tape the students' responses to her questions, but unfortunately, the tape recorder malfunctioned and this data was lost. She did note, however that:

"I found that all the students by now had some notion of endothermic and exothermic reactions. They all had some theory of why the temperature of the liquid dropped - having to do with an exchange of energy from the liquid to the dry chemical. Some felt that the temperature change was more dramatic because there was more "fizzing", more chemical reaction on this day than the day with the water. Some even ventured the speculation that the more dramatic temperature change had to do with the fact "that one is a base and the other is an acid...""

She felt that students in general had assimilated more information about the movement of molecules, the release of heat in a chemical reaction, and about chemical reactions than they had before the experiments. She also believed that the teacher activity of having students "act out" the reactions contributed significantly to the students' understanding of the reactions. She stated this because, "...so many of them told (her) about it, when (she) first talked to them." Acting out the reactions brought the theory to a more concrete, visual level that was also amusing for the students. They tended to remember things that they were more actively involved in. The computer-generated data served as another mediating activity that was to have helped them reinforce or contradict the ideas about the scientific activity that they may have constructed from the dramatic activity..

Her conclusions were that "they (the students) certainly were better able, on the whole, to verbalize an understanding of the principles (the teacher) was trying to get across to them."

This can be supported by one of the conversations with a student during the experiment that was captured on videotape:

Leslie: Why did the temperature go down?

Student: You have lots of bicarbonate de soude...it's using the water's energy because it doesn't have none.

Leslie: What's using the energy?

Student: The baking soda is using all the heat that's in the water to break all the molecules up so it's taking away all the heat away.

Leslie: Is that going to do the same thing with this (vinegar)?

Student: I don't think so.

(Both watch the reaction with baking soda and vinegar. the graph on the screen shows the temperature decreasing.)

Leslie: Is it going down same as the water?

Student: Yeah, what happened was that there probably wasn't lots and lots of energy so you needed all of it so all the heat was taken away and the temperature went down but if you probably put more baking soda and less water the temperature would probably go up.

It seemed to me that having Leslie make the students verbalize their thoughts as they did the experiment helped them to clarify their thoughts for themselves and their partners. An excerpt from one of the interviews demonstrates this (T=teacher, S=student)

T. Okay, what did you think about the experiment?
S. I thought it was pretty fun but sometimes I didn't really understand but then after I got to understand.
T. How come you got to understand it better?
S. When (Leslie) came in, she started to ask us questions and I was thinking about it a lot, while I was saying it and, well, like for the endothermic, like, oh, boy, we, where we had l'eau and what's that?
T. Baking soda.
S. Yeah baking soda, when we put it together, the molecules like, they separated, whatever, and they caused like the l'eau to become, um, okay the energy between the molecules changed and they went to different partners and everything sort of like became, like the liquid sort of disappeared and everything...

Student Interviews

Although I had decided to interview just three students based on the groupings of the responses of the questionnaires, I was so interested by students' responses that I ended up interviewing eight students - four students individually and one group of two girls and a boy and a group of two boys. The interviews were informal without any set questions. I asked them about their feelings on science in general and then gradually about the experiment on endothermic and exothermic reactions. I made it clear that this was not a test and that their answers were to be used to help me improve my teaching. Despite this, some students felt that they had to give me a "right" answer and were cautious about expressing themselves. Some of the students' ideas that came from these interviews were:

1. Vinegar is "stronger" than water.

2. There are acids and bases in chemical reactions.

3. There is "action" that occurs within molecules.

Students also tended to have a different meaning of the term "environment" than I did and mixed up the meanings of endothermic and exothermic in their explanations. I also found that students were more comfortable being interviewed individually rather than in groups. In the groups it seemed that students were reluctant to express their thoughts in front of the other students and myself because they did not want to take the risk of "looking stupid." It was hard for them to express themselves in front of me, harder still in front of their peers. While I was interviewing them, some students would not look at me directly, but at the floor or glanced uneasily at the person next to them. I think that they perceived the group interview to be more threatening than a one on one situation. In the case studies that follow, I will be examining the interviews of three of the students more closely.

Case studies

I decided to focus my study mainly on the answers of three students on their written reports as well as their responses during interview sessions. These three students were chosen because they represented a cross section of student responses from the most naive to the most sophisticated in terms of their understanding of the reactions presented for their explanations. From my analysis of the questionnaires and my own observations, Kristy was consistently in the naive grouping, Jerome, the transitional and Erin, the chemist's understanding. Furthermore, they were the most articulate in that they tended to write the most in the questionnaires and participated well in class discussions. (volunteering ideas and asking questions.) The next part of this paper will deal with the responses of the three students, Kristy, Erin and Jerome. In my view, Kristy possessed a naive understanding of endothermic and exothermic reactions, Erin, a more sophisticated understanding and Jerome, a level of understanding somewhere between these two.

Kristy

Questionnaire

The questionnaire did not reveal much about Kristy's reasoning. She wrote that the major observations of the experiment were "the different reactions that happened when adding different substances together. She did not answer the question that required her to explain her observations.

For the question about which parts ot the experiment were confusing, she stated " discovering the difference between endothermic and exothermic. It was only confusing until I figured out the answer" She felt that the easiest part to understand was "...the help of the computer. If the computer wasn't being used, the experiment would have been much harder." She does not explain, however, why the computer was helpful in helping her understand the reactions. She said that she felt good about the experiment and that it was fun. The diagram that she drew depicted a beaker of baking soda and vinegar and the bubbling of the mixture which she labeled as "reaction".

Laboratory report

For the first part of the experiment using water and baking soda, Kristy stated that she did not observe what she had expected to observe during the experiment. She reports that the temperature drops when there is more water than baking soda and that the temperature rises when there is more baking soda. Her answer to the question "Why can't the ratio between baking soda and water be increased indefinitely to produce lower and lower temperatures?" was that "because when the baking soda uses the heat, it just uses all it can, not more" (translation from French). For the question, "How is this experiment an example of chemical bonding?", she responds that "the heat is used to break the forces between the molecules."

For the second experiment which used combinations of baking soda and water, baking soda and lemon juice and baking soda and vinegar, she describes an endothermic reaction as being, "when the temperature drops." She noted that the reaction occured faster than in the previous experiment. Her response to the question, "As you altered the proportions of baking soda and liquid, which combination caused the greatest temperature drop? Why?" was incomplete. She wrote that "The vinegar made the greatest drop in temperature." The next question on the laboratory report dealt with the application of an endothermic reaction: "Adding rock salt to the ice in an ice cream maker causes an endothermic reaction. Explain how this reaction occurs and describe the results." Kristy's response was " Because all the heat is used to break the force between the molecules of salt and there isn't any other." The next question asked, "The temperature drop in this experiment was greater than in the previous experiment. Why is this so?" Kristy wrote: "In this experiment we used different products than the first experiment. It made a different reaction."

In the third experiment, the exothermic reaction using calcium chloride and water, Kristy wrote that the exothermic reaction starts when the temperature rises and finishes when the temperature stays the same. The endothermic reaction starts when the temperature drops and then finishes when the temperature no longer changes. When asked to give the difference between an endothermic and exothermic reaction, she writes: " An endothermic reaction is when the temperature drops and exothermic reaction is when the temperature rises." Her answer to the question, " How do the experiments help you to understand the difference? " was that, " It gives a chance to determine if the theory is true."

Test

For the question, "What is the difference between an endothermic reaction and an exothermic reaction? Give an example for each", Kristy wrote, "An endothermic reaction is when the temperature drops and then stays constant, ex. water and alcohol. An exothermic reaction is when the temperature rises and then doesn't change, ex. calcium chloride and water" She draws a very rough graph of these reactions but does not explain them.

Kristy thus gives a graphical interpretation of the reactions and does not use the concepts of heat absorption or liberation nor the molecular theory in her explanations. Also, her example of the exothermic reaction is incorrect and she uses the example from the experiment rather than one that would be more common, like the burning of a match.

Interview

In the first part of the experiment on endothermic reactions using baking soda and water, Kristy was able to identify the visible characteristics of an endothermic reaction, that is, that the temperature decreases during the reaction, and realized that heat energy has something to do with the reactions.

> I. Why do you think the temperature went down?
> K. The heat, the heat that breaks the molecules, the heat breaks them, so then it separates them and the molecules go apart.

She was unclear about where the heat comes from. She tended to quote from her notes that the heat comes from the "environment" but was not clear about what the environment was. She also claimed that there is no heat in air. She attributed the heat to the addition of baking soda and used the analogy that the addition of each spoonful of baking soda to the water is like adding a blanket to the water.

In the second part of the experiment which also involved an endothermic reaction, this time using vinegar or lemon juice, she stated, "...heat changed the environment from a liquid to vinegar - from water to vinegar." Furthermore, she explained the rise in temperature in the reaction with baking soda and vinegar (which is supposed to be an endothermic reaction that absorbs heat from the water so that the temperature of the mixture drops) by stating that the reaction was "stronger".

> I. Why did the temperature go up?
> K. I don't know. It's a lot stronger...you can smell it and you can tell that it's a lot stronger.

In the last reaction which was an exothermic reaction using calcium chloride and water, she noted that "This time, instead of the water being stronger the calcium is stronger than water." She is unable to explain further in molecular terms but reverts back to the analogy of the blanket - the more that is put in, the hotter it gets.

Erin

Questionnaire

Erin's major observations of the experiment were that "...the calcium de chlorure (calcium chloride) with water raised the temperture also. The bicarbonate de soude (baking soda) with all the liquids lowered the temperature." Unlike Kristy she explained her observations:

> "The calcium de chlorure raised the temperature because there is a lot of action in the molecule and when the forces between the molecules are broken the heat goes into the environment (water). The bicarbonate de soude lowers the temperature because all the heat in the water is used to break the forces between the molecules."

Furthermore, Erin claimed that she did not find any parts of the experiment confusing but that some of the questions for the laboratory report were confusing. She also felt that "...it was easy to understand why the temperature was changing. This was because they were explained to me very well." She felt rushed during the experiment. She also wrote that the computer was helpful because "it shows you exactly when the temperature is rising and falling."

Her diagrams of the experiment showed two beakers - one with water and baking soda and the other with water and calcium chloride. She also drew molecules depicted as circles with a line between the being the force (O-O) and wrote that the water (heat) breaks the force. For the diagram with water and calcium chloride, she depicted the force as being different and that the heat between the forces goes into the water.

Laboratory report

When asked "Did the results look the way you thought they would?", Erin wrote " No, I think that it goes down automatically and doesn't go up before going down." She recognized the importance of measuring the temperature of the water before beginning the experimnent. She noted that during the reaction from the first mixing of baking soda and water, "the temperature doesn't change as fast." She explained the discrepancy between her expectations and the results by stating that "the temperature goes higher because there is a lot of action in the baking soda and when the water breaks the molecules, the heat goes into the environment". She then explains the consequent drop in temperature: "the temperature drops because the heat is used to break the forces between the molecules of baking soda." She further reasoned that the ratio between baking soda and water cannot be increased indefinitely to produce lower and lower teamperatures because "the dissolving is all finished and all the heat is used that is needed to be used."
She concluded that for this part of the experiment that "When there is more baking soda the temperature is higher

but when there is more water, the temperature is lower...The heat is used to break the forces between the molecules."

For the second part of the experiment which combined baking soda with either vinegar or lemon juice in different proportions, she defined an endothermic reaction as being "...when the chemistry takes the heat from the environment. Because of this reaction the mixture feels colder." She noted that for this part of the experiment, the mixture became colder right away. She accounted for this difference by writing "because there is different liquids and the liquids are more different." It would be interesting to know why she thinks that different liquids are a factor.

For the third part of the experiment Erin explained the results of the experiment as follows:

> "The exothermic reaction began when you add the calcium chloride. The reaction is finished when the temperature stays the same. It's because when the calcium chloride is put in the water, the water begins to break the forces between the molecules. When all the forces are broken and all the heat is in the environment the reaction is finished."

She described the difference between between the reactions as:

"If the temperature on the strip chart rises, it's an exothermic reaction. If the temperature of the reaction drops, it's an endothermic reaction...In an endothermic reaction heat is needed. In an exothermic reaction has a lot of heat."

Test

Like Kristy, Erin answered the test question using the graphical interpretation: "In an endothermic reaction the temperature drops. In an exothermic reaction the temperature rises. Endothermic - salt and water. Exothermic - matches and oxygen." For the second question she gave a rough representation of the graphs for each reaction and explained that for an endothermic reaction the heat in the molecules is used to break the forces between the molecules and that for the exothermic reaction the heat in the molecules goes in the environment.

Interview

Erin was more comfortable than Kristy talking about the reactions in molecular terms. She summarized what has happened in the experiments by stating: "The molecules were broken up by the heat of the liquid, in the liquid and the temperature changed according to what the substances were." When asked about how she knew that the heat breaks up the forces between the molecules when she could not see them, she referred to the notes and the explanations given by the teacher. She later explained that there are forces in between the molecules because: "It's matter and there are forces in all matter to hold it together." She saw the experiment as proving the notes and lectures given in class. However, she found it difficult to explain discrepancies between her notes and her experimental data:

> E. "The temperature...I thought it was going to go down right away but it went up first and then started going down.
> I. Why do you think it went up?
> E. Why do I think? I don't know.
> I. No idea?
> E. No.

Moreover, in the second part of the experiment, she veered away from explaining her results in molecular terms but was caught up with the visible events of the experiment. She believed that the temperature went down right away because the vinegar was stronger than water. She made this claim because of the visible reaction - "It fizzed alot more. There's bubbles and everything."

In the third part of the experiment, she stated that the rise in temperature was due to "...more energy in the calcium and when it breaks, it, the energy goes into the water which heats the water. It's exothermic." Although she realizes that forces (molecular bonds) are being broken and energy is being used to break the bonds, she did not talk about new bonds being formed as a result of the reaction which also release energy. She was clear about the difference between exothermic and endothermic reactions.

Interestingly, she also discussed the advantage of using a computer in this type of experiment: "...it's all there on the computer and it's actually taken down and it shows the graph as you went along. You can make a graph which shows you too, but during the experiment you kinda know what's going on."

Jerome

Questionnaire

The questionnaire revealed very little about Jerome's thinking. He did not respond to the question about the major observations of the experiment but for the explanation of the observations he wrote, " You add the substances together and put the sonde (probe) in the cup and observe on the computer." He claimed that he understood "everything because (he) read the experiment." He answered the rest of the questions very generally.

Laboratory report

Like the other two students, Jerome did not have difficulty explaining the importance of establishing a starting temperature before beginning the experiment. He accounted for his results in this part of the experiment as follows:

> "When you have a lot of baking soda and there isn't a lot of water the temperature rises. The reason for this is because that there is alot of energy and you don't use a lot of energy and there is heat left in the environment. But you have a lot of water it doesn't have a lot of baking soda, the temperature drops because you use a lot of energy and there isn't heat in the environment."

He also claimed that the increase in temperature could be due to the observation that "there is more baking soda for water and water is soaked up in the baking soda and there isn't enough heat to make a reaction and the thermometer is only measuring the temperature of the baking soda."

For the second part of the experiment, he defined an endothermic reaction using the same wording as Erin: "The endothermic reaction is when the chemistry takes the heat from the environment, because of this reaction, the mixture feels colder." He also discussed his results stating that the lemon juice or vinegar "overcomes" the baking soda and that "different things used" will cause different reactions. He then explained the reaction that occurs when rock salt is added to the ice in an ice cream maker by writing that "when you add salt to ice cream, it makes a reaction and the heat in the liquid and uses it to break the forces and the temperature drops past zero degrees and it is solid."

One interesting factor about Jerome's report was that his group did not get to the third part of the experiment according to his comments in the interview, yet he answered the questions for this part. He wrote:

> "An endothermic reaction is when the temperature of the mixture drops. An exothermic reaction is when it rises. But I think that the graph and the experiment don't prove this except for the second part of the experiment."

His response after doing this third part (I had the students repeat this part of the experiment at a later date) was "an endothermic reaction is when the temperature decreases and exothermic is when it increases. The experiment helped me because it is right, the experiment is exothermic." He also noted the exact time that the reaction started and finished although he did not justify these times.

Test

Jerome's answer for the first question was brief - "For endothermic the temperature drops and exothermic the temperature rises." He does not give examples. His answer to the second question included two rough graphs of the reactions and an explanation that the endothermic reaction takes the heat from the environment and there isn't any heat that's left in the water. He gave no other explanation for the exothermic reaction.

Interview

For the first part of the experiment he explained that the drop in temperature was due to the fact that heat energy was used to break the forces between the molecules. Like Kristy, he was confused about the term environment:

> "The temperature would go down because all the heat is being used to break the forces in between the molecules and the heat goes into the environment and there isn't any heat left in the water and the temperature goes down."

He believed that forces (chemical bonds) were being broken but could not tell why in his own words - he reverted to the explanations given in class. Moreover, he said that when more baking soda was added to the water, the mixture was no longer a liquid. He was having a difficult time explaining the increase in temperature in his results:

> "You see when we had three tablespoons of water and just maybe one of baking soda it would go down and when we had more of baking soda and maybe one of water then I think it went up because it wasn't a liquid anymore, so there wasn't really any heat in the water, it was part of new water, we just measured the temperature, so..."

He also claimed that when the heat energy was used up the temperature started to rise again: "Like at first it went down then when all the water had gone down, it went back up." Although he realized that the water is important for the reaction, he did not see the relationship between the amount of baking soda and water and the rise or fall of the temperature.

Jerome's ideas were based on his comprehension of the explanations in class and what he has been told by his parents.

At that time, Jerome's group did not get to the third part of the experiment (the exothermic reaction) but he predicted that the temperature would probably have dropped if there was more water and go up if there was less water.

He did not immediately distinguish between the words endothermic and exothermic.

The second time that I interviewed Jerome after his group completed the third part of the experiment, he explained what he did in the experiment. When I asked him about the variables of the experiment which he had not identified in his laboratory report, he wanted me to ask the questions in French. Jerome' desire to have the questions asked to him in French may indicate that his conceptualization and learning of the scientific principle is in this language and thus he would be more at ease discussing it in French. We identified the variables of the experiment together and then discussed his observations. He said that the mixture got hotter and hotter and after awhile it started to go down. His reason for this was that "Probably when it started to go down all the force would be used up." When asked what would happen if there was more water than calcium chloride, he responded that the reaction would be faster and that if there were more calcium chloride than water, the mixture would get hotter. He believed that it would get hotter "coz there's more molecules and then when they get broken it makes more and more heat. And after a while it would take longer coz... loses some heat for the forces, for them to break." He realized that water was also important for the reaction to occur because when asked if calcium chloride could be added indefinitely to cause an indefinite rise in temperture, he stated:

> "Don't think so coz after awhile there wouldn't be enough water, it would all soak up the water. Coz that's what happened in the last experiment when you are able to make up your own experiment...you probably need at least 25% of water before it would actually work."

Followup

At the end of the year, the students reviewed for the final examination. During the review, they were asked orally to describe the difference between an endothermic and exothermic reaction. The students noted that there was a difference in the temperatures, that is, during an endothermic reaction, the temperature drops and for an exothermic reaction the temperature rises. Two students remarked that heat is absorbed or liberated. No students discussed the role of chemical bonds in the reactions. It seems that the students need more experience with the principle of chemical bonding and more opportunities to discuss it before they will internalize and be able to apply it.

CHAPTER FIVE

DISCUSSION OF RESULTS

In this section, I will discuss the implications of my research in relation to the reseach questions that were specified at the beginning of this study and examine how my teaching strategies could be improved in order to promote student conceptualizations.

Grade Eight Use of Computer-Generated Data

One of my research questions was, "How do Grade Eight students use computer - generated data to understand endothermic and exothermic reactions?" My observations indicated that students seem to enjoy working with the computer and that it is a mediator for student ideas. From the questionnaires, students noted:

- "I thought that I understood the concept pretty well because I could see what was happening on the computer."

- "It was easy because we were using the computer to get the temperature and not a thermometre."

- "The part which was really easy is the graph on the computer because the computer shows you alot."

- "Visually seeing the temperature rise made it easy to understand."

These observations support PIMMS (1987) assertions that, "...it (the computer) reduces the tedium involved in the collection of data and allows students to devote more time to an understanding of the concepts." (p.6) Because students did not have to collect the data, they were able to watch the movement of the curve of the graph. Doing this, they could immediately estimate the rate of reaction, the direction of temperature change and the extent of the change. Erin too, noted this in her interview when she stated that, " ...it's all there on the computer and it shows the graph as you went along. You can make a graph after which shows you too, but during the experiment you kinda know what's going on."

Seeing the temperature change on a graph as the reaction occured seemed to enable students to make more accurate predictions, that is, whether the temperature would rise or fall with varying proportions of substance. During the interviews, most students were able to accurately predict and explain what would happen to the temperature if the proportions of water and calcium chloride were varied by mentally extrapolating the results. For example, when Jerome was asked what would happen if there was a higher proportion of water than of calcium chloride, he stated that the temperature would increase but not as high if there had been more calcium chloride to water. He attributed this to the increased number of molecules that would be broken if there was more calcium chloride.

Furthermore, because the students did not have to devote time to data collection since the data was computer - generated, they were able to observe what was occuring in the styrofoam cup where the chemicals were added. They were impressed by the "fizzy" reaction of the baking soda and vinegar. Some students were distracted by the visible event and interpreted the "fizzing" as being "stronger" and releasing heat when in fact heat was being absorbed during the reaction. One student stated, "...when we put it in it caused a reaction, it all came up...it fizzed a lot...and then it just dissolves, like all the energy came out of it or something because most of all when it reacted." This physical reaction influenced the students' thinking about the principle. Some students used the theory to account for the temperature drop and the "fizzing". An example of this is Jerome's explanation, "because if the forces between the molecules were strong then it would either make a big reaction and the temperature would go down or it would break the forces and the temperature would still go down."
For other students, although, they could see on the computer screen that the temperature was decreasing as the reaction

progressed, they interpreted the "fizzing" of the substances to mean that energy would be given off and that the mixture would get hotter and remembered only this. This concurs with Duckworth's (1987) observation that children do not even see conflicts in their own thinking. More student sharing of information in small groups might have averted this problem since learning can be viewed as a social construction. In comparing answers and ideas, students can assess their own understandings in light of others'.

Also, because the data were collected by the computer, students were able to repeat the parts of the experiment that they did not understand the first time. In addition, they could work at their own pace, thereby allowing them to watch the graphs, develop their ideas about what is occuring, and answer the questions about the experiment as they do it. From my experience, students tend to devote their attention to the data collection and wait until the experiment has been completed before analyzing and answering any questions. During the experiment, I noted that some of the groups were attempting to answer the questions in the laboratory report while in the process of doing the experiment. Thus, I think that these students were able to use the questions as a guide for their observations and analysis of the data. Using the questions in this manner, may have helped some students to really think about what was occuring in the reaction and "to keep the underlying goal of (the) lab investigation in sight" (Stein,1987,p.227).

Another advantage of using the computer - generated data was that students were able to observe the speed of the temperature change as proportions and chemicals varied. This would have been difficult to monitor using conventional means since many students probably would have found it too demanding to monitor both the temperature change and the rate of reaction. From my study, students using the computer seemed to be able to make comparisons in reactions. During the interview, one student stated from her observations with vinegar and baking soda that the temperature went down much faster "...because the bigger the reaction, the faster the temperature goes down."

However, while using the computer-generated data seemed to promote the students' understanding of the absorption and liberation of heat with the combination of different chemicals, it did not really help them with the scientific terminology - endothermic and exothermic. On the questionnaires, laboratory reports and tests, some students still confused the terms although they were able to describe what was happening in a reaction depending on the temperature curve. For example, Jerome was able to describe what happens when the curve of the graph drops: "the temperature would go down because all the heat is being used to break the forces in between the molecules and then the heat goes into the environment and the water then it goes down..." However, when he was asked "So what do you think is the differnce between endothermic and exothermic reactions?", he responded, "Well, I don't really know that one too well." The terminology could have been linked to the data if I had explained to them beforehand the meanings of the prefixes "endo" and "exo" - "endo" being associated with enter (heat is absorbed during the reaction) and "exo" being associated with exit (heat is liberated during the reaction). If heat "enters" or is absorbed from the solvent into the solute, the solution becomes colder. If the heat created from the mixing of the solute and solvent "exits" or is liberated into the solution, the temperature of the solution will rise. This explanation combined with the other mediating activities (ex. the dramatization of the reactions) could assist students in linking the definitions to the computer-generated data.

One of the major drawbacks that I encountered was the wording of the questions in the laboratory handouts. My Grade Eight late immersion students found the syntax and vocabulary too difficult and this may have distracted them from thinking about the computer - generated data since they would be too busy trying to interpret the questions. As I circulated around the laboratory during experiment, much of my time was spent helping the students read the procedures and decipher the wording of the questions. The students as learners were faced with the challenge of not only trying to make sense of the scientific language but also of the French. My role as a teacher should have been to facilitate discussion of the questions beforehand, so that students would have the opportunity to discourse, to "talk science" and with the help of each another, find meaning in the questions.

Another problem that I encountered was the deviation of the computer - generated data from the students' expectations (and mine). As my "critical" friend, Leslie noted, there was a range of hypotheses for this discrepancy. I later realized that the water temperature at the beginning of the experiment was not at room temperature. Students used tap water which was either hotter or colder. This would have affected their results. I later discussed with the students some possible reasons for some of their results, but some students retained the images of what occured in their experiments and this may have led to their confusion of the terms endothermic and exothermic. Further experimentation using different starting temperatures of water could have enabled students to reconstruct their thinking.

The graphs that the students handed in as part of their laboratory reports depicted the lowest temperatures of different proportions of the chemicals used for the endothermic reaction. These graphs were not the same as those that the students had seen on the computer screen. The purpose of these student made graphs was to make comparisons of the lowest temperature as the proportions of the substances changed. These graphs did not show the temperature curve for each proportion. However, for the exothermic reaction, the students were required to go to the data table of the computer program upon completion of the reaction, copy the results and reproduce a similar graph to the one that they saw on the computer screen. If students referred to these graphs to review the experiments and did not read them carefully, they may have been confused by the results. The problem with this particular computer program is that while it is easy to use, it does not print the graphs for the students to refer to at a later date. If students did retain inaccurate information in their long term memory, such as the "fizzing" of the solution meaning that heat was being liberated, and if they could not review the experimental graphs, they would not make an effort to reconstruct their ideas. Students do need notes, graphs, and diagrams to assist them in making sense of the scientific principle and language in conjunction with other mediating experiences.

Principles of Chemical Knowledge for Endothermic and Exothermic Reactions

My second research question was "What understandings of chemical principles do students construct about endothermic and exothermic reactions?"
Before researching this question, I asked myself "How would students think about these reactions? What would be their levels of conceptualization? What would be the easiest and hardest ideas for them to understand?" At the outset of the study where I tended to be more developmental in my thinking about student conceptualization, it seemed to me that the more concrete notions would be the easiest for them to comprehend, that is, the things that they could touch, feel, see or smell. The harder levels became progressively more abstract.

The principles of chemical knowledge that had been outlined earlier in this study were:

1. Observable/Concrete
2. Interpretation of Graphs
3. Concept of Absorption or Liberation of Heat
4. Molecular Level: Changing of Chemical Bonds
5. Terminology: Endothermic and Exothermic

These categories seemed to be accurate except for the position of the fifth category. Most of the students were able to use the terms endothermic and exothermic in their explanations although using them be it in tests, written reports or even in verbal sentences, did not necessarily indicate comprehension of what is occuring during the reaction. Students could have simply memorized the words without internalizing the principle. The scientific language does not necessarily enter into their own "voice" or language. This category should have been second or third in the hierarchy of understanding.

The majority of students were able to interpret the meaning of the computer generated graphs. That is, when the curve goes up, the temperature rises, when the curve goes down, the temperature drops and when the curve does not change the temperature is constant. This may be attributed to what they had learned last year in science with thermometers. I can not be certain however, since I did not look at the students' preconceptions before the experiment.

During the experiment, the students were fascinated by the "fizzing" of the baking soda and vinegar mixture and interpreted this to be a "bigger" reaction because there was more visible "action" in the molecules. Some students thought that because there was more "action", the temperature of the mixture would go up. Furthermore, according to the questionnaires, very few students associated endothermic and exothermic reactions with the absorption or liberation of heat or with the breaking and reformation of chemical bonds immediately upon completion of the experiment. However, many of the students interviewed discussed the use of heat energy in the breaking of "forces" or chemical bonds. In the interview, unlike the questionnaires, students were prompted to give reasons for their statements and had more time to think about possible explanations. While the interviews lasted 20-25 minutes, the questionnaires were given 5-10 minutes before the end of the class.

By the time of the test many more students seemed to be able to make this association:

Absorption or Liberation of Heat

- Questionnaire - 14%
- Test - 48%

Chemical Bonds

- Questionnaire - 18%
- Test - 24%

The reason for this change is difficult to ascertain but it may be because students studied and memorized their notes for the test or they may have taken the time to read over their notes and laboratory reports. They could have then made the connection between what they had seen on the graphs and what was actually happening with the chemicals. The test results gave me the product of their studying, and what aspects of the principle they deemed important to remember. It did not provide me with the process that students used to try to understand the principle and the mediating activities that enhanced their conceptualizations.

The laboratory reports did not give a clear indication of individual student reasoning because several students wrote similar or the same answers which may indicate that they had discussed the results of the experiment with each other or that they simply copied the answers from each other. The interviews and Leslie's observations were probably more reliable gauges of student reasoning. Indeed, I found that my groupings of students from their questionnaires, based on Hesse's categories of naive, transitional and chemist's understanding were inaccurate. I had initially perceived Kristy as a student who possessed a naive understanding of chemistry but during the interview, she talked about the use of heat energy in the breaking of forces (bonds) between the molecules of a substance. She incorrectly used the word "environment" which was from her notes and did not connect it to the water. She was concrete in some of her observations such as "smelling" that a reaction was stronger. The use of an analogy to explain her results on the exothermic reaction indicates her attempt to make the scientific language part of her own language.

Jerome, too, possessed some knowledge that was more advanced. He attributed this knowledge to what he had learned in class as well as to what his parents had told him. Clearly, Jerome's conceptualizations have been influenced by his social contacts - his parents, his classmates, etc. In order to clarify his thoughts, and reconceptualize others, he needs to verbalize his ideas to others and get feedback from them. This is consistent with Lemke's (1990) views on language,

> "Learning is an essentially social process. Talking to one another, in small group work or even in side-conversations, gives students an opportunity to talk science in a different way, free of the pressure of talking science with the teacher." (p.169)

Erin had little difficulty discussing heat energy and chemical bonding but still was partial to the observable characteristics of the reactions. She too had some difficulty resolving her ideas about the reactions to the experimental results. Yet her reasoning about the existence of chemical bonds was logical to her and formed the base for her comprehension of endothermic and exothermic reactions:

I. How do you know there are forces between the molecules?
E. I just know it.
I. You know it and it makes sense to you.
E. Yeah, because it's a material and there are forces in all material.
I. You mean something has to hold it together?
E. Right.

The students' conceptualizations did not really conform to the hierarchy that I had constructed. Their thinking tended to be more non-linear and fluid rather than in discrete categories with defined boundaries. For example, they did not need to have the observable events of the experiment to be able to interpret the computer -generated graphs. They could draw upon past experience to make sense of the graphs since they had already worked with graphs in previous grades. Moreover, my labelling of students using Hesse's categories was not indicative of the students' abilities to conceptualize. Students whom I had perceived as being "naive" thinkers displayed levels of thinking that approached the chemist's knowledge.

Influences of Teacher Strategies on Students' Knowledge Constructions of Endothermic and Exothermic Reactions

In analyzing my own instruction, I discovered that much of my teaching was based on the transmission of concepts. That is, the students would copy the definitions and explanations of the concepts, do an experiment to prove the notes and then regurgitiate the material on a very factual based test. While there is a place for the transmission of knowledge in science instruction, in order for students to form their own reality of the concept, the teacher needs to provide learning settings that stimulate students' thinking and if necessary, challenge the conceptions that they already have. However, as teachers we do not want the students to construct any reality but one that approaches our own or the scientist's. We want to promote "science thinking" while at the same time, to have students display understanding on their own terms. Thus, the transmission of definitions and ideas is of necessity but should not be the **only** source for student reasoning because in such a case learning becomes memorization. Socialization with other students and other adults enable students to compare and construct their ideas. This idea had important ramifications for teacher and student roles and the classroom environment. (This is discussed in the next section)

My "critical" friend felt that the portrayal of students as molecules in a reaction seemed to have a positive impact on student comprehension. Students seem to remember those things in which they are actively engaged in. From the videotape, one of the students was explaining this activity to Leslie during the experiment in order to explain how she knew that forces were being broken and reformed and that energy from the water was involved. This student stated that, "She did it with us as people...like she put , how many of us, five? She put two in pairs...and there was one person beside them...they were the molecules and they split the energy and then...and then they'd go together and make new pairs..."

This activity seemed to be conducive to the stimulation of this students' reasoning. It seemed to be for her, the link between the notes and the experimental data.

As was mentioned earlier, students tended to memorize the definitions of endothermic and exothermic reactions. Some of the students confused the terms. This was probably due to my method of transmitting this information. Because of the method of instruction that I chose, students became limited to the "cohesive" and "robust" understandings of the concept (see p.11). As noted in the test results, the majority of the students could not give any commonplace examples of endothermic and exothermic reactions. They could not construct common uses for the reactions from the scientific principle. Instead of simply giving the students the definitions, I could have provided mediating activities which would help them construct their own meanings. That is, starting off with everyday examples of these reactions without naming them and getting the students to come up with other examples. Lemke (1990) states that

> Teachers should ensure that students' own ideas about each topic are discussed, so that alternative views on the subject are "on the table" for everyone. Teachers should show respect for commonsense views and alternative religious or cultural views while presenting the view of science and the reasons for that view. (p.171)

Knowing students' preconceptions about a topic assists the teacher in developing instructional settings that enhance the development of student reasoning. Analogies such as the one Kristy used where the baking soda was like a blanket that generated heat when put upon the water can be examined and analyzed as a class. Students could come up with their own analogies that other students can use that may help them conceptualize the reactions. Coffman and Tanis (1990) have used anologies in their classes to explain the kinetic theory and they found that

> ...our analogy has increased understanding and that students were far more able to move from a concrete example to abstract theory than previous years' students had been. Perhaps we should explore more creative analogies with students before we ask them to think abstractly, even at the secondary level (p.29).

Once students were able to give examples and contexts of reactions that gave off heat and absorbed heat, we could then discuss what the reaction would look like on a temperature graph. The students could be put in small groups to discuss hypotheses for why certain substances liberate heat while others absorb heat. As a group we could talk about chemical bonding and then do the activity where the students acted as molecules. Hapkiewicz (1991) also suggests simple demonstrations such as a ball-and-stick model of a molecule where students separate the atoms. They would feel that work had to be done to separate the atoms. Also, the two atoms are connected, so there must be some attractive force holding them together.

Furthermore, it is important for students to verbalize their thoughts to each other as well as to the teacher.

This verbalization is especially important in a French immersion setting which is already challenging to most students. Not only do they need the practice of expressing themselves in a second language but they have to learn to communicate using the scientific language. "The language of science is not part of students' native language...and it sounds foreign and uncomfortable to most students until they have practiced using it for a long time." (Lemke,1990,p.172) Students could try explaining the terms in colloquial French before using the scientific terms. Discussion in English with parents or friends should be encouraged since, if they can explain the concept in English to others, they probably have a fair understanding of what is happening in class. Keeping a journal in English would also be useful for both the teacher and the student since it may provide a means of self-reflection for the student and a gauge of the student's understanding for the teacher. The teacher may also write notes in it to the student which could help personalize instruction. However, both the students and the teacher need to be instructed in the use of a journal in class and be prepared to make time for it. A collaboration with the English teacher may make journals a feasible procedure in the science classroom. The students could write their journals in English during the English class and be taught how to write a journal since this is in the domain of this subject. The journals could then be read by the science teacher.

My strategy of giving the students a "cookbook" type science experiment did not really promote student conceptualization. By telling them ahead of time which reaction would be endothermic or exothermic, I was helping to foster the idea that the purpose of the laboratories was to prove the theory. I should have provided them with the substances, given them just enough instruction to help them get started and then they could continue from there and discover for themselves which reaction was exothermic or exothermic. I would simplify the questions and instructions so that I could spend more time monitoring their learning rather than giving instructions. I thought that I would save time by giving the students the instructions but instead I wasted time since the students had to repeat one part of the experiment.

I believe that it was a good idea for the students to answer the questions as they did the experiment rather than after because I think this procedure could be helpful in guiding them to the "scientist's reality" and making them reflect on what is happening in the reaction. They would "appropriate" the language of science in context. I think, however, that the wording of the questions for the laboratory report were too leading and difficult for the students. I noted this in my observations of the class as I circulated around during the laboratory.

When the results of the data did not match the students' expectations, I should have used this event as a learning opportunity. Students could have discussed in small groups and brainstormed hypotheses for the discrepancy. They could have then tested their hypotheses on the computer. "Thus the emphasis in the laboratory may shift from record-keeping and rote procedures to the procedural tasks of planning, testing and revising hypotheses which underlie all problem solving" (Stein,1987,p.227).

Thus, through analysis of my teaching strategies, I was able to determine where I could have provided or improved on activities that would help develop student conceptualizations of the scientific principle. Knowing more about the student has revealed more to me about my teaching and my teaching perspective.

CHAPTER SIX

PERSONAL REFLECTIONS

From this study, I learned much about student conceptualizations, my own teaching and how computer-generated data mediated student thinking. I also discovered that my perception of their thinking was not accurate. Student reasoning cannot be accurately assessed strictly by laboratory reports and tests. Those students who may be labelled as naive may have more advanced understandings that the teacher can draw upon. Moreover, a students' ideas about science may range from naive to sophisticated depending upon the situation. Students will utilize scientific theories and concepts that they have internalized if they believe that the situation merits it or if the teacher expects it, whether they have understood them or not. Students will use analogies to make sense of results. Analogies, can be considered as being the student's attempt to bring the scientific language to their way of thinking and may range from simple to more complex.

I found researching my own teaching to be a productive undertaking. I have discovered that the way I was teaching was a product of the way that I had been taught myself and that I was continuing this tradition of transmission teaching. I know now that the direct transmission of knowledge is a small part of concept building and that students need to be provided with other experiences that will enable them to build realities that concur with our own. We cannot force our understandings upon them. Moreover, in order to promote student conceptualization through the use of mediating activities, the role of the teacher and how teachers are perceived by students need to be examined. The teacher should be seen as a facilitator of student thinking and activities rather than seen as the "giver of marks and scientific expert". Students who are so concerned about marks that they will not risk being wrong or feel intimidated by the teacher will be uneasy or unwilling to reveal their thoughts and ideas and open themselves to the opportunity of discourse. It is through discourse with other students as well as the teacher and other adults that students can conceptualize and restructure their ideas.

Other factors need to be considered here as well. Discipline, time constraints, school philosophies and the availability of resourses are possible obstacles that may present themselves. I know that I try very much to be in control of all student activities and that I have a low tolerance to noise in the class. Evidently, being that student discourse is an important aspect in the development of student ideas, I will need to be more tolerant of student talk and plan for more small group and whole group discussions. However, students at the junior high level enjoy socializing about subjects other than science so it may be difficult to ensure that they are all on task.

Another problem is my school philosophy. Because the school is French immersion, both students and teachers are expected to speak only French in the classroom. This makes it difficult for the teacher to assess student comprehension thoroughly since students express themselves best in their mother language. The students are also faced with two challenges - discoursing in the language of science and in their second language. Using Leslie as another source of information is one way of circumventing this problem since as an English teacher she was able to discourse with the students in English.

Another big factor is time. The curriculum covers a diverse number of topics and teachers are expected to teach the students all of them. With large class sizes, a diversity of students, with many topics to cover, making time to interview and to research students' thinking is difficult.

Despite these problems, with school support and professional development, the exploration of students' conceptualizations and the examination of teacher's own teaching can become valid activities in the classroom . Teachers can take workshops about constructivist theory and strategies from other teachers or at the university given the time and the support. They can explore their thinking as I have done through the writing of research papers and share their findings with others. Also, teachers can use the time allotted for professional development to enter other teacher's classrooms and act as "critical friends" and aid that teacher in examining students' conceptualizations. In the long run, the time spent on finding out what children know, how they learn, and how they perceive the teacher will save time as teachers will be able to plan for more effective activities that enable students to mediate their ideas and the scientific principle. Students will then no longer perceive science as being an inaccessible "club" with only elite members of the class being able to join and speak the scientific language but will be able to appropriate the language and make it their own. Science will become something that makes sense to them.

The reconciliation of practice and theory has not been an easy task for me. Three different "lenses" have been used to look at my practice. These were the children's conceptualizations in science; learning as a social/mediation process; and teacher reflections. What these lenses revealed have been summarized in the tables that follow. On one side I have described my interpretation of the constructivist theory and on the other, the aspects of my practice which I believe apply or can be improved upon in light of this theory.

Thus, this study demonstrates the importance of teachers looking at their own teaching. Vicariously, through the experiences of others, we can learn about our own teaching and student learning.

IMPLICATIONS OF CHILDREN'S CONCEPTUALIZATIONS IN SCIENCE

Theoretical Perspective	Practical Implications
- Students require time to think, to make sense of what they learn, to share and negotiate their personal understanding with others so they can come to a common understanding of an event: clarify alternate understandings, elaborate, justify and evaluate personal understandings.	- Students memorize terms without necessarily understanding their meaning. Without the time and discourse to think about and organize their ideas; the students focus on marks rather than on understanding the scientific principles.
- Learners should be seen as active rather than passive agents-knowledge is constructed, not received.	- Students control their own learning-Students were distracted by the observable event (the "fizzing") and associated this with the rise in temperature (more energy) despite what they had learned in class.
- The learner regulates his/her own learning.	- Students enjoyed working with the computer and were able to construct relationships. They were able to predict what would happen to the temperature if proportions of substances changed.
-Knowledge is not a separate entity but is intimately associated with the action and experience of the learner.	- Teachers should not use Hesse's groupings to label students - students' knowledge is contextually based.

IMPLICATIONS OF CHILDREN'S CONCEPTUALIZATIONS IN SCIENCE

Theoretical Perspective	Practical Implications
- Math and Science involve the construction of relationships and patterns.	- Principles of chemical knowledge are not rigid categories and do not necessarily lead into each other. They are more transactional or fluid. - Learners use analogies to try to make sense of chemical principles and relate them to their own understandings and experiences.

IMPLICATIONS OF LEARNING AS A SOCIAL/MEDIATION PROCESS

Theoretical Perspective	Practical Implications
- The classroom should be a place of intellectual conversation where students and teacher discourse and negotiate meaning.	- More activities with small and large groups discussions should be implemented.
- Most learning is dependent upon language and communication.	- Student talk rather than teacher talk should be encouraged in the classroom. (perception of roles)
- Only the student knows what he has constructed, but such learning always takes place in a social context. - Learning is the product of self-organization and reorganization.	- The use of questionnaires can be used more frequently, ex. laboratory reports-the students were able to keep the underlying goal of the laboratory experiment in sight and used the questions to discourse with other students in their group to construct and reconstruct their ideas.
- Teachers cannot put ideas into students' heads but can provide the mediating activities that promote conceptualizations.	- The computer can be used as a mediating activity to assist students in understanding what is happening during a chemical reaction. Ex. Students immediately estimated rate of reaction, direction of temperature change and the extent of the change. It also allowed for repetition of the experiment. - Other mediating activities already used in class: notes, graphs, diagrams.

IMPLICATIONS OF LEARNING AS A SOCIAL/MEDIATION PROCESS

Theoretical Pespective	Practical Implications
	- The use of dramatics proved be a good mediating activity. Students tend to remember those activities they are actively involved in.
	- Teachers should encourage students to share their ideas about what they learn in science with significant others such as parents. ex. Jerome claimed that he got some of his ideas from discussions with his parents.

IMPLICATIONS OF TEACHER REFLECTIONS

Theoretical Perspective	Practical Implications
- Teacher should consider a change of traditional roles so that instead of transmitting knowledge, provide links between children's ideas and formal science.	- My role in the lab was that of a manager rather than facilitator- more emphasis needed on process rather than procedures.
- Teacher is more of an experimenter than follower of the given curriculum.	- Philosophical stance at the beginning of the study - transitional - more developmental (transmission) based than constructivist. Because of study, I am more aware of how constructivism can enter into my teaching strategies.
- Teacher should be a receiver, facilitator and sense maker of children's ideas and should develop mediating activities that challenge their ideas.	- It is important to develop activities that challenge the students' thinking but do not overly frustrate them so that they give up. Ex. The difficult vocabulary in the laboratory questions created too much disequilibrium for the students. They had to decipher the questions, make their observations and link them to the scientific principle.

IMPLICATIONS OF TEACHER REFLECTIONS

Theoretical Perspective	Practical Implications
- It is important to determine how students perceive the problem and why their paths towards solutions seem promising to them.	- I need to determine students' preconceptions since this was not seen in my regular teaching. I usually start with objectives and definitions. - I need to explore students' ideas more - interviews, journals, questionnaires.

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APPENDICES

Student Questionnaires
Example of Teacher Notes and Observations
A Sample of a Complete Interview Transcript
Critical Friend's Field Notes
Translation of Student Laboratory Reports
Letter of Consent

QUESTIONNAIRE ON STUDENT LEARNING

DIRECTIONS: Answer the questions as completely as possible based on the lessons learned in science class. If there is not enough room in the spaces provided, continue on the back of the page. If you don't know the terms in English, use the French words.

1. What theory did you learn in this part of the chemistry unit?

____

____

2. How do you know if the theory is right or wrong?

____

____

____

____

3. What aspects of the theory were confusing? (if any) Why was it confusing for you?

____

____

____

____

4. Name the things about the theory that were easy to understand. Why were they easy to understand for you?

____

____

____

____

5. How did you feel during the lessons about the theory? (confused, frustrated, glad you understood, determined to understand, etc.) ______________________________

____

____

6. Draw (if possible) what the scientific theory is about. Explain your drawings if necessary.

Questionnaire on Student learning

1. What ideas did you learn about in science today?

2. How did you learn them?

3. what things about the ideas did you not understand? Why?

4. What made the ideas easy to understand for you?

5. Draw the scientific ideas. Explain your diagrams if necessary.

date page

they'll have to be taught how. I have to choose 3 students to interview. I wonder if I should focus the videotaping on these 3 or even tell them that they will be interviewed. I'll have to get a hold of my advisors.

It's been difficult making time to write in this journal.

Nov. 15

date page

I find this class really challenging. I thought that the students would understand the concepts better if I used them as models. I tried to portray atoms as represented by certain students. I then diagrammed it graphically on the board. Unfortunately some of the kids were being silly and it was difficult to make it understandable. I think I'll try to make it more clear using more diagrams. I gave the questionnaire too late after my discussion of the subject. Of the students definitely, 4 understood the theories. 4 had

date page

a fair or good understanding - I'm beginning to suspect that the 2 others don't understand aren't really making much of an effort. I don't think they're reading their notes at night or reviewing. I think that alot of them cram for the tests + do alot of memorization rather than try to really understand what's going on. They didn't have enough time to write in their journals. The results were disappointing.

Nov. 24

date page

The students worked well in the lab on Fri. Eric + Darnell drank lemon juice from a beaker + got a detention. Filming of the video involved all the groups. I told the students that they wouldn't receive their report cards until they had finished + cleaned up the objects. I guess that's why they worked really well. Leslie went around asking them questions about what they were doing. She found that each gp had some idea about the reactions + what they were doing. They were date page

used up alot of baking soda. This time I ~~sent~~ put out water at room temperature as suggested by Dr. Williams. I wonder if the kids will make the connection. Anyways the kids noticed that they were to use water provided by me. Some asked why. I did not give them a straight answer but told them that the temperature of the water to start with would affect the reaction. I was really excited about the students' comments being so forwarded [illegible]

date page

listened to the results last night, I think the batteries had died b/c I couldn't get their reactions. Later said that she could do it from memory. It really helps to have a supportive critical friend. I hope to have a chance to look at the video. I think I'll interview the grs first s̄ out seeing the video + then review it with them after having seen it.

VIDEO

date page

Students discussed with each other about procedures + amounts of material + responses to H's + what was happening on the screen

- had to ~~a~~ assist student c̄ the program to start

c̄ - Students were able to note right away ~~that~~ the temperature was changing

- Students made mistakes c̄ software such as resetting it when they didn't need to

- they figured that they were doing it wrong when the graph

date page

didn't get the results they expected as they did the expt.

- Students looked in the cups to see if there was anything happening

- Students were unsure what was supposed to be happening they asked ~~to~~ me if it was supposed to be like this.

- Students did the expts s̄ really reflecting on ~~the~~ the results

SAMPLE OF INTERVIEW

JEROME

T. What do you think so far of science?

S. It went good.

T. (Likes?)

S. I don't know... it's kind of fun.

T. Are you understanding everything?

S. There are some things I don't understand.

T. Like what?

S. I don't understand some of the names of the reactions.

T. You didn't get to (type) the mixture?

S. No.

T. What did you mean, what mixture did we do?

S. Like when you put gas in one together, it's not that I don't get it, it'd just that I always forget the names.

T. Oh. Which ones are the solute and which ones are the solvent?

S. Yeah, stiff like that.

T. How about this experiment, do you understand it?

S. Yeah, I think so.

T. What made you understand it it better than the one we did before... they're both endothermic and exothermic reactions.

S. Coz I already know it... yeah, about the endo- and exo- reactions.

T. So you thought this experiment would be exothermic. How come?

S. The hypothesis was it was going to be exothermic. Coz ot was easily known. Powder...

T. Calcium de chloro?

S. Yeah, calcium de chloro. So I thought it would be exothermic.

T. What do you mean by exothermic?

S. I mean the temp. goes down and then that's exothermic.

T. So when temp goes down what does that mean? It's getting colder or hotter?

S. Oh...(mumble mumble) the temp. went up. that's endo...

T. Temp. goes up. So okay ,so exo- means temp. goes up. Yeah.

S. Okay. So you didn't put independent variable, dependent variable or controlled variable. Can you fill it now? What did you control the experimant that's changed?

S. What I think is that my group went on longer and longer, like we didn't have to do this part right here. We didn't have to go that far. So I guess you could call that __________ de information sur la chart.

T. So the var. independent would be the what? Like what depends on what would change with the amount of info. that you get?

S. Say that one more time please.

T. You said that independent var. is amount of info., right? So if the dependent var. depends on the independent var. then what's the dependent var.? Usually the independent var. and the dependent var. are in the objective. Le termine sur la creation dans solution exothermique ou endothermique?

S. Could you say those things in French please?

T. Alors la variable de dependente depende da variable of independent. La Var. of independent c'est qu'elle que chose que tu choisi que que change _____ L'experience. Alors dit determiner sur la creation d'une solution east exothermique ou endothermique. Alors qu'est-ce que tu (contre) l'ici qui change, le type de solution ou le type de reaction?

S. Le type de solution.

T. Alors la var. of independent est quoi?

S. C'est la type de solution?

T. ...Alors la var, dependent is an exo- or endo- le type de reaction. Alors tu etes faites experience avec d'autre chose. Tu etes faites experience avec carbonate desoude et cette...avec CaCl. Quelle chose arreste constiante? Quand le deux essaie?

S. Meme group...

T. Okay, what did you do in this experiment?

S. We made the solution, then we put the little thing coming out of the computer that tested the temp. in the cup with the solution in it. And we'd look at one minute, we'd look at the temp. and then we'd go for one min. 30 sec., then 2 min., then 2 min.30 sec. and then you'd write the temp.

T. So what happened in this experiment? What were your results?

S. It started to go up like we got a lot harder from the beginning. then after awhile it started to go down just a little bit. Rest goes down at the end.

T. So that's what happened in the graph, right? So What's happening that you couldn't see/. That's what you saw in the computer. But what was happening in the solution that you couldn't see?

S. Probably when it started to go down all the force would be used up. Couldn't see it by the water, couldn't see it completely.

T. What do you mean by forces being used up?

S. They're all broken and la space________ was broken? And like all the heat that created heat in the______ and they're all...

T. What created heat?

S. The... like it kinda blew up, sort of?(mumble)

T. Which molecules blew up?

S. Pardon?

T. Which molecules separated, blew up? What did you use in your experiment, what was the solution?

S. CaCl and l'eau.

T. Which were the molecules that separated?

S. CaCl.

T. What happened to them, where did they go?

S. Into the environment.

T. Into the environment. What's the environment?

S. The water.

T. Okay, it went into the water. So what happened, what did it do to the water? Just floats around?

S. Not floating around, just the reaction was finishing? Just died down.

T. So the molecules of Ca Cl Separated and then it went into the water and it didn't do anything into the water? Did it float into the bottom or what?

S. No. I don't know. All my info. says that and all the other experiments it was like the same thing. It would get hotter and hotter into the(mumble).

T. Which other experiment?

S. The one... Couldn't think exactly what we did at that time. You had to have one exo= and one endo-, two graphs and a whole bunch of queations on it. The big one with lots of...

T. there's three parts of experiment. The first one was baking soda and water, the second was baking soda and lemon juice/vinegar, and the third one was this one. So the first one was baking soda and water, what kind of reaction was that?

S. I think it was exo-.

T. Exo-? The temp. went up?

S. No, no. sorry, endo-.

T. Endo? How can temp. go down in that one and go up in this one?

S. Coz force in molecules doesn't exactly...it was not as strong, like it didn't blow up as well so it just...so now it started off hotter and you go down. The force between the molecules wasn't strong.

T. So the force between the molecules are strong?

S. Aren't as strong?

T. So it's stronger here. What makes you think that?

S. I don't know. Somehow I think that they the forces in between the molecules and something would blow up and that would...9mumble) so they had to go down.

T. So what makes you think there are forces when you can't see them? How do you know there are forces in this book?

S. I don't know. All my info. says that and everybody thinks that it kinda proves it too.

T. How?

S. It doesn't exactly prove it but, it's possible.

T. What would happen if you had lots of water and not a lot of CaCl?

S. Water it would be a lot faster. I still think it would be exo-. It would go just barely hotter than when it started, then it starts to go down,

T. Are you telling me that it would get hotter faster or hotter slower?

S. Probably hotter at the same speed but wouldn't get as hot. It wouldn't be this temp., probably it would reach about right there.

T. What makes you say that?

S. I don't know. It's sort of like a guess, but also I think the more CaCl the hotter it will get.

T. Why would it get hotter if more CaCl?

S. Coz there's more molecules and then when they get broken it makes more and more heat. And then after awhile it would take longer coz... lose some heat for the forces, for them to break.

T. Could you keep on adding CaCl and it would get hotter and hotter?

S. Don't think so coz after awhile there wouldn't be enough water, it would all soak up the water. Coz that's what happened in the last experiment when you are able to make up your own experiment.. You put in a lot of powder and just (taking the temp. of the powder becoz there was no water, just powder, no reaction, not enough water. You probably need at least 25% water before it would actually work.

T. Why is water important then?

S. Coz it makes it liquid...makes with reaction heat. It breaks down molecules.

T. The water breaks the molecules?

S. Yes.

T. What breaks molecules between CaCl? I thought molecules are broken in between. The forces broken? You said the forces are broken between the CaCl?

S. No, not exactly. It's when they're mixed together. When we added the...If you just...too much powder and none ofwater...it just doesn't...you just get temp. of powder.

T. What does water do when you mix with CaCl?

S. Makes reaction. If you just had one type of one thing instead of a mix together you can make a reaction sitting there, but when you add it with something... same with baking powder, leave it by itself, it's not gonna make a reaction. It needs vinegar before it can actually do something.

T. What does the vinegar give it? What's the point of adding water? Or Vinegar? Does it give something to the carbonate desoude or to the CaCl? What's happening with CaCl when you put it in water?

S. It's mixing with water and then heat breaks the force.

T. Where does heat come from?

S. Environment. The surroundings, the water. (Teacher prods student further) Oh! That's the water, it's giving off heat!

T. Good!

KRISTY

T. That's the experiment where you add CaCl and water. You measured temp. with water. Were you unhappy about missing experiment?

S. Yes. I didn't get to write it all out and understand what happened. It's a reaction and it's exo-T. What makes you say it's a reaction and it's exo-?

S. The temp. rises?

T. The temp. rises and then?

S. It's constant?...

T. What's happening here? You see in the computer screen the temp. goes up and you see it stay the same. What is exactly happening that you're not seeing in the reaction?

S. What's happening in front of the cup?

I wasn't really watching and nothing seemed to happen. I just watched what the computer said.

T. But why is the temp. rising then?

S. Coz you're adding CaCl.

T. What exactly did you do in the experiment?

S. We took water, added a teaspoon of CaCl and that's it. We just waited what the reaction was. The temp. went up.

T. Why do you think the temp. rose

S. Coz the CaCl was power ful.

T. What do you mean by power ful?

S. It's got certain functions in it that make it stronger than other things.

T. What does strength do; what does it matter if it's stronger or not?

S. (mumble)

T. So in this reaction what happened?

S. Temp. rose and stayed the same.

T. Temp. rose because Ca is more power ful?

S. She just added on baking powder. It wouldn't have been the same reaction coz it's not quite as power ful.

T. If you had baking soda what would happen?

S. Temp. would rise but not quite as much. And probably not as fast.

T. Why did temp rise again?

S. Coz CaCl made a reaction and temp. rose.

T. What kind of reaction was happening?

S. Exo-....temp. rises.

T. Why does it stay the same?

S. Coz it's taking up all energy it can.

T. What happened if you had lots of water but not that much CaCl?

S. Temp would rire as much.

T. How come?

S. Coz it depends on temp. of water but I guess that it's not as...you have to balance it out to make a bigger reaction or a smaller one.

T. Balance what out?

S. The amts of substance.

T. What would happen if you had lots of CaCl but not very much water?

S. Temp. would rise, I guess.

T. Even if you put tons of CaCl temp. keep rising?

S. No.

T. Why?

S. Coz not enough water to make a reaction. If you ____ up all the water then just powder.

T. So you need a certain amt of water?

S. Yep, to absorb the powder.

T. So the water absorbs the powder? That's what water is for then?

S. The powder sort of takes over the water though.

T. What do you mean takes over?

S. It's got the CaCl... it's stronger.

T. What does it do to the water? If it's stronger than water.

S. It takes over. I don't understand "takes over" What do you maen?

S. It goes over top? Like cool-aid. It takes up the space of the water. It's colored water. When you add CaCl the water sort of gets stronger. It's not water anymore. It's CaCl water!

T. So when it gives strength to the water the temp rises?

S. Yep.

T. What was your hypothesis in this experiment?

S. I thought it would be exo-.

T. What do you think the independent var. is? Objective is determine si la creation exo- ou endo-. What's your var independente?

S. The water.

T. The solution, right? What changes becoz of the solution?

S. The water.

T. What sense? When change solution, what changes?

S. the water?

T. What changes in the water?

The texture, the temp.?

S. The temp. and the inside.

T. So the temp change means the rxns endo- or exo-. (French explanation of the independent and dependent variables.) What do these say between the exp. and the other experiments?

S. Amount water, amount CaCl.

ERIN

T. Did you find anything diff from this exp. than last time?

S. No. I don't think so...it just went down about just a fer points and then it went up again so it was just the same.

T. Can you explain exactly what you did?

S. Like the points? We got the computer ready then we put 10 mL of water, put the _____ on the computer.

T. And what did you notice in the temp?

S. It went up.

T. How come?

S. Becoz when water breaks molecules of CaCl the heat from inside molecules goes into the water and heat it up. T. How's that diff from using baking soda and water?

S. In baking soda and water the water needs more heat or it uses all its heat to break the molecules. So it has to take more heat from the environment. And so it uses all the heat and the temp. goes down.

T. Where does it come from?

S. From the endo-?

T. Both.

S. From the environment?

T. What's the environment?

S. It's the water and then when it needs extra heat it comes the air.

T. So what's this part here?

S. I don't know why but it went down first and then it went back up. I think it was becoz when we were mixing it all up it just came out of the water or something.

T. Explain the part about the molecules again.

S. For the exo-? When it breaks down the molecules in the CaCl the heat from the inside the molecule goes into the water.

T. So the heat is absorbed. Heat is absorbed in the CaCl?

S. No. It's absorbed into the water but it comes from the molecules.

T. During the reaction the heat is given off or taken in?

S. Taken in to the water.

T. If Heat taken in the water...so the water gets hotter. Did the computer help you understand what's happening?

S. You can see exactly what's happening all the time. You don't have to take the temp. and write it down from the thermometer.

T. Can you see what's happening with the molecules?

S. No.

T. How do you know this is happening?

S. It's in the notes so you just understand from the notes.

T. How come this makes sense to you?

S. I don't know. It was explained a lot and so I understand and I read it from my notes a lot so I understand it.

T. Did you connect this with the past?

S. Like last two years? Not really.

T. Just what you learned this year.

S. Yeah.

T. Okay.

JOURNAL - CRITICAL FRIEND

Wednesday, November 5, 1991

Rodelyn explained and demonstrated the procedure to the students. She had a very sore throat

Students sat in pairs or in groups of three and listened carefully.

They then proceeded to follow the instructions, and do the experiment which was to make a supersaturated solution of sugar and water, taking the temperature of the solution at the point where the supersaturated solution was reached.

Rodelyn turned on the burners as the students were ready, to heat the solution and note the temperature . When 50 degrees was reached they were to turn off the burners.

Several students could explain what they were doing, several could not.

My question was: do the students understand the purpose of the activity?

We tried out the video machine, and the librarian explained the techniques to the students...more to familiarize them with the idea of being video-taped than to actually tape them at this point.

Students cleaned and sat down to write up the experiment.

It was evident that half did NOT understand what they were doing and why....Rodelyn said that was to be expected, it was quite normal, at this point.

Wednesday, November 20, 1991

Rodelyn entered with students who attended to their assigned tasks immediately.

Rodelyn explained with cups in hand, directions to the experiment...good use of visuals, especially in a second language class.

Most students were paying attention, except for one who fiddled with his books, until his seatmate finally helped him find the pages in his book. After that, his eyes wandered all over the room, and he seemed not to be paying attention.

Some students clarified directions, verbally.

Rodelyn showed, with the computer and the screen what would happen . She explained when the temperature rises again,after it stabilizes at the lowest point, that is the time the experiment is over.

She explained, with overheads how to follow the experiments and how to fill in the sheets (results).

There were lots of directions to follow...some students were not paying attention, were gabbing during the explanations.

The students asked a few questions and then were told to go start.

Students worked in groups of 3 or 4.

Several groups were not working, but several groups were able to explain the experiment to me, showing understanding of what they were doing and the underlying scientific concepts.

I circulated amongst the students, feigning ignorance, and asking each group to explain what was happening - in English (I used the excuse: "I'm an L.A. teacher and don't understand, can you explain what you think is happening?"

I had some very interesting responses from , "I dunno" to "cause she (Rodelyn) said so", to "the temperature is <u>supposed</u> to go up (or down), but it didn't ...maybe we didn't measure correctly..." and " it gives off heat because the changing of molecules takes energy" and " because she (Rodelyn) made us be molecules...and we held on to each other..." etc.

There was very obviously a lot of thinking going on...a lot were uncertain of what the computer experiment was supposed to show...but most seemed to understand the exchange of molecular energy/heat in chemical reactions. They were able to guess why their experiments weren't working as they expected them to do (when that happened) with thought if not necessarily accuracy. It seemed to help the students "explain" what was happening to tell someone who they thought had no notion of what was going on, nor understood the language (how would an L.A. teacher know Science or French???). They were very patient and very precise in their explanations.

Friday, November 22, 1991

During this class, the students were repeating the experiment, but replacing the water with vinegar, then lemon juice. At the end, they replaced the bicarbonate of soda with calcium sulfate.

I attempted to tape the students' responses to my questions but the recorder malfunctioned part way through the period. The students for the most part ignored or weren't aware I was recording them and were quite candid. Towards the end, they became self-conscious, but they weren't recorded then, anyway!

I found that all the students by now had some notion of endothermic and exothermic reactions. They all had some theory of why the temperature of the liquid dropped - having to do with an exchange of energy from the liquid to the dry chemical. Some felt the temperature change was more dramatic because there was more "fizzing", more chemical reaction on this day than the day with the water. Some even ventured the speculation that the more dramatic temperature change had to do with the fact " that one is a base, and the other is an acid"....

It was evident to me, that in general, the students had assimilated more knowledge/ information about the movement of molecules, about heat release being a result of molecular energy expended, and about chemical interactions, generally , than they seemed to have at the beginning of these experiments. The single most noticeable event in the students' acquiring this knowledge seems to me to have been Rodelyn's having had them "act out" the role of molecules, previous to doing the experiments. I say this because so many of them told me about it, when I first talked to them. However, in retrospect, they all seemed much more knowledgable by the time the second set of experiments was over, than when they first began. They certainly were better able, on the whole, to verbalize an understanding of the principals Rodelyn was trying to get across to them.

TRANSLATION OF STUDENT LABORATORY REPORTS

Kristy:

A2. No, because the results were not what I thought.

vable/ rcle → A3. To compare the results of the proportions.

A4. There is not a reaction that you can see.

rpretation graphs → A5. The temperature decreases when you put more water.

A6. The temperature increases when you put more baking soda.

A7. The temperature increases with baking soda.

s absorbed / berated → A8. Because when the baking soda uses the heat it just uses all it can, not more.

A9. When you have more water compared with baking soda the temperature decreases.

cular level → A10. The heat is used to break the forces between the molecules.

B2. The gas that is produced is carbon dioxide.

B3. An endothermic reaction is when the temperature drops.

B4. The reaction is faster than the other experiment.

B5. The vinegar makes the biggest drop in temperature.

B6. Because all the heat is used to break the forces between the molecules of salt and there isn't any left.

B7. In this experiment we used different products than the first experiment. It makes a different reaction.

C1. When the temperature increases and when it stays the same.

C2. When the temperature drops and when it stays the same.

C3. You see if the temperature rises or drops.

C4. Baking soda is responsible for each reaction.

C5. An endothermic reaction is when the temperature drops.

An exothermic reaction is when the temperature increases.

It gives a chance to determine if the theory is correct.

entific
nology

Erin:

A2. No, I think that it goes down automatically and doesn't go up before going down.

A3. In order to know that the temperature goes higher or lower.

A4. The temperature doesn't change as fast.

A5. The temperature goes higher because there is alot of action in the baking soda and when the water breaks the molecules, the heat goes into the environment.

A6. The temperature drops because the heat is used to break the forces between the molecules of baking soda.

A7. See questions 5 and 6.

A8. The dissolving is finished and all the heat is used that is needed to be used.

A9. When there is more baking soda the temperature is higher but when there is more water, the temperature is lower.

A10. The heat is used to break the forces between the molecules.

B2. We made the gas carbon dioxide.

B3. An endothermic reaction is when the chemistry takes the heat from the environment. Because of this reaction the mixture feels colder.

B4. It was different because this mixture becomes colder right away.

B5. Mixture #2 caused the greatest drop in temperature because there is a greater amount of movement in the lemon juice than the water.

B6. The temperature of the water drops because all the heat is used to break the forces between the molecules.

B7. Because there is different liquids and the liquids are more different.

C1. The exothermic reaction begins when you add the water and it finishes when the temperature stays the same. I don't know why because I didn't look at the results on the computer.

C2. See #1.

C3. You know that the reaction is exothermic or endothermic when the graph goes higher it's exothermic and when the graph goes lower it's a reaction endothermic.

C4. The liquid is responsible for each reaction.

C5. An endothermic reaction is when the mixture drops and an exothermic reaction is when the mixture goes higher. The experiments helped because I could see the results on the computer.

Chris:

A2. When we added more water was the part that we had the response that I thought.

A3. To see if the temperature rises or falls.

A4. The only reaction is that the temperature drops.

A5. When the proportions have more baking soda the temperature decreases.

A6. The temperature increases by one or two.

A7. No answer.

A8. The temperature drops.

A9. Yes, when there is more water the temperature decreases.

A10. No answer.

B2. The gas that was produced was carbon dioxide.

B3. An endothermic reaction takes the heat and the environment becomes colder.

B4. The temperature has big differences and the reactions are different because we used lemon juice and vinegar.

B5. 1/3 (baking soda/water) because lemon juice and vinegar have less water.

B6. The ice cream froze.

B7. No answer.

C1. The exothermic reaction starts when we touched the space bar and finished when it stayed the same.

C2. The exothermic reaction started and finished like the exothermic reaction.

C3. The strip chart says if the reaction is fast or slow.

C4. Baking soda, vinegar, calcium chloride, lemon juice, water.

C5. No answer.

Jerome:

A2. No, it's different than I thought.

A3. It is important to get the temperature at the beginning of the experiment in order to see that the temperature becomes hot or cold.

A4. The temperature rises or falls.

A5. When you have more baking soda and not alot of water the temperature increases.

A6. When you have more water than baking soda the temperature drops.

A7. When you have alot of baking soda and there isn't alot of water the temperature rises. The reason for this is because that there is alot of energy and you don't use alot of energy and there is heat left in the environment. But you have alot of water it doesn't have alot of baking soda , the temperature drops because you use alot of energy and there isn't heat in the environment.

A8. The dissolving is finished when all the heat is used up.

A9. When you have more water than baking soda the temperature drops because but when you have more baking soda the temperature increases and I think that the reason for this is that there is more baking soda for water and water is soaked up in the baking soda and there isn't enough heat to make a reaction and the thermometer is only measuring the temperature of the baking soda.

A10. No answer.

B2. The gas is carbon dioxide.

B3. The endothermic reaction is when the chemistry takes the heat from the environment, because of this reaction the mixture feels colder.

B4. There are different things used and it is an endothermic reaction.

B5. When you have alot of lemon juice/vinegar because it overcomes the baking soda.

B6. When yo#u add salt to ice cream, it makes a reaction and the heat in the liquid and uses it to break the forces and the temperature drops past 0 degrees and it is solid.

D7. Because the forces between the molecules are stronger and the solution uses more heat in order to break the forces than in the first experiment.

C1. When the temperature begins to rise and it finishes when the temperature drops.

C2. It starts when the temperature begins to drop and it ends when the the temperature rises.

C3. When the temperature rises it's exothermic and when it drops it is endothermic.

C4. For endothermic it is baking soda and for exothermic it is calcium chloride.

C5. An endothermic reaction is when the temperature of the mixture drops. An exothermic reaction is when it rises. But I think that the graph and the experiment don't prove prove this except for the second part of the experiment.

Emily:

A2. The results obtained weren't what I thought.

A3. Because when you compare the results of the proportions.

A4. You can't see the reaction. It just mixes and goes.

A5. The temperature decreases.

A6. The temperature increases.

A7. The temperature increases with more baking soda.

A8. Because when the baking soda uses the heat it just uses what it can not more.

A9. When you have more water compared to baking soda the temperature drops.

A10. The heat is used to break the forces between the molecules.

B2. The gas produced is carbon dioxide.

B3. When the temperature drops.

B4. There is a faster reaction than the other experiment.

B5. The vinegar creates the greatest drop in temperature because the heat is used up faster.

B6. Because all the heat is used to break the forces between the salt molecules and there isn't anymore heat.

B7. Because we used different chemicals. ← best inference / different chemicals, different reaction

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C1. When the temperature rises and when it stays the same.

C2. When the temperature drops and when it stays the same.

C3. You see if the temperature rises or drops.

C4. Baking soda.

C5. An endothermic reaction is when the temperature drops and an exothermic reaction is when the temperature rises. The experiments gave us a chance to see if the theories were true.

Kaleigh:

A2. No. I think that the temperature drops automatically.

A3. In order to know that the temperature drops or rises when you add baking soda.

A4. The temperature does not change as fast.

A5. The temperature rises because there is alot of action in the baking soda when the water breaks the molecules.

A6. The temperature drops because the heat is used to break the forces of the molecules of baking soda.

A7. See #5 and 6.

A8. The dissolving is finished.

A9. When you add more baking soda the temperature rises. When you add more water the temperature drops.

A10. There are more bonds to break and the mixture is colder.

B2. We made carbon dioxide.

B3. An endothermic reaction is when a reaction takes heat from the environment.

B4. The first experiment when we added more baking soda than water the temperature rose. In the second experiment we used different liquids. But when we added more baking soda than lemon juice or vinegar the temperature rose.

B5. The 2nd mixture caused the greatest drop in temperature because there was more action in the lemon juice.

B6. It takes the heat from the environment.

B7. In this experiment the liquids are different.

C1. The exothermic reaction started when the temperature moved. It finished when the temperature stayed the same because the dissolving was complete.

C2. No answer.

C3. You know by if the temperature rises it's exothermic and if the temperature drops, it's endothermic.

C4. The baking soda in the experiment and there was different results.

C5. An exothermic reaction is when a reaction liberates heat. An endothermic reaction is when a reaction takes heat from the environment. The experiments helped us by giving the proof and we could see what was happening in the dissolution and why.

Stacy

A2. When we added more water and the part that we chose the answer was the same as I thought.

A3. To see if the temperature rises or falls.

A4. The only reaction was that the temperature dropped.

A5. It was not constant because the heat breaks all the forces and now there is nothing else to break.

A6. the temperature drops.

A7. See #5 & 6.

A8. Same answer as #5.

A9. Yes, when there is more water the temperature drops.

A10. Because when the heat breaks the forces it enters the environment.

B2. The gas produced was carbon dioxide.

B3. It is a chemical reaction that takes the heat from the environment.

B4. the reaction is faster than the other experiment.

B5. The heat is used faster with the vinegar thus there is a greater drop in temperature.

B6. It's because the environment around is cold.

B7. Because it is an endothermic reaction and the other is an exothermic reaction.

C1. Yes, it begins when the temperature rises and it finishes when the temperature stays the same.

C2. Yes, it starts when the temperature drops and finishes when the temperature stays the same.

C3. You see if the temperature rises or falls before it stays the same.

C4. The baking soda.

C5. a) In the endothermic reaction the temperature dropped but in the exothermic reaction the temperature rises.

(b)' Because when I draw the graph of the experiment I see the drop in temperature more easily.

Kate:

A2. When we add more water and the part we chose, the answer was the same as I thought.

A3. To see if the temperature rises or falls.

A4. The only reaction is that the temperature drops.

A5. It isn't constant because the heat breaks all the forces and there isn't anything else to break.

A6. The temperature drops.

A7. See #5 & 6.

A8. The same answer as #5.

A9. Yes, when there is more water the temperature drops.

A10. The temperature drops and there is an endothermic reaction. The heat is absorbed to break the forces between the molecules.

B2. The gas is carbon dioxide.

B3. It's when the temperature drops because all the heat is used to break the forces.

B4. It was different because we used different substances which produced a faster reaction.

B5. The lowest temperature is with vinegar.

B6. When you add salt to water, the heat is used to break the forces between the molecules and the water gets colder.

B7. It's because you use different substances which produce different, faster reactions.

C1. It started when the temperature rose and finished when the temperature stayed constant.

C2. It started when the temperature dropped and finished when the temperature stayed the same.

C3. If the temperature rises it is exothermic and if it drops it is endothermic.

C4. The substance is baking soda.

C5. In the endothermic reaction, the heat is liberated and in the exothermic reaction, the heat is absorbed.

The experiments did not help me, I understood the theories before the experiments but not after. memorized the words - understanding is debatable

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Eric:

A2. When we add more water is the part that was the same as we thought.

A3. To see if the temperature rises or falls.

A4. The only reaction was that the temperature dropped.

A5. It isn't constant because the heat breaks all the forces and now there isn't any to break.

A6. The temperature drops.

A7. See #5 & 6.

A8. Same as #6.

A9. Yes, when there is more water the tempearature decreases.

A10. The mixture of two objects.

B2. The gas that is produced is carbon dioxide.

B3. It is a chemical reaction that takes heat from the environment.

B4. The reaction is faster than the other experiment.

B5. The heat is used to faster with vinegar thus there is a greater drop in temperature.

B6. It's because the environment around is cold.

B7. Because it is a different substance.

} experience assumption

C1. When you start to do it and it finishes when the temperature stays the same.

C2. Same as #1.

C3. Exothermic is when the temperature rises and endothermic is when the temperature drops.

C4. The substance that is responsible is baking soda.

C5. Same as 3.

Ted:

A2. No, I thought the temperature drops.

A3. To know if the temperature rises or drops when you add the baking soda.

A4. The temperature doesn't change very fast.

A5. The temperature rises because there is alot action in the baking soda and when the water breaks the molecules, the heat goes into the environment.

A6. The temperature drops because the heat is used to break the forces between the molecules of baking soda.

A7. No answer.

A8. The dissolution is finished and all the heat is used that needed to be used.

A9. The more solvent that you put the temperature drops.

A10. In the 2nd experiment we used vinegar and lemon juice.

B2. We made the gas carbon dioxide.

B3. An endothermic reaction is when the chemistry takes the heat from the environment , because of this reaction the mixture is going to feel colder.

B4. It is different because this mixture starts right away.

B5. The heat is used faster with vinegar thus there is a greater drop in temperture.

B6. It's because the surrounding environment is cold.

B7. No answer.

C1. When you start to do it and it finishes when the temperature doesn't change.

C2. Same as #1.

C3. Exothermic is when the temperature rises and endothermic drops.

C4. No answer.

C5. Same as #3.

Erenee:

A2. Yes, because when we started, I thought that the more water that we put, the temperature would drop. I was correct! Also that when we put more baking soda the temperature would rise.

A3. It is important to take the initial temperature of the water in order to understand what happens to the temperature when we put different proportions.

A4. The first mixture was a fast reaction, it maybe bubbled a bit and after it was calm.

A5. When the proportions have more baking soda, the temperature drops.

A6. When the proportions have more water, the temperature rises by one or two degrees.

A7. When we have more baking soda the temperature drops and when we put more water the temperature rose. The ratios change with different proportions.

A8. Because the temperature stays the same, so,

A9. When we put more baking soda the temperature dropped. When we put more water the temperature rose.

A10. We saw that when we did this experiment, the temperature of the mixture dropped because all the heat of the environment which surrounds the mixture was used.

B2. Carbon dioxide.

B3. An endothermic reaction is a chemical reaction that takes the heat from the environment while new chemical forces are created between the substances.

B4. We could see that the temperatures were greatly different. Also, the reactions were different because in this experiment, we used lemon juice and vinegar.

B5. Mixture #1 - baking soda and water - 1/3 - the lowest temperature of 21.5 degrees. I think that this is because lemon juice and vinegar have less forces than water.

B6. Because the ice cream froze.

B7. No answer.

C1. The exothermic reaction started when we touched the space bar and it finished when it stayed the same and again we touched the space bar.

C2. The endothermic reaction started in the same time, in the same way that the exothermic reaction started and finished.

C3. We can tell what type of reaction is happening by watching the strip chart explain because the strip chart says if the reaction is fast or slow.

C4. Baking soda, water, vinegar, lemon juice are the substances resposible for the reactions.

C5. An endothermic reaction a chemical reaction that takes the heat from the environment while new chemical forces are created between the substances. An exothermic reaction a reaction that liberates heat. We have a chemical product with alot of energy and we mix it with another substance which releases this energy, the chemical reaction will produce heat. This experiment helped me to understand the differences I knew before.

Melissa:

A2. No, I thought that the temperature would drop.

A3. To know that the temperature rises or falls when you add the baking soda.

A4. The temperature does not change quickly.

A5. The temperature rises because there is alot of action in the baking soda.

A6. The temperature drops because the heat is used to break the forces between the molecules of baking soda.

A7. See #5 & 6.

A8. The dissolution is finished and all the heat is used which was needed.

A9. No answer.

B2. Carbon dioxide is the gas produced.

B3. An endothermic reaction is when **the temperature drops** because

B4 In general, the temperature rises in this experiment.

B5. the mixture with vinegar and lemon juice at 3/1 because the vinegar and the lemon juice when mixed make a smaller temperature.

B6. when you add salt to ice the ice melts because the temperature in the ice rises when you add the salt.

B7. No answer.

C1. You push the space bar and when you finish push.

C2. It starts..

C3. When endothermic the line of the temperature rises and when exothermic the temperature drops.

C4. The baking soda is responsible for each reaction.

C5. The endothermic reaction is when a reaction takes heat, an exothermic reaction is when a reaction releases the heat.

Bruce:

A2. No, I thought that the temperature would drop.

A3. To determine the amount of change in the temperatures.

A4. The temperature decreased slowly.

A5. The reaction is faster or slower.

A6. The reaction is faster or slower.

A7. There are different reactions with different amounts.

A8. Because all the molecules are broken.

A9. The more water you have the faster the temperature goes.

A10. The reactions stop and this means that the bonds are broken.

B2. The gas dioxide was produced.

B3. An endothermic reaction takes alot of energy and doesn't put back the energy and the temperature drops.

B4. We used different substances like lemon juice and the (experiment) the reaction goes faster.

B5. The vinegar caused the greatest drop in temperture because it is more acidic and has more energy to break the forces.

B6. You put the salt on the ice and the salt takes the heat from the ice to break the forces and when it takes this energy the ice melts.

B7. Because the substance we used has more energy (acid) and it dissolves the baking soda faster.

C1. When the temperature begins to rise the reaction starts. And when the temperature no longer changes the reaction has finished.

C2. It's the same as the exothermic reaction but when the temperature drops it starts.

C3. An endothermic reaction is when the temperature of the water drops and an exothermic reaction the temperature of the water rises.

C4. Water is resposible for the reaction with calcium chloride.

C5. It's the same as #3 and these experiments did not help me to understand the concept because I knew the concept before.

Tracey:

A2. No, I did not get the results that I thought.

A3. If you do not measure the water, you don't know if the temperature rises or falls.

A4. The temperature rises a bit faster.

A5. When you have alot of baking soda and there isn't alot of water the temperature rises.

A6. When you have alot of water and not alot of baking soda the temperature drops.

A7. When you have alot of baking soda and not alot of water the temperature rises because there is more energy and you don't need alot of energy and the rest of the heat goes into the environment. But when you have alot of water and not alot of baking soda the temperature drops because you use alot of energy and there isn' any heat in the environment.

A8. It stays the same because when you use as much as you can so you don't take anymore.

A9. No answer.

A10. All the energy you need is to break the forces.

B2. The carbon dioxide is produced.

B3. An endothermic reaction is when the temperature rises.

(B4) The temperature changes (rises/falls) very fast that the other experiment.

B5. When you have alot of lemon juice /vinegar because it

strength → overcomes the baking soda.

B6. When you add the salt to the ice cream it makes a reaction and the heat in the liquid is used to break the forces and the temperature drops and it is solid.

B7. Because the molecules aren't broken very fast in the other experiment.

C1. Yes, because it has a big reaction so you could see when it started and when it finished.

C2. No, because there isn't a big reaction so you can't see when it starts or finishes.

C3. Because the line drops or rises depending on the temperature.

C4. Endothermic- baking soda. Exothermic- lemon juice and vinegar.

C5. a) An exothermic reaction, the temperature rises very fast and in the reaction endothermic the temperature falls.

b) The thermometer/computer helped me because this thing lets me see the things I can't see in the experiment.

Holly:

A2. No, I thought that the temperature would drop.

A3. In order to know if the temperature rises or falls if you add baking soda.

A4. The temperature does not change quickly.

A5. The temperature goes higher because there is alot of action in the baking soda.

A6. The temperature goes lower because the heat is used to break the forces between the molocules of of the baking soda.

A7. See #5 & 6.

A8. The dissolution is finished and all the heat is used that is needed to be used.

A9. When you add baking soda it's hotter and when you add water it's colder.

A10. Because something changes.

B2. Carbon dioxide is the gas which is produced.

B3. When all the heat in the water is used to break the forces between the molecules.

B4. There are different substances.

B5. The baking soda and water because it's "fizzy" and bubbles alot.

B6. All the heat is used to break the molecules in the salt and the the ice cream melts.

B7. Because it's a different substance and the reaction is faster.

C1. You push the space bar and when you finish push it.

C2. The endothermic reaction started when the temperature moved and it finished when the temperature stayed the same.

C3. When endothermic the line, the temperature rises, when exothermic the temperature goes lower.

C4. Baking soda.

C5. An endothermic reaction is a chemical reaction which takes the heat from the environment and an exothermic reaction is a reaction that releases heat.

Ryan:

A2. No, I thought that the temperature would go lower.

A3. In order to know if the temperature rises or falls when you add baking soda.

A4. The temperature doesn't chage as fast.

A5. The temperature drops because there is alot of action in the baking soda and when the water breaks the molecules the heat goes into the environment.

A6. The temperature drops because the heat is used to break the forces between the molecules of the baking soda.

A7. See #5 & 6.

A8. The dissolution is finished and all the heat is used that needed to be used.

A9. No answer.

A10. No answer.

B2. We made carbon dioxide.

B3. An endothermic reaction is when the chemistry takes the heat from the environment because of this the mixture gets colder.

B4. It is different because this mixture goes immediately.

B5. The molecules break and the heat by the molecules goes in the water.

B6. No answer.

B7. No answer.

C1. It starts when 24.2 degrees C and finishes when 19.9.

C2. It starts when 19.7 , finishes 18.9.

C3. No answer.

C4. Baking soda is responsible.

C5. An endothermic reaction is when it mixes the heat.

Kevin:

A2. Yes.

A3. To find how many degrees the temperature drops.

A4. When you mix water and baking soda the temperature drops.

A5. More baking soda, the water is more thick.

A6. More water, the solution has more liquid.

A7. By the difference between the amount of baking soda.

A8. More baking soda, less the temperature.

A9. The more solides, the less the temperature.

A10. By placing the baking soda into water.

B2. Carbon dioxide (CO)

B3. An endothermic reaction is when the liquid uses more heat to break the molecules than is in the molecules.

B4. By stopping the temperature at different times.

B5. Mixture #3 1:3 baking soda and vinegar.

B6. The salt makes the temperature drop.

B7. Because this experiment uses other liquids.

C1. Because the temperature rises.

C2. No answer.

C3. Exothermic - rises; endothermic - drops.

C4. Calcium chloride.

C5. Endothermic: When the liquid uses more heat to break the forces between the molecules then the amount is in the molecules. Exothermic: when the liquid uses less heat then the amount of heat in the molecules.

Darrell:

A2. Yes.

A3. To measure the difference.

A4. It causes the temperature to drop.

A5. The drop is slower.

A6. The drop is faster.

A7. The more water = the more change.

A8. Because the reaction is too small to become cold.

A9. Make a chart with three things.

A10. It's an example of chemical bonding because there is a reaction when the substances are mixed in certain proportions.

B2. Carbon dioxide.

B3. It's a chemical reaction.

B4. The temperature changes faster.

B5. Vinegar because they're opposite.

B6. The salt breaks the molecules of the ice cream.

B7. The solvents are stronger.

C1. When we started the computer and placed the probe in the solution and finished when the temperature no longer dropped.

C2. Same thing.

C3. Exothermic falls more rapidly.

C4. The solvent-vinegar, water, lemon juice.

C5. Reaction endothermic - the temperature drops slowly, and there isn't a visible reaction. Reaction exothermic - the temperature drops quickly and we could see the difference. We could see what was happening with the temperature when the substances are mixed.

Neil

A2. Yes, I thought that when you put more water the temperature drops.

A3. To see that the temperature rises or drops.

A4. The only action is that the temperature drops.

A5. When you put more baking soda the temperature drops.

A6. When you put more water the temperature rises.

A7. No answer.

A8. No answer.

A9. I think that the more water, the temperature decreases.

A10. No answer.

B2. The gas produced is carbon dioxide.

B3. Endothermic is when the heat in water is used for breaking the molecular force - the temperature drops.

B4. The results are different because we used the vinegar - the temperature dropped faster.

B5. Mixture #1 - baking soda /water 1/3, the temperature is 21.5 is the highest. The only reason is because the vinegar and the lemon juice has less force.

B6. The heat drops and the ice creme freezes.

B7. No answer.

C1. The reaction starts when you push the space bar. It finishes when it stays the same.

C2. The reaction starts and finishes the same way as the exothermic.

C3. The graph says if the reaction is fast or slow.

C4. Water, baking soda, lemon juice, vinegar and calcium chloride are responsible for the reaction.

C5. No answer.

Ada:

A2. No answer.

A3. Because if you don't measure we won't know if the molecules changed and if the water gets hot.

A4. Baking soda takes the water to make energy.

A5. It goes slowly.

A6. If you put water first there is a bit of change in the temperature.

A7. No answer.

A8. Because the molecules do not make a reaction because the salt is still the same.

A9. No answer.

A10. You can see if the temperature changes when you put two molecules if they make a reaction and change the temperature.

B2. The gas that is produced is carbon dioxide.

B3. It's when you put a liquid and the solid it makes the water change and drop.

B4. There is a big reaction because the chemicals are opposite molecules.

B5. Baking soda and vinegar are two opposite molecules and cause a big reaction and the water drops.

B6. I think that the temperature rises because there isn't a reaction, the ice only makes the reaction.

B7. No answer

C. No answers.

Graeme:

A2. It was different than I thought.

A3. Because the temperature can change the results.

A4. Baking soda goes until it can and nothing else happens. (mixes).

A5. The heat breaks all the forces.

A6. The temperature drops.

A7. See #5 & 6.

A8. The temperature drops.

A9. Yes, when there is more water the temperature drops.

A10. Because the thing we put changed the force and the temperature dropped.

B2. Carbon dioxide was the gas.

B3. A chemical reaction is when the reaction takes the heat from the environment.

B4. It's faster than the other.

B5. The heat used with vinegar is faster so the temperature goes up.

B6. The environment is colder.

B7. Because we use more chemicals like vinegar and baking soda.

C1. The temperature is constant when we start.

C2. the temperature is constant when we start.

C3. Exothermic is when the temperature rises. Endothermic is when the temperature drops.

C4. Baking soda.

C5. Exothermic is when the temperature rises thus when you put the things in the beaker it affects whether it rises or falls.

Letter of Consent

September 16, 1991

Dear Parent(s),

I am writing to request permission for your child to participate in a research study aimed at determining the effect of microcomputer-based science laboratory activities on student understanding of science. A microcomputer-based laboratory (MBL) involves using the computer to collect and analyze scientific data using electrical probes and sensors. If patterns of student understanding can be identified, this may promote more effective use of the MBL in the instruction of scientific concepts.

As a participant in the study your child will be involved in a series of lessons using the computer in the laboratory. Students will be required to keep a journal of their learning progress during a chemistry unit and may be chosen for interview purposes to determine what learning is taking place using the MBL. The unit should take about 2 months to complete.

All information gathered will be confidential and anonymity of participants will be ensured.

Students are encouraged to continue their participation in the study once a committment has been made. However, the right to withdraw is available and students are subject to no penalty if they do so.

The findings of the study will be used in a Master's of Education thesis for the University of Manitoba and will be available to parents upon request once it is completed.

Further information may be obtained by contacting me at Viscount Alexander School, 452-8945, during school hours. Please complete the form on the back of this page and have your child return it to me.

Yours truly,

Ms. R. Stoeber
Science teacher
Viscount Alexander