Reflections on Implementing a
Constructivist Approach in Teaching Magnetism:
A Case Study of a Fifth Grade Classroom

by

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Children have prior knowledge, or mini-theories about science topics presented at school before being formally taught that is constructed from their everyday experiences. Teachers generally do not take this knowledge into consideration in the planning of science units and are often confused about why their students fail to learn. Hewson (1983) suggests that students will experience conceptual change only if it is intelligible, plausible, and fruitful and that prior knowledge, which is often an alternate conception of a scientific idea, must be challenged or clarified.

Schon (1984) claims that teachers need to reflect on their actions in order to understand their own as well as their students' "constructed worlds". He suggests that teachers, when they reflect, become their own researchers. This case study examines how I, a teacher/researcher, adopted a constructivist perspective towards teaching a unit in magnetism and how the students responded. Vignettes of selected incidents tell the story of the difficulties that my students had learning some of the concepts of magnetism and how I reacted to the knowledge that they were having difficulty.

The unit in magnetism was taught to my class of thirty-two students (10/11 year olds) at an elementary
school in a community in British Columbia using a constructivist teaching sequence developed by Driver (1986). The lessons in magnetism were video-taped and both the students and I kept a journal. To elicit students' ideas about magnetism a diagnostic test was given at the beginning of the unit. A continuing record of students ideas was kept throughout the study and at the end a post diagnostic test was given to see which, if any, alternate conceptions persisted.

It was found that teaching with a constructivist approach had its' difficulties. Reflecting, for myself and my students, took practice and taking students' ideas into consideration, both in the planning and teaching stages, may have taken more time than many teachers have available. However, the knowledge that I gained about my students' beliefs, through the process of reflecting, was valuable in planning lessons that both challenged and clarified the students' alternate conceptions.

Teachers are recommended to take their students' ideas into consideration in lesson planning and to use activities that will encourage conceptual change. However, teachers should consider the time factor and the difficulties in reflecting before using a constructivist approach in teaching science.
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CHAPTER ONE

1. Introduction

The following case study is based upon an idea that is widely held among science education researchers, that children possess prior knowledge that they bring to learning and that this knowledge affects how they learn. The study is also based on the suggestion that teachers who are aware that their students possess this prior knowledge can better plan activities to further student learning.

This study was carried out in a British Columbia elementary school, with average ability fifth grade students by myself in my own classroom. The primary objective of the study was to document children's beliefs about magnetism and how I responded to those beliefs.

Because this case study was carried out in my own classroom over a specific period of time caution must be exercised in generalizing to other grade five classrooms. However the concept area and the pedagogical problems addressed are applicable to current issues in science education.

The study is presented in five chapters. The first chapter considers the major issues addressed in the study. A review of the current research on children's prior knowledge, the principles of constructivism, reflective practice and the constructivist approach in the classroom is
presented. In the third chapter the background to the case, and the methods used to collect and analyze the data, is addressed. The fourth chapter presents vignettes that highlight the problems that students' experienced while studying magnetism. Finally, in chapter five, a summary of the effects of the constructivist perspective on both students and teacher, and further implications of the study are given.

11. Background to problem

Before children are faced with a formal science curriculum in school they have already been exposed to what Claxton (1982) calls "gut" science, first hand explorations and interactions with the environment, and "lay" science, founded in language, family, community and the media. He claims that when children make sense of a situation they develop mini-theories based upon these personal experiences.

By the time "school" science is introduced the average child already possesses much knowledge, and holds many beliefs. The science curriculum, while they give, on the whole, a clear presentation of the conventional scientific theories, they do not take into account the childrens' mini-theories that often persist after teaching. (Smith and Andrson, 1982).
Several research groups such as Anderson and Smith (1982), who investigated textbooks, teacher guides, and teacher planning, tried to develop materials that take into account both children's mini-theories and those of the scientific community. Driver (1986), who is currently working on an approach to reconstruct the science curriculum, is in the process of trying to design a teaching sequence that encourages teachers to consider children's mini-theories and that suggests ways to restructure them.

The Children's Learning in Science Project (Driver, 1986), which adopted an approach to implementing a constructivist perspective that takes children's prior beliefs into consideration in curriculum planning, has worked with a group of teachers to produce and evaluate teaching approaches using a cyclical process of teaching, monitoring, reflecting, and revising.

According to Driver, the teachers in the Children's Learning in Science Project have generally valued their involvement with the research group but the teaching that happened in their classrooms was interpreted by participant observers not the teachers and failed to take into consideration the teachers' beliefs of how their classrooms work and how their students think.

Easley (1982) suggests that from any position in the classroom an observer/researcher tends to see the student's perspective better than the teacher's perspective. He claims
that "only by becoming the teacher for a time can the researcher see what the teacher sees better than he sees what the pupils see" (p.197).

It is within the above context that it seems necessary for teachers to conduct their own research in order that those who interpret that research for the purpose of classroom application get a better understanding of how teachers view their classroom operation and students thinking.

This thesis will present a case study, from a my own perspective, that documents the beliefs that elementary children hold about magnetism, and how I responded to them.

III. Statement of research problem

A. General problem area

The classroom teacher who understands that children's mini-theories, or alternate conceptions, can influence their learning has to be prepared to respond to students' ideas with appropriate activities and challenges. At the same time teachers need to recognize that their own alternate conceptions, of science concepts and of how children learn, may influence how they respond to their students and that constant reflection on their own actions and decisions made in instructional planning, is required.
Schon (1983) captured this requirement very nicely when he wrote "The practitioner recognizes that his actions may have different meanings for the client than he intends them to have and gives himself the task of discovering what these are" (p.295). In educational research the "constructed worlds" of both the researcher (in this case myself) and observed (the students) need to be accounted for.

This research project addressed as one general question:

How does a classroom teacher adopt a constructivist perspective towards the teaching of a unit about magnets and compasses?

B. Specific research questions

The general problem is by nature, a very complex one and several specific questions need to be addressed:

1. What are the students' beliefs about magnetism before formal teaching?

2. How do students' alternate conceptions of magnetism interact with their conceptual understanding of magnetism?

3. What are some effective teaching strategies a classroom teacher can use to utilize students' alternate conceptions of magnetism?

4. What role does teacher and student reflection play in a constructivist approach to teaching magnetism?
While the last question is the most complex it is the primary focus of this study. Reflection-in-action "is the recognition that one's expertise is a way of looking at something which was once constructed and may be reconstructed and there is both readiness and competence to explore its' meaning in the experience of the client" (Schon, 1983, p.296).

The constructivist approach to teaching implies that the teacher, as well as the student, has the opportunity to reflect on and compare ideas. The case study will document how my students' responded to a constructivist teaching sequence through my own reflecting.

IV. Research design

"When someone reflects-in-action, he becomes a researcher in the practice content. He is not dependent on the categories of established theory and technique, but constructs a new theory of the unique case." (Schon, 1983, p.68)

The research project occurred in my classroom at a school in an urban school district in the Vancouver metropolitan area. My intent was to present a case study reflecting how I applied a constructivist perspective to teaching a unit called "Magnets and Compasses", outlined in the textbook S.T.E.M. (Rockcastle et al. 1977), and of how the students responded to the instruction.
Based on Schon's (1983) notion that "when a practitioner does not reflect on his own inquiry he keeps his intuitive understandings tacit and is inattentive to the limits of his scope of reflective attention" I made the decision to become a researcher of my own teaching situation. An effort was made to increase trustworthiness of the data collection and analysis through the use of: an observer, video tapes, diagnostic tests, student journals, and a teacher journal. After each of the teaching periods I held a debriefing session with an observer, who was filming my teaching, to express concerns and successes that came as a result of the lesson.

The unit began and ended with a diagnostic test designed to seek out students' alternate conceptions of five major concepts of magnetism presented in the S.T.E.M. 5 unit "Magnets and Compasses". The intent of the post diagnostic test was to determine if and how the students' original beliefs of magnetism had changed and what the persistent conceptions of magnetism were, if any.

The format of the instructional method loosely followed that developed by The Childrens' Learning in Science Project (Driver,1986), and emphasis was placed on group learning.

Following an orientation period the first instructional activity elicited and recorded students' ideas that were kept for later reflection. The next activity included the clarification and exchange of ideas through small group
tasks, exposure to conflict situations, construction of new ideas, and evaluation. Students were then encouraged to apply and use their ideas by designing "experiments" and by problem solving.

The entire class was included in the research but the case study focusses on selected students who found the learning of the concepts presented difficult or who demonstrated a persistent alternate conception. My interactions with these students were also documented and are discussed in chapter four.

V. Educational significance

The "thick description" and interpretive effort of explaining the complex context of a classroom is best done through an ethnographic approach such as the case study. (Magoon, 1977). Clearly such a study does not allow the researcher to make generalizations to other teaching situations, nonetheless it can make a significant contribution to educational practice and farther research in this important area.

One of the reasons that teachers do not consider educational research relevant is because the researcher is not viewing classroom practice from the teachers' point of view (Easley, 1982). Case studies done of classroom situations by teachers will add a new dimension to
educational research that may make research more acceptable to teachers.

Schon (1983) argues that with the increasing crisis of confidence in the professions it is important that teachers begin to challenge the prevailing knowledge structure of their schools through reflective teaching in order to build a learning system that is able to withstand constant criticism and change. He suggests that descriptions and analysis of cases are needed to help build a repertoire of the practitioners situations.

Research on constructivism is still in its early stages and little research has been conducted in the elementary classroom on the effects of application of the constructivist perspective on teaching science concepts. This research project will add to this growing body of knowledge.
CHAPTER TWO

1. Introduction to current research

Since the early 1970's a large number of researchers have tried to identify the views that children hold of various concepts in science (Driver and Easley, 1978). Often these views are different from those held by scientists and attempts have been initiated to find ways to encourage conceptual change (Hewson, 1981; Posner et al, 1982).

The curriculum, while perhaps giving a clear presentation of conventional scientific theories, does not consider the ideas that children bring to the learning situation. Thus teachers frequently wonder why so many concepts taught in science are so difficult for children to learn. Several research groups, (Anderson and Smith, 1982; Driver, 1985; Nussbaum and Novick, 1982; Osborne, 1985) have been working on curriculum materials, teaching strategies, and teaching models to help teachers make science concepts more comprehensible to students.

This chapter is divided into three major sections, beginning with a constructivist view of children's ideas and the theory of conceptual change as outlined by several researchers. The idea of reflective practice, as suggested by Donald Schon, (1985) is then reviewed with some parallels drawn to a constructivist model of teaching science as outlined by Driver, (1986). Finally, a review of current
constructivist research in elementary classrooms will be
discussed along with an interpretation of a constructivist
teaching sequence.

11. Constructivist perspectives

Magoon (1977) states that a constructivist perspective
towards knowledge and behaviour assumes that people are
knowing beings and that their knowledge influences their
behaviour. It also assumes that behaviour must have a
purpose so that complex behaviour, such as teaching and
learning, cannot be studied without accounting for meaning.
He further suggests that a constructivist perspective
assumes humans are social beings that can organize knowledge
and understand complex communication.

As a result of his views Magoon suggests that
educational research take an ethnographic approach that
includes a "thick description" and an interpretation of some
of the complex issues which are a part of schooling.

Research, prior to the 1980's, has largely failed to
take into consideration how both teachers and students
construct and interpret their situation. "The claim is made
that a significant part of the context of behaviour that
educational researchers observe is a structure produced by
the constructions of the observed subject" (Magoon, 1977,
p.686).
To understand how students and teachers might adopt a method of learning and teaching that takes their constructed worlds into consideration it is necessary to understand the basis for students' and teachers' belief systems and how or why these systems may or may not change.

A. Children's ideas

The notion that students have knowledge or personal beliefs that may be interfering with their conceptual understanding of science concepts is not a new one and researchers have been working on the problem for many years. Current literature reveals that different researchers, grappling with the same problem, refer to "students' beliefs" with a variety of different labels and make many suggestions that have led to the development of a constructivist teaching sequence.

David Hawkins, (1978) calls it a "critical barrier phenomena" when students fail to assimilate elementary science concepts. Concepts may, in fact, be partly assimilated but do not prove retrievable or applicable in new situations. Students' ideas, constructed from their everyday experiences, may interact in several ways with current accepted science theories creating a conflict. Hawkins suggestion, however, that students' ideas are barriers to learning may be only partially correct as other researchers
are suggesting that students' ideas may also be building blocks (Claxton, 1982).

Claxton refers to the personal theories or beliefs that students have as "mini-theories" that stem from a need to make sense of and to act on new situations. He claims that these mini-theories, which are a product of the natural experimenting that children do outside of the school setting, gradually change through learning and become broader. Each theory is defined by a domain of experience and triggered by one of four learning experiences:

- **Extension**: when a mini-theory applied to an event works.
- **Withdrawal**: when a mini-theory does not work.
- **Engulfing**: when a mini-theory turns out to be part of a more general case.
- **Abstraction**: when separate mini-theories contain a sub-theory.
- **Reconciliation**: an overlap of several mini-theories that generate conflict.

Claxtons' view of mini-theories seems to suggest that understanding the types of ideas that students' have may help teachers decide how to approach the teaching of a certain concept. He further suggests that teachers spend more time listening to what students are thinking about rather than spending time telling students what to think. In so doing, it should provide an opportunity for mini-theories
to be subsumed by school science. Claxton also warns that teachers must use tact, understanding and respect when approaching students' sometimes cherished beliefs if change is to occur.

Champagne, Gunstone, and Klopfer, (1983) claim that people young and old have personal belief systems for explaining scientific phenomena. These explanatory systems or beliefs (which they refer to as naive conceptions) differ from those students are expected to learn. They show consistency across diverse populations, abilities and nationalities and are resistant to change.

Naive conceptions are sometimes found in the pure state but generally their ideas are contaminated by schooling. For example, students may say, "Magnets are attracted to an object because of gravity pulling at it." It is not the students' lack of prior knowledge that makes learning some science concepts so difficult but rather their conflicting knowledge.

It has been suggested by several of the above researchers that a Socratic teaching method that requires students to deal with conflict situations be used when working with students' naive conceptions. Students would be expected to construct frameworks that stand up to any criticisms received from their participation in dialogue.
Driver and Erickson (1983) suggest that researchers have had difficulty in defining frameworks. Some view frameworks as individual constructs while others describe them as a combination of ideas shared by many students. However they are defined, an important factor for learning difficulties is the reluctance or inability of students to change or alter their frameworks in favour of school science. The suggestion is made that "the extent to which students have to modify or fundamentally reorganize their ideas will depend on the nature of their prior experiences of phenomena relevant to a topic". (p.49)

The source for frameworks are sensory and linguistic experiences. Subject matter areas which are rich in these experiences, such as mechanics, heat, and temperature, generally result in stable frameworks and are more likely to be resistant to change. As suggested in this study, magnetism fits into the category of stable frameworks.

B. Conceptual change

It has been suggested that alternate frameworks that are stable are generally resistant to change and a concerted effort is needed to change them to a scientific way of thinking.

Hewson (1981) states that conceptual change can happen in several ways: an addition of new conceptions through personal development, contact with other people or further
experiences; a reorganization of existing conceptions or as a rejection of some existing conception.

After being presented with a new concept a person could reject it outright or incorporate it into an existing framework. The concept could be memorized by rote and so not interfere at all with existing beliefs. It could be captured and reconciled with existing beliefs or the concept could be exchanged with an existing belief and then be reconciled with the remaining conceptions.

A conceptual exchange model, developed by Hewson (1981) and Posner, et al (1982), is based on the notion that "learning may involve changing a person's conceptions rather than adding new knowledge to what is already there." The conceptual exchange model suggests four conditions that must exist before a learner can successfully integrate a new concept into existing knowledge. First, there must be dissatisfaction with an existing concept. Secondly, the new conception must be intelligible although it does not have to be believable. Thirdly, the learner must not only understand what the new concept means but must believe it to be plausible or potentially true. Finally, the new conception must be fruitful particularly if the learner is giving up an existing belief which worked to their satisfaction.

The Hewsons do not suggest specific activities that could be used by teachers but the conceptual change model does provide strategies that could be applied to conceptual
change teaching. For example it is suggested that the teacher begin with a diagnosis of the students' beliefs as a necessary prerequisite. Then integration should be pursued in order to reconcile two conflicting conceptions. When two closely related science concepts are confused then differentiation is needed to clearly define meaning if conflict is to occur. An example of this is when students confuse gravity with magnetism. Their belief is that because gravity "holds you to the ground it must be like magnetism". The students' then need to see that the two concepts are not the same otherwise their belief is quite plausible. Finally, an exchange strategy is used to create conceptual conflict and to resolve the problem.

One concern with the conceptual change model is the implication that teachers should persevere with conceptual change for all students. Perhaps this notion is overly ambitious and requires compromise and flexibility within the classroom context.

Nussbaum and Novick (1982) have developed instructional strategies where conceptual conflict is used to produce the sort of conceptual change suggested by the Hewsons'. They present an "exposing event" which they expect students to explain using their own conceptions. This is followed by the introduction of a "discrepant event" which creates conflict between the students' conceptions and an observed phenomenon. These two events are followed by a "resolution
phase" where students are encouraged to discuss results and clarify the desired conception.

Driver (1985) has outlined in more detail (see section IV.) a constructivist pedagogy that includes five basic steps: orientation, elicitation, restructuring, application and review.

111. Reflective practice

As a classroom teacher, it has become apparent to me that to be successful with students is to understand their difficulties in learning and to treat each one as an individual. The task of recognizing and dealing with each student's learning problems is of course a formidable one and many difficulties are encountered in accomplishing this end.

Schon (1983) claims that a competent teacher sees a student's difficulties to learn as a challenge to her own instruction and therefore must find out what the difficulties are. The teacher does not necessarily have an immediate explanation for a student's unique problem but must be ready to invent new methods of teaching and somehow develop the ability to be able to discover them (p.66).

One of the ways that a teacher can begin to recognize students' ideas that may cause them difficulties in learning is through the process of reflection.
When teachers reflect-in-action they reveal their own intuitive understandings. The teachers' conceptions of how they view the subject taught and how they believe their students learn are as important as understanding the students' beliefs. Even if the descriptions are not very good they may be good enough to enable teachers to criticize their own teaching and restructure their thinking so that new strategies are produced.

Through reflection a teacher becomes, in effect, a researcher except that there are no rules, techniques, or theories which must be applied to every case. Instead, in bringing past experiences to bear on a unique situation, teachers draw upon a collection of examples, images, understandings and actions in order to develop a new theory for a specific case.

Reflection-in-action involves experimenting with reframing the problems that students encounter in learning concepts. Reflective conversations (discussed earlier as Socratic dialogues) with the students enable the teacher to explore the students' understandings and to encourage conceptual change.

IV. Teaching implications for a constructivist perspective in the classroom

How many times have teachers, after thinking they have prepared a good lesson or unit, been frustrated to find that
their students simply did not appear to understand the information presented? Erickson, (1981) has stated that teachers are often aware of the lack of understanding their students have of science concepts but are uncertain of the learning blocks or alternate conceptions that are exhibited by their students. He suggests that being aware of students' alternate conceptions has been overlooked as part of a general teaching strategy.

But being aware of students' alternate conceptions is a difficult task that requires the teacher to be constantly reviewing or reflecting on classroom behaviour and dialogue. The teacher has to become aware of the "constructed worlds" of both herself and the students as Schon has suggested and develop an understanding or "partnership in learning" with each student. Constructivist teaching likely will require both dialogue and reflection to be effective.

A. Constructivist teaching approaches

A number of researchers have begun to use constructivist perspective as a basis for teaching science in the classroom (Nussbaum and Novick 1980; Eaton, Anderson and Smith 1982; Slinger, Anderson and Smith 1984; Driver 1986).

Anderson and Smith, in conjunction with the Planning and Teaching Intermediate Science Project, have been interviewing and observing elementary science teachers in an
effort to assess the needs of the classroom teacher. They studied how teachers interpreted and used curriculum materials and found that even though teachers were encouraged to use a conceptual change approach in their teaching they tended to ignore the recommendations and interpreted the curriculum in a way that was consistent with their own way of teaching.

One result of this work has been to rewrite teacher guides for the text based science programmes to include information about children's ideas which was found to be missing in the prescribed textbooks but even then teachers tended not to follow the suggestions recommended.

Driver and Oldham (1986) outline a constructivist approach to teaching science that includes a specific teaching sequence. The Children's Learning in Science Project is an attempt to apply the research on children's thinking in science and current theoretical developments in cognition with a method of teaching that includes activities to encourage the elicitation of students' ideas and opportunities for students to restructure their ideas. The teaching model is flexible enough that teachers can adjust their approach towards the needs of their particular class.

1. The constructivist teaching sequence

The aim of the Children's Learning in Science Project is to develop curriculum that will allow the teacher to
create a setting in which the student is given the opportunity to construct knowledge. The project is a naturalistic inquiry set up in order to design and evaluate teaching approaches to improve students' understanding of various concepts in science.

The general model for developing curriculum adopts a view of learning as conceptual change in the broad sense. Developers have taken the stance that students should be exposed to certain experiences but there can be no prescription about the ideas they will acquire, only a suggestion about what ideas may be constructed.

The constructivist teaching sequence encourages the active construction of meaning starting from students' personal beliefs and then providing opportunities for building on and modifying these towards a more scientific way of thinking.

One of the most important aspects of the teaching sequence is the necessity for sufficient time for students to carefully consider their ideas in the light of the instructional activities. The teacher, therefore, must be sensitive to students' ideas that they bring to the classroom and to the meanings they construct from activities and observations. The teacher also has to ensure that the learning environment is supportive and that teacher and students respect each others views. Students need
opportunities to make their ideas known and to communicate them.

The sequence is composed of five phases:

1. orientation - an opportunity for a sense of purpose and motivation to be developed.

2. elicitation - achieved when the students make their ideas known through a variety of activities.

3. restructuring - a phase that includes the classification and exchange of ideas once the students' ideas have been made known, the exposure to conflict situations that may occur through disagreement or demonstrations and finally an evaluation of ideas.

4. application - students use new ideas in both familiar and novel ways.

5. review - an important aspect of the teaching sequence that requires students to reflect on how their ideas may have changed over the course of study.

The constructivist teaching sequence, as developed by Driver, and an earlier model, by Nussbaum and Novick, was used with junior high school students so may not be totally appropriate for elementary students. However, there appears to enough flexibility for most teachers to adopt it to meet the needs of their particular classes.
V. Summary

The literature on childrens' ideas in science suggests that not only are these ideas the product of everyday experiences but that they are diverse and resistant to change. They can be seen as barriers as well as building blocks but conflict may be created when they overlap with scientific theories. Students' ideas are not always "pure" but are often "contaminated" by "schooling".

It is suggested that teachers not only recognize that their students have alternate ideas to those presented at school but that they understand the types of ideas that children have. It is recommended that teachers listen to their students rather than "tell" them, using tact, understanding and respect for students' beliefs. A suggestion for dealing with students' alternate ideas is to engage them in dialogues that will enable them to deal with conflicts and construct new frameworks.

The classroom teacher who understands that children's mini-theories, or alternate conceptions, can be either a barrier or a building block to their learning has to be prepared to respond to students' ideas with appropriate activities and challenges. At the same time teachers need to recognize that their own alternate conceptions of science concepts and of how children learn may act as barriers or building blocks to the students' learning. Thus constant
reflection on actions and decisions made in instructional planning and classroom strategies is required.
CHAPTER 3

1. Introduction

Chapter three will discuss the methodology of the study. The first section discusses the importance of the teacher/researcher in developing a classroom case study. The second section contains a brief outline of the unit on magnetism that is offered to the students. The teacher's current teaching approach is then discussed in some detail as well as the model of the constructivist teaching sequence.

Section three will provide an explanation of how the data were collected and the problems encountered with that collection. Finally the social context of this particular case to give the reader an understanding of the community, school, parents, teacher, and students involved will be presented.

II. Background to methods used in study

Over the course of the last eight to ten years naturalistic inquiry has become popular among educational researchers. The case study, the most common form of reporting naturalistic enquiry, is considered to be an appropriate method for exploring the learner's cognitive structure. (Easley, 1982).
Certain characteristics of the case format are especially advantageous to the naturalistic enquirer. For example, the case study reporting mode provides the "thick description" necessary for judgements of transferability and for probing internal consistency. (Lincoln and Guba, 1985).

In most cases the naturalistic inquiry is carried out by an observer who reports the case from his or her own point of view. But Easley (1982) makes the point that "learning to see another person's experiences strikes any researcher as a very unreliable process" (p.197).

This particular case study, of how I applied a constructivist approach to the teaching of a unit in magnetism, is reported from my point of view with the hopes of presenting a more reliable documentation of my experiences.

A. Teachers as researchers

One of the most important features of the constructivist teaching sequence (as discussed in ch.2) is the reflection encouraged of both students and teachers. It therefore seems appropriate that the story of how a teacher adopts this method of instruction should be told through reflection.

Donald Schon, (1985) strongly supports the notion that reflective practice take the form of a reflective conversation not only with the students but with the
situation. In other words reflective practice not only includes dialogues with students in the Socratic manner but includes a continuing review of actions and thought.

Schon is concerned that the teacher's isolation in the classroom works against reflection. "She needs to communicate her "private puzzles" and insights and test them against the views of her peers" (p.332), and so it is important for teachers to find a technology which helps students as well as themselves become aware of their intuitive understandings.

I recognize the particular problems of trustworthiness, in relying on documenting reflections, to present my point of view. I believe that in this instance the biases that I may show do not interfere with the structure of the approach that is being adopted. The constructivist teaching sequence allowed me to use reflection in a way that was beneficial to my students and enabled me to closely examine my approach to teaching not only magnetism but science in general.

III. The unit - "Magnets and Compasses"

The teaching of the unit in magnetism took place over a period of six weeks. There were twelve sessions that lasted from one to one-half hours in length. The original plan had been to present ten lessons of one hour each but changed as the unit progressed.
The choice of magnetism as a vehicle for this research came after having taught magnetism to grade five a number of times rather unsuccessfually. Twice prior to the research, I had questioned my students about their beliefs on magnetism and each time was amazed at the variety of ideas that they had. Later I began to see that some of their ideas seemed to affect how they responded to my teaching and too often they had the same ideas at the end of the unit as they did at the beginning.

The unit to be taught in this study is found in STEM SCIENCE level 5, and is titled "Magnets and Compasses". Many other information sources of about magnetism from the school library and several secondary and tertiary level text books were consulted to plan and carry out the unit. The students did not use the textbook but I used the teacher's guide extensively.

I planned the unit, initially, by following the order of concepts followed in the S.T.E.M. text. After the diagnostic test was given the first lesson called "Attraction by Magnets" was modified then extended to allow for activities that would permit children to experiment. They were given the opportunity in order to find out which metals were attracted to magnets, to do some problem solving, and to design experiments that allowed them to investigate various notions they had about how magnets perform under water.
The next series of lessons were concerned with magnetic shields, and the making and weakening of magnets. These topics led to the introduction of the particle theory of matter and experiments with heat, neither of which was in the textbook but was of interest to the students, and extended the unit for a further three lessons.

The students then were presented with the concepts of the interaction of magnets, and magnetic fields. The students made diagrams of various magnetic fields, solved problems about magnetic fields problems and made compasses of their own design. The last series of lessons dealt with how compasses work, and magnetic/true north. We did not deal with electromagnetism at this time even though it was part of the unit in the text book.

An in-depth look at the difficulties that certain students experienced in learning about magnetism will be presented in the next chapter.

IV. The teaching approach

A. Background

Having decided to present a case study about adopting a unit in magnets and compasses it was then necessary to begin to decide how. Rosalind Driver (1986) had been working with teachers in the Children in Science Project in England and she along with her researchers and teachers in the study had
developed a teaching model that encouraged the eliciting of students ideas and challenged the students' alternate conceptions. At this point there was no research on teaching with this model at the elementary level so I began my planning using the Driver model influenced by an enquiry or discovery approach to teaching science that I was used to using.

I did not consider myself a "discovery teacher" strictly in the E.S.S. tradition, that is a teacher who provides a learning situation where the learner's behaviour is goal-directed and learns without help from the teacher. But rather offered guided discovery in group situations combined with many approaches that I have no name for and that probably developed from classroom survival skills and from the adaptation of other teachers ideas.

My task was to view the teaching of magnetism from a constructivist perspective in order to deal with the student's alternate frameworks but I was not sure how or even if I should give up the teaching method I was already using. However, I knew I was not effectively dealing with student beliefs even though I was aware that they existed and I wanted to try a new approach.
B. The constructivist teaching sequence

The constructivist teaching sequence, a series of activities aimed at promoting conceptual change, is a product of the Children's Learning in Science Project being conducted at the University of Leeds under the direction of Rosalind Driver,(1986). The sequence comprises of five phases:

1. orientation
2. elicitation
3. restructuring
4. application
5. review

The sequence, which frequently overlaps, continually encourages the active construction of meaning by starting with the student's own ideas (elicitation) and by providing opportunities for conceptual change towards the scientific theory (restructuring). The students are then encouraged to use their developed ideas (application) and to reflect on changes in thinking.

The model of this teaching sequence was loosely followed for the case study with more time for enquiry in the application phase and less involvement in the review phase. It was found that reflecting, for both teacher and students, was particularly difficult and would require practice.
V. Data collection

The difficulties of data collection for a study of this nature with a teacher researching her own classroom were many. Trustworthiness was the most obvious problem and was dealt with by triangulation.

It was assumed right from the beginning that the data could not be generalized to other classrooms although it was felt that the data may uncover activities, suggestions and problems to avoid that may benefit another teacher.

A. Methods of data collection

Data collection for this study was done through the use of video taping, teacher journal, student journals, and diagnostic testing. Except for the video taping the methods used were unobtrusive and were a natural part of the teaching of the unit.

1. Video taping

The video taping was done by an observer who was interested in constructivist research and who had some teaching experience at the elementary level. The purpose of the video taping was to provide a basis of reflection and to capture examples of the five phases of a constructivist teaching sequence.
Initially tape recordings were used to record students' conversations in group work but this interfered so much with classroom mobility that after the first three lessons the taping was discontinued. The students had become accustomed to the tape recorders in previous science units and were used to seeing it in the room but having recorders at each work table did not produce enough data to offset the distractions they caused.

The students found the video camera distracting until it was set up after each lesson started and maintained in one location at the back of the room. Class discussions were usually held on the carpet at the back of the room, and the camera was simply turned around as needed. Occasionally, when the students were busy at group work the camera would be moved so that each group could be filmed. However, the camera often interfered with the smooth flow of students around their table so we limited the filming of groups working.

The students were very excited about being apart of a study and my participation in the classroom for the two months prior to the study helped to reduce the novelty created by the event. At the start of the study, however, the students were intrigued with the video camera and wanted to help set up the equipment each day. Since a video camera had magnets in it we pointed that fact out to everyone and made it part of the study. However the students spent so
long experimenting with the camera at the start of each lesson that eventually we had to stop their involvement.

I found that the intrusion of media in the room sometimes affected behaviour but did not interfere with the teaching sequence of the lesson which is what we were trying to film. The non-intrusive methods of collecting data were the same as could be used by any teacher with a constructivist perspective towards teaching science and did not interfere with the teaching but were apart of it.

2. Teacher journal

The teacher journal was invaluable in keeping a record of my thoughts. I kept the journal with me and would often write in it at home as well as at school. The journal was an extension of lesson planning and made a rich source of ideas, problems and thoughts that I would undoubtedly have forgotten. The journal was also a source of reflection not only for the study but for the planning of lessons.

I found the journal difficult to keep at first because I wasn't sure of what was important to write about and what was a waste of time. Sometimes I would forget about the journal and not write anything. But as the research progressed and I was searching for ways to challenge ideas the value of the journal became quite apparent. I began to write very regularly about ideas that I had for activities, unusual things that the students had said or done, any
criticism that I heard from other teachers, and philosophical thoughts about the constructivist perspective. The journal was kept separate from my lesson planning book but when I do it again I will keep them together for the sake of convenience and to provide a better picture of a particular lesson.

3. Student journals

The purpose of the student journals was to record their ideas and changes in thinking about magnetism and to have the students reflect on these ideas as the unit progressed. The journals were of more value to me than to my students as they were not very interested in reflecting but I used the information to plan for conflict situations and to address common problems.

4. Diagnostic tests

The pre-diagnostic test was developed from the concepts presented in the text-book S.T.E.M. to discover a starting point for teaching the unit by eliciting the students prior knowledge of magnetism. The post-diagnostic test was used to see if the student's ideas of magnetism had changed toward a more scientific view. There was a limitation to this test because the route that the students and I took to finish the unit led us in a different direction from the original planning and many different questions were asked on the post-test that had not been asked on the pre-test. The
information from the post-test should be viewed in conjunction with student journals to provide a more complete understanding of the changes in thinking.

VI. Social context

A. The setting

The setting for this case study is an elementary school in a municipality adjacent to a large metropolitan city. The school, with a population of 256 is situated at the western edge of the community, next to a golf course, and overlooking a ferry terminal. One third of the students are bussed in from a smaller middle class community 11 km away. As a result of its' location the school has a majority of middle to high income families and a few low income families which differs slightly from other schools in the larger community.

The staff of the school numbers 15, which includes administrators as well as Learning Assistance Staff. There are differing philosophies amongst the teachers that sometimes lead to animated discussion and disagreement but the staff generally respect one anothers right to think differently. As a result there is an atmosphere of co-operation and support among staff members and with administration.
The parent body is generally well educated and has high expectations of their children as well as high aspirations for them. The parents are supportive of the staff and have shown their appreciation in a variety of ways on many occasions. They have, for example, sent letters of thank you, arranged staff lunches, and organized a special Valentines Day in appreciation of the teachers.

For the purposes of the study I was granted a four month leave by my school board and a part-time teacher was hired to teach the class from September until December, except for science which I taught from September on. I then took over the class from January until June. This arrangement allowed me the time to finish a graduate course and to take the time necessary to prepare for the study.

My replacement had done much substituting for many staff members as well as myself over the previous two years and was familiar with my teaching style and the operation of the school. As well, she was a personal friend and I had taught both of her children. We agreed beforehand that together we would make a general plan of the four months of the leave and that I would teach the science. We arranged to meet with parents at a "Meet the Teacher Night" and we conferred on the fall report card.

I spent the first week of school in the classroom with the new teacher so that I could get to know the children and then met with their parents at the end of September to
explain the study and how their children would be involved. It was quite evident that after this meeting the parents were as interested in the study as their children were and offered verbal support.

Generally speaking there were few problems created with sharing the classroom with another teacher in this manner and those that there were will be dealt with in another section.

B. The teacher

For the past ten years I have been teaching in a small but affluent community adjacent to a large city. At the present time I am a fifth grade teacher at a school where I have taught for four years. I am also the science resource person, and the computer co-ordinator for my school. One year after graduating with a B.Ed. I became a part time student for two years and completed a fifth year in education in language arts. Then six years ago I began graduate studies in science education on a part-time basis.

The decision to develop a case study of my own classroom was not a difficult decision to make. In fact it seemed to make appropriate that someone who spend the majority of her life concerning herself with lesson planning, classroom management, and how students learn would want to conduct research that would make a direct impact on those students as well as herself. I had decided not only
was I interested in science education and wanted to do a specific piece of research but I believed I had the perfect opportunity to do something useful that my own staff of teachers might read and not passover as work done by "some researcher somewhere who doesn't know the first thing about how we work in this school".

The school district that I work in has become very interested in having a new look at teacher supervision and evaluation. A committee, composed of a panel of educators that include a cross section of teachers as well as administrators, is looking at different teaching styles and how teachers can self-evaluate their current style of teaching as part of the evaluation process.

The kind of classroom research that I wanted to do seemed to be appropriate. Not only would I have a focus for self-evaluation but I would have the chance to research a problem, that of children's alternate conceptions, that I had found to be evident in my own classroom. At this point no other case study had been written about an elementary classroom teacher using a constructivist teaching sequence so I did not know what the problems might but be I did know that I had good reasons for wanting to make the effort.

The role of the teacher/researcher was not an easy one but there was only one person who could research in my classroom and come closest to understanding the complexities
of my particular problem and my point of view regarding children's alternate conceptions - myself.

C. The Students

Thirty-two students took part in the study and no one in the class was excluded. The pupils were a healthy active group who were very involved in school life as well as community activities. They had a wide range of personal interests and had had many experiences with their families that broadened their general knowledge.

The class in general was considered to be average in ability as compared to previous grade five classes in the school. There was no attempt made to group the students in any way at the beginning of the term although children who the staff felt might not adapt to a change in teachers mid-year were put into another class. For example there was a sight impaired student with an aide who the staff decided would not benefit from the teaching arrangements of the study.

VII. Analysis of data

The teacher data collected in the study of magnetism will be analyzed by looking closely at the constructivist teaching sequence as developed by Driver, (1986) and picking out characteristics of that sequence that appeared in my teaching. The student data will be analyzed by the same
method except that examples of student behaviour or ideas will be used to consider the effect of the constructivist sequence on my students.
CHAPTER FOUR

1. Introduction

This study was conducted with two ideas in mind. One that teaching with a constructivist perspective takes into consideration the notion that students come to the learning situation with knowledge and/or experiences that influence how they learn. The second idea is that the teacher must take these ideas into consideration when planning and teaching lessons.

In order to begin to understand what knowledge the students brought to this study of magnetism a series of activities was instigated to identify their ideas. To begin with a diagnostic test was given to the class. The results of that test gave some indication about students' ideas about magnets and compasses. The students were asked to keep a daily journal of their ideas about events that happened throughout the unit. Finally, large charts, which recorded individual student responses during discussion times, were displayed prominently on a classroom wall.

As the teacher/researcher I not only had written lesson plans but I also kept a journal that reflected my ideas and thoughts about what I was teaching and about how the students were reacting. These techniques helped me keep track of the ever-changing directions that the class took in
responding to the many activities involved in this unit on magnetism.

As the students became more confident about expressing their ideas in both their journals and through discussion they became more thoughtful about what they were saying. The students' queries became increasingly more challenging and eventually led us well beyond the confines of the standard grade five curriculum.

Through the reflections of the teacher/researcher this chapter will show that the continuous monitoring of students' ideas, through a variety of activities, helped to uncover not only the concepts that students had difficulties with but also many of the reasons why they seemed to experience this difficulty. This knowledge helped the teacher plan situations that enabled students to come to a clearer understanding of the concepts presented.

The chapter will present a status report of students' prior knowledge of magnetism and then focus on five concepts in magnetism of interest to students but found to be the most difficult to understand. The chapter will accomplish this latter aim by presenting a series of vignettes which deal with situations that occurred during the study that brought to light the problems that the students experienced with particle theory.
ll. Students' Prior Beliefs about Magnetism

At the beginning of the unit called "Magnets and Compasses" a diagnostic test was given to the class to get an idea of what thoughts the students had about the major concepts that would be presented to them during the study. The results of previous teaching with a constructivist perspective had given me a general idea about how the students may respond but I wanted to see what this particular class was thinking about.

The diagnostic test questions were based on the concepts presented in the S.T.E.M. textbook at the grade five level. I had used these same questions in previous years and felt they were reasonable examples of what knowledge might be expected of a typical grade five student before beginning the unit.

The purpose of the pre-test was not to discover what "school type" knowledge they had retained from another year but to determine a starting point for instruction by uncovering some of their common-sense ideas about magnetism.

The questions (appendix 1) were written on paper but were asked orally and then demonstrated so that there would be less confusion about what the questions meant. Also I did not want the students to be confused about the language used in the questions, ie: attract, repel. There was no intent to measure the results of this diagnostic test with a post-
test with the aim of giving a grade as I believed that the post test should reflect the students experiences during the course of the study not what the textbook or curriculum dictated. The results of the pre-test simply indicated a starting place for the teacher.

The questions asked, which can be grouped into five categories, try to elicit explanations of the following:

1. magnetic objects
2. repelling and attracting
3. magnetic fields
4. magnetic shields
5. magnetic north

There was a wide variety of responses to the questions but most students did not respond with the scientifically acceptable answer to any more than three or four of the nine questions asked. However, the students responses were interesting and generally thoughtful.

In general the students seemed to understand that metals were attracted to magnets but they were not aware that only a limited number of metals would be attracted. Almost every student responded with a similar answer to question 1 (see appendix 1) for example:

Daria: The ones I circled all have some metle(sic) on them.

Many students could point out the poles of a magnet although it was clear they did not understand what was
significant about the poles. A number of students indicated that the bend in a horseshoe magnet was also a pole. A large number of students believed that the north pole was more powerful than the south.

At least half of the students demonstrated that they believed that the N/N and S/S poles repelled while the N/S and the S/N poles attracted. Later questioning revealed that they did not know why this happened, although John did explain that:

"There are atoms in the magnet. When electrons go in opposite directions they push away."

I later learned that John enjoyed the study of magnetism so much that he and his father (a curriculum advisor for a local school board) got involved in learning about magnetism at home. Some of John's ideas that he brought up at school were a result of seeing films and having discussions with his father.

Ideas about magnetic shields did not really surface until the unit was well underway as the pre-test had not asked probing questions. Generally most students believed that an object on a table could be attracted by a magnet under the table because the "force" goes through the wood. In answer to the question "How does a magnet attract an object (pin) through a table?" some of the responses were: John: The magnet can send force through the table.
Robert: A magnet does not stop until it hits something metal.

Wesley: It's attraction goes through the table but if it's too thick it won't work.

Matthew: When the table is metal the table becomes magnetic and the pin goes to the source. If the table is wooden it does not become magnetic.

Several children expressed the notion that the "force" grabs the object. For example:

Matt: There is a certain length that the object can be attracted from. If the object is in it's reach it (the magnet) will grab it.

The questions concerning compasses and how they work uncovered some of the most interesting ideas of the study and will be covered in later sections of this chapter. For example many students believed that a compass pointed north but the reasons why were varied:

Wesley: The compass points north because it is pointing at the magnet underneath the compass. It stands for magnetic north.

Colby: The compass points north because thats the main direction.
Caroline: The compass points north if the needle points north.

The questions, explanations and thoughts that the students had during the remainder of the unit were extensions of their ideas about the five categories mentioned previously and gave many insights into why they had difficulty understanding many of the concepts of magnetism. It is quite clear now that the diagnostic test did not even begin to uncover the depth of the students' ideas about magnetism. Only through continual monitoring during the teaching of the unit were these discovered.

The rest of the chapter will deal with several interesting problems that arose from the students' involvement with magnets. It is speculated that some of these ideas could act as a type of barrier (Hawkins, 1978) to their understanding of magnetism in the future.

III. Vignettes

Over the course of the unit my students struggled over "why" certain phenomena occurred and I struggled over how to present them with activities that would enable them to better understand the concepts presented to them. The areas of greatest interest, and those that caused us the greatest concern, are discussed in this chapter and are portrayed in terms of vignettes. They have been titled as follows:
FIGURE 1  **Student drawings of magnetic fields**

Sam  
Robert  
Natalie

FIGURE 2  **Student drawings of broken magnetic fields**

Chris  
Amy  
Caroline
1. Marias' Attraction - magnetic shields
2. Particles Galore - making magnets
3. To the Forge! - weakening magnets
4. One Pole? - magnetic fields
5. Roberts' Magnetic Islands - magnetic north

Each vignette tells the story of one particular incident but also highlights at least one of the activities that I considered helpful to applying a constructivist approach to teaching the unit on magnetism.

A. Marias' Attraction

The idea of magnets being composed of atomic particles became a focus for discussion many times during the study of magnetism. I quickly realized that the lack of understanding of particle theory would be a barrier to a true understanding of how magnets and compasses work. However, the students were never satisfied with passing over a concept they wanted to find out as much as possible about an idea that interested them.

The first stumbling block with particles came after a group activity when the students had been asked to experiment with different materials to see which ones would block a magnetic field. During a class discussion, in which the students were trying to come to consensus, Maria proclaimed quite confidently that a can lid (made partially
of steel) was not acting as a shield after the rest of the class had agreed that it was. She was quite eager to show us we were wrong and proceeded to demonstrate.

What she had done was to make a magnet out of the can lid by having the magnet touch the lid thereby attracting the paperclip underneath. The remarkable thing was that the whole class, without exception, agreed with her findings that the lid did not act as a shield and refuted their own results on the spot!

I reminded the class that the material being tested as a shield was not to touch the magnet but as I spoke the words I realized that the students did not understand the reason why the lid could not touch the magnet. They did not seem to believe that such a small detail was important. I also knew that most students had listened and followed instructions and that their test results were a product of their diligence but their results had made very little sense to them so they were quite attracted to Marias' findings and were quite prepared to accept them.

During the next lesson, at my request, Maria and James demonstrated the difference between Marias' way to do the experiment and James' way (which was to keep the lid separate from the magnet) and I asked for suggestions as to which way produced the magnetic shield. The students gave all the "right answers" as to the "textbook" procedure for doing the activity but something was still missing -
understanding. As James and Maria carefully demonstrated the activity again I narrated what was happening and caught myself calling the can lid, which was the material being tested, a "tin can lid" and have wondered ever since how much of the problem I created. By this time the students understood that magnets were attracted to iron based materials but I had not thought to explain the lid composition to everyone before the activity started.

So, to help with Maria's problem the particle model was introduced to show the north and south poles of the atoms aligned in the commercial magnet and the random way in which the particles were aligned in the can lid until Maria made a stronger magnet out of the lid by attracting opposite poles and bringing them into alignment. This model seemed to make sense to the students - or so I thought. It also cleared up the notion that a "magnetic force" goes around objects (which some students still believed) rather than the atoms attracting each other.

One of the most valuable incidences of the unit took place during the episode with Maria when she took the responsibility for demonstrating and discussing her ideas before the class came to consensus. There was no arguing with the teacher over results.

These student demonstrations happened frequently in the remainder of the unit. I asked questions but the students argued amongst themselves and the situation became
comfortable enough that even shy students were not afraid to speak out.

With the episode featuring Maria came the first true understanding of not only how a constructivist perspective can make teacher and student more active partners in learning and but how much time this unit was really going to take! Up to this point I had been trying to do what I thought a constructivist teacher should do (Driver, 1986). But at the same time I was trying not to allow my ideas about discovery learning get lost as I was not sure that the two approaches could co-exist. At this point I was not prepared to give up what had been for me a comfortable way of teaching science. I wanted to allow plenty of activity and discussion but not worry if we did not come to consensus. Conversely I wanted to help the greatest number of students possible understand the concepts before going onto the next activity. My problem was that I believed that in doing so I would have to spend an unacceptably large portion of class time in discussion which would take students away from manipulating materials and "discovering" for themselves.

What I ended up doing was allowing my students to discover for themselves by encouraging them to express their ideas in many different ways. In this manner I could learn when they were having difficulties and spend the time needed trying to get the majority of students to understand a
concept rather than just leaving an idea and hoping that they would understand when they were ready.

The incident with Maria showed me that the students were willing to spend considerable time in "interpretive discussion" when the discussion arose directly from their experimenting and problems. In so doing their ideas were considered or compared with those of their peers. I began to feel quite comfortable with the idea that discovery learning was a philosophy, while the constructivist perspective seemed to lend itself to a method, (Driver, 1986) and that the two could co-exist quite comfortably. My viewpoint changed again several months later, after getting back to the daily routine of the classroom, but for the remainder of the study my actions were affected by what happened after the incident with Maria.

B. Particles Galore

The students almost always worked in co-ed groups of four that consisted of two female and two male partners. This arrangement initially gave the students a partner to share ideas with and a small group to share equipment with. Eventually the group of four were able to share their ideas but in the beginning discussions were not always productive as there was a certain amount of arguing and "fooling around". But generally as the unit progressed the students became eager to discuss results and since the group leader
was responsible for presenting their results a much more serious approach was taken toward group activities.

A subsequent group activity was to make a magnet. The problems that the students had in doing this activity convinced me that the idea of magnetic particles in the magnet meant little to them or at the very least they were not transferring the new information from their discussions with this model from the previous lessons.

Ideas gleaned from the students' journals showed that the greatest number of students believed that when you stroked an object with a known magnet you transferred magnetic particles to that object. For example when I asked the question:

"What happens to the steel object when you stroke it with a magnet?" some of the responses were:

Morgan: The magnetism transfers to the object.

Maria: The object scratches little pieces off the magnet.

Alison: Stroking an object with a magnet sends off energy that dives into the object.

Roderick: The object pulls the magnetism onto it.

Since the students could not see particles moving in the magnet I assumed that their idea of stroking them or pulling
them off was closest to their own experience as often pieces fall off an object when you brush it or stroke it briskly as they were doing with the pin and the magnet in the activity.

Recognizing why the students had these ideas didn't make things any easier but certainly they did confirm that the whole issue of particles had not been solved and was going to be difficult to deal with.

With the knowledge that the class had some unusual ideas about the particles in a magnet and with the help of the particle model we spent time in discussion about atoms and how atomic particles react to heating and cooling.

A number of students helped to demonstrate that the particles did not change size during heating and cooling but that the spaces between them expanded and contracted. The students simulated particles by standing in a small circle and reacting to two questions: 1. What would you act if you were cold and needed your friends for warmth? and 2. How would you act if you were very warm? The students could see that they did not change size but that the spaces did. I reminded the students that they were making a human model representing how particles behave and that particles did not really "think" about warmth when they expanded or contracted.

My own journal dated for the day of this discussion says quite simply:
"Surely NOW they understand about particles!"

C. To the Forge!

The students' interest in heat began with the question,

"How can you weaken a magnet?"

The response to this question yielded a variety of interesting ideas that we kept posted on chart paper on the wall.

John: Drop the power from an electromagnet.

Roger: Break the magnet in half.

Eric: Bang the magnet against something.

Morgan: Paint with heavy paint.

Natalie: Put the magnet in water.

Amy: Freeze the magnet.

Leah: Get the magnet really hot.

James: Melt it!

The last two responses opened up topics for discussion and prompted activities that lasted for days. The students' pre-occupation for heating the magnet to destroy it, not just weaken it, was amazing. Since James' idea of melting the magnet would not be possible in the classroom their
regular teacher, Mrs. Stewart, suggested that perhaps they could take a magnet to the forge at Fort Langely during a coming field trip. That idea met with great approval and for the moment James' method of weakening a magnet was put aside.

The students, working in groups, set up a variety of activities to see which of the ideas they had talked about might work. During the discussion period the class was divided on whether heat would really weaken a magnet. Many students, including James who was determined that "it didn't work", had difficulties making a magnet strong enough to pick up more than one pin. Thus they had little to compare when they weakened their magnet. The students who claimed they were successful also had poor results and were not really convinced that heat could weaken a magnet very much.

So the graduate student, who was filming the sessions, helped me set up a demonstration with a propane torch (I was sure this would convince James!) and a paperclip. The magnet was clamped to a ring stand with a paperclip attracted to one end of the magnet. The paperclip was heated with the propane torch and it fell away from the magnet.

At first the class argued that the paperclip fell because of the wind created by the hot air blowing on it. But in doing the demonstration again it was quite clear that the clip fell straight down and was not blown away. Then the students declared that the paperclip was not really a
magnet. Groan! Even after observing Marias' results, making magnets, and having discussions about atoms they could not accept that the strong bar magnet had aligned the particles in the steel paperclip. The fact that a "real" magnet had to be a commercial one demonstrated to me that most students still did not understand what was happening with magnetic particles. The class and I had our first real argument over this issue.

James demanded that I heat the "real" magnet then if the paperclip fell away he would believe that heat weakened a magnet. To my consternation the class nodded in agreement.

Well I did try to heat that LARGE bar magnet but eventually the torch ran out of propane and the hour long struggle dealing with the heat problem left the class and I at odds - for the moment. Fortunately the class field trip to Fort Langley was coming up the next day so the magnet was left in James' care to deliver to the blacksmith in the forge, who I sincerely hoped had a sense of humour.

My journal entry for that day is blank. I came away from the lesson feeling frustrated that I did not seem to be making my point about particles. The entire lesson had been videotaped though and as I looked at the tape of that day weeks later I realized that the class was really interested in what they were doing. Even though James was getting a little out of hand with his demands about heating the large
magnet at least the students felt comfortable about expressing their ideas.

I felt that I understood why the class was having so much trouble understanding. I did not just pass it off with, "They weren't listening," or "They just don't care". The journal entries and discussion charts were really giving me an insight as to how the students were dealing with new concepts. I had to learn to be more patient and perhaps not expect so much from them.

The trip to the forge occurred before the next lesson. The blacksmith heated the "real" magnet almost to the melting stage (there was the problem of, "What do you do with a melted magnet?"
) and then allowed it to cool. James proudly brought the magnet back to class and presented it to me. I produced a box of steel pins and James tried, unsuccessfully, to pick them up. Then Roger asked,

"Can you make it work again?"

The magnet was then put into an electromagnetizer, the particles were realigned and much to my relief (after the previous day I believed anything could go wrong) the magnet picked up half a box of straight pins. There was just a hint of a smile on James' face! The students had understood how the electromagnetizer worked - more or less - and recognized that it was like stroking the magnet in that all the particles became aligned. I asked,
"What did the heat do to the magnet?"

Some of the students believed that the heat caused the particles to move out of alignment but most did not. Some of their journal entries for that day were:

Caroline: I think the particles got too hot and went in all directions and lost their power.

Matt: The particles got really hot and started turning away from the heat.

Leah: Particles were burned and disintegrated.

Chris: The heat drained the energy out of the magnet.

Colby: All the particles got smaller and smaller and then just disappeared.

Emma: When the magnet is really heated the particles bust open.

Quinn: The particles melt because they are so small.

Lara: When you get hit by fire you run in all directions. So when the ends of the magnet get heated the particles at each end run to the middle and they all bunch up in different directions.

All of the ideas made sense to these students because they indicated their own experiences with heat. Laras' analogy is a good example. Things do burn up, or melt, or
burst from high heat exposure. People do turn away from something hot and one's energy becomes drained on a hot day. Obviously these prior experiences with heat create beliefs that can be transferred to other situations, such as a heated magnet, and they will continue to be used until a more powerful idea takes its' place.

After some discussion with the class I had to decide how much I expected them to know. We had spent three days on the heat problem, and while many interesting things happened I was willing to carry on with the next activity and leave the problems of heat for another year.

D. One Pole?

The students' ideas about the poles of a magnet were uncovered after a series of group activities were completed on magnetic fields.

Students were asked to make diagrams of the magnetic fields surrounding a variety of magnets. The group leaders were given the materials (ie: bar magnets, horseshoe magnets, round magnets, broken magnets, iron filings and clear acetate sheets), to set up at their tables and the students worked with partners, sharing results and discussing. It was obvious that the students had a wide variety of ways of representing their ideas but many of the illustrations were confusing so at the start of the next lesson the class was asked to review their drawings of what
they thought the magnetic field would look like around a bar magnet. Volunteers were asked to share their ideas by illustrating them on the board. Some of these are portrayed in Figure 1.

From previous experience I knew that asking students to represent magnetic fields was not an easy task but I wanted them to do acceptable drawings that everyone could understand and share so we did the magnetic field drawing over again showing how using dotted lines and arcs might clarify their ideas. The students then proceeded to work with their materials to illustrate the magnetic fields surrounding repelling and attracting magnets with much better results.

During a discussion following these group activities various students presented their illustrations of various magnetic fields and the class tried to come to consensus on the results. It was not until we came to the broken magnet that the students began to disagree vigorously about what they were observing. The students' individual drawings from the previous lesson are shown in Figure 2.

The drawings were so different that the students were not able to come to consensus with the issue of broken magnets. I found this situation very puzzling because they had done their own activities and it seemed amazing that their observations were so diverse. At the end of the lesson I asked them to describe in their journals what they thought
happened when a magnet was broken. Many responses reflected the illustrations done in their notebooks:

Chris: All the particles go to the end and become a pole. (This was a very popular idea with many students)

Maria: Some of the magnetism went to the other half.
A revised explanation in her journal states:

The particles broke up inside the magnet until it stopped working.

Amy: The particles grew smaller and got mixed up.

Erik: The broken magnet works the same as a whole magnet. The magnetism in the middle of the magnet didn't attract anything but when it was broken an opening was made so it was strong again.

Caroline: The broken magnet has two poles because when it is broken the particles go to the end that is broken.

At the beginning of the next lesson I asked several children with different ideas to put their representations of the magnetic field of a broken magnet on the board. Then I demonstrated, on an overhead projector, with iron filings and a broken magnet.

At this point I was trying to address the one pole idea and so asked the class what the iron filings at both ends of the magnet might mean. (The day before when the students were doing their own activity I had observed that every
student had got the same result that I now had on the overhead.) A number of students proceeded to count the number of iron filings on the ends of the magnet. When I enquired as to why they were doing this the response was, "We want to find out which end is the weakest because then we will know the other end is the pole." It was then that I realized that their beliefs of what a broken magnet was had actually influenced how they would do their drawings regardless of what they observed.

I was also interested to note that the journal entries about broken magnets reflected some students' interpretation of particle theory in their attempt to explain an idea:

Beodl: All magnets have two poles. Some particles will turn around and face the end that was broken.

Matt: If the south end was broken off the broken end would start working as south, and the little particles of magnet would start pointing south.

Wesley used the first analogy I had read or heard from a student:

"A broken magnet works the same as a whole magnet because it's like an earthworm. If it's broken it still lives. If you break a magnet the particles will be the same. It's just making a smaller one."
The use of analogies, up to this point, had been left up to me and so it was exciting to have a student use one. The class probably picked up on my enthusiasm, (particularly after I posted Wesleys' analogy on the bulletin board), because several other students tried to explain themselves by using analogies. Note Laras' explanation of what happens when you heat a magnet in section C.

The whole notion of poles became even more interesting when I introduced a magnet, again on the overhead projector, that appeared to have three poles! The students, as well as the teacher and the graduate student, were incredulous. No matter how many times we did the demonstration there were still three poles. Eventually we decided that perhaps two log shaped magnets had been welded together although the third pole did not appear in the middle of the magnet. We did not feel we had to come to consensus on this one and it was a good way to bring this part of the unit to closure - with something else to think about.

**E. Rogers' Islands**

Eventually our lessons in magnetism led us to magnetic north and compasses. From the diagnostic test and the discussions following from day one of the unit I knew there was a variety of ideas about how and why compasses work:

Teacher: Why does the compass needle point to north?
Erik: It's from the equator. It's all to do with the equator.

Teacher: Oh, can you explain?

Erik: In the middle of the earth it is burning hot and in the middle it's being pulled by both directions. The south pole......it's way down......pulling down, and the north pole is pulling up. It's being pulled by both directions.

Morgan: A compass points north because we are closer to north.

Colby: A compass needle points in the same direction that you put the compass.

Emma: Magnetic north has a small magnet in the air......and the needle is......metal and when you put it down, it just points there.

Roger: There's an iron island in the Arctic Sea......and the magnet points there because magnets attract iron. There's a magnetic island.

Kier: Yeah, just like Roger said.....there is an island....well, a couple of islands.......that 'cause the water is so cold......the volcanic eruption came and the water cooled it down......so if there is any magnets in the water......the magnetic stuff.......it got in and when the
island was formed the volcanic rock had magnetic stuff in it.

The idea of the magnetic island was very common among the students. For example the following lesson when I asked the students to help me make a list of where you might find a magnet the "island" came up again:

Roger: Well, I looked on the atlas and I found the magnetic island up around the north pole....Magnetic Island.

Teacher: Do you want me to put that on the list?

Roger: No, I found it......on the atlas. You know that island we were talking about?

Because Roger's idea of the island was popular and he seemed to feel very strongly about it I asked him if he could explain exactly what he meant because I had never heard of Magnetic Island. He told me that his Scout Leader had taught him that the compass needle pointed to "magnetic islands" near the north pole. He was absolutely insistent that there was an island called "Magnetic Island". He was so interested in this idea that we continued on with the discussion after class and I said that I would try to find the island on a map of North America.

I spent a long time looking at every map that I could lay my hands on trying to find the island. Eventually I realized that because the current position of the North
Magnetic Pole is in the vicinity of Bathurst Island the cartographer, who had developed the maps for the school atlas, had labelled the map in such a way that gives the impression that there is a "North Magnetic Island". The name Bathurst is over to one side of the island and the word pole is placed below the island so that it looks like they do not belong with the rest of the words. Roger had looked at our school atlas and had his notion of the magnetic island confirmed, along with that of his Scout Leader and so this idea was very strong for him.

Scientists, of course, are not really sure about how magnets work and there is some speculation that perhaps there is magnetite at the poles but the students' idea of the magnetic islands being the cause of compass movement was not one that I wanted to stress. The idea of the earths' magnetic field (whatever its' source) interacting with the magnets' magnetic field, similar to that of two magnets, seemed to be more in line with what we had been studying previously.

The groups spent time making their own magnets and setting up short demonstrations but we kept coming back to Rogers' island. Eventually, with the help of diagrams that showed the similarity of the earths' magnetic field and the magnets' magnetic field, the students could see that it made sense that the magnetic compass needle was attracted to the north magnetic pole.
We did of course have to spend time discussing the notion that the N on the magnet or compass meant north-seeking not north. The idea of N not being north was confusing for many students but for most the idea of unlikes attracting (especially when someone came up with the idea of male and female) was quite strong and having the south end of particles called the north-seeking end of the magnet suddenly made sense.

The concepts of magnetic north and compass interaction with the earth’s magnetic field are both part of the S.T.E.M. unit in magnets and compasses. The information in the textbook is very confusing unless the teacher has done some preliminary work with particles (not included in the textbook) and there is very little background information for the teacher. I found myself continually referring to secondary physics textbooks whose authors complained about the fact that students had such a weak understanding of magnetism.

IV. Evaluating Students' Beliefs About Magnetism

As the unit on magnetism progressed more and more information concerning how the students were thinking about certain concepts of magnetism was being collected. By the time the unit had come to a conclusion the bulletin boards in the classroom were covered with charts that contained student ideas about magnets and compasses. The students'
journals were full of entries, at least one for each lesson and sometimes two, there were problem sheets that students had worked on and notebook entries that displayed the results of their own experimenting. There seemed to be more than enough work done to evaluate students without a formal test but for my own future planning I decided to use the information that was available to see if there had been any change in their thinking about magnetism by giving a second diagnostic test.

The students were told that this was not a test they could study for and in fact even if they had been told to study no text book had been used and they had not taken any notes to study from. The students were informed that this test was similar to the one given at the beginning of the unit and that it would show if there had been a change in their original thinking and if that thinking was similar to what scientists thought. The purpose of the test was not to grade right or wrong answers. I was not surprised with the reaction of concern on the part of the students as their notion of any kind of a test at the end of a unit was quite different from what I had in mind.

I made up questions similar to the ones on the diagnostic test given to the students at the beginning of the unit but added to that questions that covered other topics that we had studied about magnets and compasses. The test was a paper and pencil one but was read out orally and
demonstrated when applicable just as the first test had been done. This time, however, the students were told that they should use their journals, charts, problem sheets and notebooks to help them answer the questions.

The students were asked to look back at their previous thinking to see if their current thinking had changed by referring to their pre-tests, their journal entries and to the discussion charts and then come up with an explanation for each one of the questions on the post-test. For example, the first question was to circle objects that would be attracted to a magnet. Many students had originally believed that all metals were attracted to a magnet. I wanted them to recognize that not only were certain metals attracted to magnets but that their thinking had changed.

There was no problem with copying answers from charts and journals, because the students were asked to explain, usually with diagrams, what they were thinking about.

Once the test began students got used to the idea that they could use all the sources of ideas to answer the questions. At times throughout the test you could hear students laugh as they read their previous work but overall they actually used their own written materials minimally although I directed them to the class chart work continually. I had hoped that they would spend more time comparing their new ideas with their old ones. But on reflection I can see that this idea will take nurturing as
the students' idea of a test was quite foreign to this one and they were more concerned with just answering the questions. I was pleased to see though that some students were doing as I had asked and were relaxed enough to do so. (More discussion of reflection will occur in chapter 5.)

The students received the diagnostic tests back with comments rather than a mark and an indication where their thinking had changed and if it was similar to the way a scientist might answer the question. There were nineteen concepts tested and the majority of students answered 80% of the questions with acceptable answers but what was stressed was how much their thinking had changed.
V. Students' current beliefs about magnetism

The influence of the constructivist perspective on my students was a positive one. My enthusiasm for what we were doing, the filming that was going on during the lessons, and student knowledge that the study was "special" undoubtedly influenced behaviour but those situations do not take away from the fact that the students did have many ideas about magnetism that influenced their thinking. They were given an opportunity to express themselves in a variety of ways that encouraged discussion and the sharing of ideas. Whether or not the students understood more concepts with this approach than other approaches I leave up to another researcher.

The influence of student beliefs on conceptual understanding and on how students performed activities was monitored constantly through journals, discussions, problem solving, and notebook entries.

Profiles of the following three students were made up from ideas expressed on pre and post diagnostic tests, from journal entries and from class discussions. They give some indication of the students' current beliefs about magnetism, if or how their thinking changed and some reasons for their thinking that will, hopefully, aid in preparation of the unit when it is next taught.
A. Student profiles

Maria

Maria was a new student to the school and was having trouble making friends. She had begun to resort to seeking attention by "showing off" and as a result her reputation with the students was very poor. Every time she spoke up about anything the class would moan and groan and say things like, "Oh no not her again!" This was a very disconcerting situation for me and for her classroom teacher, who was constantly trying to deal with the problem. Even though the class and I had discussed respecting the views of others, I was very worried when Maria, who was very obviously interested in what we were doing, started to make suggestions and give explanations. Her idea about the magnetic shield caught the students attention when I asked her to demonstrate for the class and then discussed her ideas using her name. I believe that the class realized that I thought that her "discovery" was important because from that time on there was rarely a time when anyones' ideas were scoffed at including Marias'.

Maria believed right from the beginning that metals were attracted to magnets but she thought that all metals were attracted. So many of the common metals around the classroom do attract metals that for Maria, and for the majority of her classmates it was a natural thing for them to think.
FIGURE 3 Marias' heated magnet

FIGURE 4 Marias' magnetized compass needle
Most of the students including Maria came to believe that metals must be iron or nickel based to be attracted to a magnet. Maria, however, never did understand what materials would or would not shield a magnet. She probably memorized the information she needed but did not understand it. Perhaps this accounts for her experiment where she made a magnet instead of a shield and everyone agreed with her.

Maria's original belief about broken magnets was:

"A broken magnet would still have two poles because some of the magnetism went to the other half."

The difficulty with the understanding of particles was, for Maria, the same as for many students. They were looked on as something that was alive and making deliberate moves.

At the end of the unit Maria indicated that when a magnet was magnetised properly (even when it was broken) the particles were aligned. She also knew that a magnet, under intense heat, would have particles that were not aligned but her drawing changed dramatically. Note that in Figure 3 the particles are very small whereas in her drawing of the magnet with aligned particles they were very large.

Maria's journal states that:

"When the magnet was heated the particles inside the magnet broke up into small pieces which weakened and weakened the magnet till it stopped working."
So, while Maria could accept that the magnet had particles that stayed the same size in a cold magnet she felt that something different must happen to their size when the magnet was hot.

Maria ended up with a rather confused idea of why a compass works. She could say that a compass points to the North Magnetic Pole because:

"The needle is magnetised and magnetic north is magnetic."

Her notion of north-seeking prompted her to do the drawing as shown in Figure 4. She had apparently decided that the particles in the front half of the needle are pointing south because she knew that N meant north-seeking but the particles in the back of the needle pointed north because she knows there are two poles. She has not understood that all of the particles, as well as the magnet, have a north and south pole.

James

Like Maria, James believed that all metals were attracted to magnets but he seemed to be able to sort out the different metals used in experimenting and was more successful in determining what materials would create a magnetic shield.
James did, however, express a view that Maria did not and that was that the south pole of a magnet was stronger than the north pole. I am not sure that he really had any reason to believe this because he changed his mind very quickly when we began to work with magnetic fields. However, many students did believe that the north pole was the strongest and there seemed to be several reasons for this thinking. First, we live in the northern hemisphere and as a result are north oriented by nature. Second, the fantasy of Santa Claus has made the notion of the "North Pole" very prominent in childrens' minds. And third, students who had any experience with compass work knew that the needle pointed north. James indicated that he knew that compasses pointed north but perhaps was not sure if both poles were the same so he just guessed.

In the beginning James' explanation of why a compass points to the North Magnetic Pole was:

"It always points north."

Later when we had experimented with compasses he revised his explanation:

"It would point in that direction because there is a block of magnetite and the north pole of the needle is pointing to the magnetic block."

His belief in the block of magnetite was quite strong and he never changed his thinking.
James seemed to have an ever-changing view of many of the concepts that we dealt with during the study. He showed a great deal of interest in the heating of magnets, although much of his approach was attention seeking, for example the propane torch experiment. Many times his answers appeared to be for my benefit rather than for his own. It was apparent that James had had little experience with magnets before the study and he did not want to appear to be unknowledgeable in front of his peers. However, James' classroom teacher was amazed at his interest level, and at his change in behaviour after we began to take an interest in his ideas. His part in the trip to the forge seemed to provide the positive attention that he sought.

Lana

Lana worked very hard throughout the unit to make some sense out of the concepts she was presented with. She had had no experience with a magnet at all - even at home. She was the only student in the class who had never used a magnet. Her interest in magnetism heightened at the same time James' did when students were making suggestions as to how to weaken a magnet. Lana wanted to "Get the magnet really hot". It was this suggestion that led to the propane torch experiment in which Lana was asked to assist.

Lana was able to draw a model of the atoms in a magnet when it was strongly magnetized, broken, and heated. Her
drawings showed the particles aligned for all three states but like Maria the size of particle for the heated magnet was smaller.

Lanas' explanation for the broken magnet was:

"...the pardekels (sic) in each side stay in that side..."

She says nothing about alignment but her diagram showed that the atoms were lined up and that they were approximately the same size. Lana may not have given a complete explanation but she was getting there.

Her explanation for a heated magnet as she explained in her journal was:

"I think the pardikels (sic) in the magnet got burnd (sic) and disinegrated (sic)."

Her diagram and explanation showed that she did not understand particle theory but the atoms were not aligned so she did know that something happened to the atoms in the magnet when it was heated and that it would not attract metals.

It was interesting to read Lanas' explanations of her ideas. She was a learning assistance student in language arts and her vocabulary and spelling was sometimes a barrier to my understanding - not hers. She never did use the words repelling and attracting - just north and south.
FIGURE 5  Lana's magnetized compass needle

FIGURE 6  Rogers' broken magnet
Her explanation of why a compass points north at first sounds like jiberish:

"Because on a comas (sic) South is North so South is atracked (sic) to North so North is not atracked (sic) to North.

If you study her drawing (see Figure 5), which explains why the N end of the compass needle is attracted to earths' N pole, you can see that it does make sense.

She is trying to say that the atoms in the needle of a compass are aligned S/N and are north-seeking (south is north). So, the south poles of the particles in the needle are attracted to the North Magnetic Pole of the earth (south is attracted to the north). The last part of her statement, "So north is not atracked to north", shows her understanding of the idea that two north poles do not attract but repel.

It is quite obvious that Lana has a long way to go before she really understands the concepts of magnetism but I think that it's important to note that students get confused with language which in turn masks the ideas they have that may be correct or at least show that they are on the right track.

Roger

Roger had had some previous exposure to magnetism with his grade three teacher and had been taught how to use a
compass by his Boy Scout Leader. He was one of the most active students in that he was always trying so hard to put his own ideas together with the new ideas he was learning so that concepts made sense to him.

On the pre-test Roger gave the impression that he remembered very little about magnetism. Like almost all the other students he believed that all metals were attracted to magnets and he knew nothing about magnetic shields. He was unsure of where the poles on a magnet were but he did remember that like poles repel and unlike poles attract. His response to where a compass points was:

"Anywhere it stops."

He did explain that a compass needle moves because of the magnetic pull of the earth (as in the Magnetic Islands). In general Roger, like most of the students, had a wide variety of ideas about magnets and compasses. Some of the ideas were confused, some half remembered, and some based on experience.

Roger gave up many of his confused ideas when he began to experiment for himself but he ended up with two very strong notions that he expressed on the post-diagnostic test. The first notion had to do with broken magnets. Like many of the students Roger was quite prepared to accept the idea that a broken magnet would work the same as a whole
magnet. But very few students could give a clear explanation of why.

Rogers' current belief about broken magnets, like that of many of his peers, is anthropomorphic:

"When you cut a magnet its' particles divide up".

But apparently not equally as you can see in Figure 6.

His original thought was:

"A broken magnet works because when you cut it, it divides the power."

He has revised his language rather than his thinking.

Some students, even at the end of the study, did not want to accept the idea that broken magnets work. The thought that something broken can work the same as something whole is hard to accept. The fact that the students wanted to count every iron filing at the ends of a broken magnet in the magnetic field experiment demonstrates that they didn't want to give up their idea. Test wise students memorize these facts but do they understand them or believe them?

Rogers' explanation of the broken magnet was quite different from that of:

James: "If you break a magnet all the particles or iron filings still go the same way."
Maria: "The particles are still in the magnet so it is still as powerful as it was when it was whole.

Wesley: "If it's broken it just gets smaller. You get two magnets but they are both weaker.

James, Maria, and Wesley believed that the particles did not move from one side to the other or divide up as Roger described. The class was divided on the issue of particle movement. Two-thirds of the students gave an answer that demonstrated their belief that the particles did not divide up and move into each section of the magnet but that the particles remained in the same place.

The second belief that was very strong for Roger was that of the magnetic islands described in section 4. As explained before many students had a similar idea to Roger's - that a magnetic island or rock hovered over or was part of the North Magnetic Pole. Roger had many conflicting ideas about this issue and I'm not sure that he has yet resolved them, but it was certainly not from trying. Roger was able to draw a representation of the atoms in a compass needle to show why N is attracted to the earth's magnetic pole. When asked to explain why the compass points to the North Magnetic Pole he said that:

"The compass needle is north seeking and it is in the northern hemisphere."

Roger had given up his island. Or has he?
VI. Summary

The students did not give up their prior beliefs easily when their own experiences were strong and the concept did not make sense to them. For example, ideas about magnetic north, broken magnets, magnetic shields, and weakening magnets (discussed in sec.3) were difficult concepts and the information learned from everyday experiences was easier for students to understand and made more sense to them. The post-diagnostic test indicates that many students still had a weakness in understanding these concepts.

The reverse of this situation is that some concepts such as repelling and attracting, and particle alignment made sense to students because of their every day experiences and so were able to accept those concepts more readily.

I will never really know if any of my students answers on the post - diagnostic test indicate a change in their beliefs. Some of the problem solving activities done during the unit, such as working out mystery magnetic field patterns, and some of the drawings, in journals and on the test, indicate they seemed to understand some of the basic concepts. Only time will really tell if the new ideas are useful.

I do know that I have a good understanding of some of the problems that my students were having. Better yet I believe that I also discovered the reasons for some of those
problems and having that knowledge helped guide me through the unit and will help me again when I next teach magnetism.
CHAPTER FIVE

1. Introduction

In general, the major thrust of this chapter will be a discussion of the influence of the constructivist perspective in the classroom and of the value of reflecting as an integral part of the application of that perspective.

In particular, the chapter will examine the common beliefs of magnetism still held by the students and how some of these beliefs interacted with the new concepts presented. The value of the strategies used in the elicitation of student beliefs, in the restructuring of ideas, and in the application of the student's understanding of magnetism in group activities and problem solving will be analyzed. Also, the notion of "ownership" that developed as the unit progressed will be discussed.

Several sections of the chapter will focus on how the teacher/researcher adopted a constructivist perspective to suit her own classroom and will discuss how reflecting - in/on - action posed problems as well as uncovered them.

Finally, the chapter will conclude with a discussion of the implications of the constructivist perspective for the classroom teacher and suggestions for further research.
11. Influence of a constructivist teaching sequence on students

The influence of a constructivist perspective on my students was a positive one. My enthusiasm for what we were doing, the filming that was going on during the lessons, and student knowledge that the study was "special" undoubtedly influenced behaviour. But those aspects of the situations did not take away from the fact that the students had many ideas about magnetism that influenced their thinking and that they had an opportunity to express them in a variety of ways that encouraged discussion and the sharing of ideas. Whether or not the students gained a better conceptual understanding of magnetism with a constructivist teaching sequence than with other approaches is not possible to address with this type of case study. I leave that question to other researchers with a different design.

It is quite evident that a number of activities used in the teaching of magnetism assisted in the application of a constructivist perspective that could be used in other grade five classrooms if the teacher was aware that student's do in fact have alternate frameworks from which they view the world.
The activities described in the next section are part of a constructivist teaching sequence, adapted for the magnetism unit from a model developed by researchers working with The Children's Learning in Science Project (Driver 1986).

A. Eliciting students' ideas

1. Pre-testing

The student's alternate framework for understanding the concepts of magnetism was only partly uncovered by a pre-diagnostic test given on the first day of the study. Even though some time was spent in giving the test and trying to clarify exactly what I meant by each question through demonstration, it was difficult to uncover the students ideas for a number of reasons:

1. the students did not have the vocabulary to express themselves clearly;
2. many students were nervous because it appeared to be a "test";
3. I may not have asked the questions in a manner that would best bring out the student's prior beliefs;
4. it was difficult to know which questions to ask that would give a good view of the student's prior knowledge. There are many concepts of magnetism taught in the unit on Magnets and compasses and the
students at this age level have trouble dealing with too many ideas at one sitting

Number five is interesting because I had given a similar pre-test to previous classes orally and found that there were certain prior beliefs of magnetism that were common to all groups such as:

1. magnets attract all metals;
2. compasses point north because of a magnetic rock or island hovering over the pole;
3. the north pole is stronger than the south pole;

But each class had their own interests and followed the unit to conclusion in their own way so that it was hard to know exactly which questions to ask another group other than the few beliefs which seemed to be common ones.

The oral pre-test had presented problems of its own such as shy students not speaking up, and students making up ideas after hearing other suggestions just to be participate. On the other hand the discussion was richer than a written test because the students who needed encouragement to speak could build on the ideas of others and I could direct the questioning in the area of their interest. Either way I could not count on a pre-test to do anything but give a starting place for discussion.

I began the study with the belief that a written test would also have its problems and so followed up the
pre-test with an oral discussion immediately after the pre-tests were handed in. The students were quite prepared to discuss the questions orally that I had just asked and had more time to think about them. Undoubtedly some of the student's responses to questions were not totally their own after hearing their peers ideas but the pre-test and discussion together gave a broader picture of where to begin the first lesson and approximately what topics would need more preparation.

The pre-test and discussion still did not uncover many of my student's ideas as was apparent as the unit progressed and more concepts were introduced. The uncovering of additional beliefs, the influence of student beliefs on conceptual understanding and on student performance of activities was monitored continuously through journals and class discussion.

2. Journals

The use of journals had been introduced early in September with a unit in Forensic Science. The students took some time to understand that what I wanted was for them to put down their thoughts -- that they were not answering questions that had a right or wrong answer. They were also encouraged to ask questions of their own that I would either answer in their journal or bring up in discussion during the next lesson. Since I could not deal with all the questions
on a class basis I looked to see if several people had similar questions and dealt with those.

It took some time for me to see how to get real value from the journals because the majority of students wrote very little to begin with and some students complained when I asked them to write in their journals because they viewed the procedure as a type of testing. They were used to keeping a daily journal of personal thoughts for their classroom teacher but this one was viewed as something very different at first.

When the unit in magnetism started we had not progressed very far with the quality of content in the journal. But as time went on and the students realized that I read their journals carefully after each lesson and then dealt with their questions in some positive way, without evaluation, most of the students spent more time trying to express their thoughts. If I failed to answer a question that a student was interested in I would sometimes get a gentle reminder to "Please answer my question from yesterday!". I did not want to get into the habit of answering all questions in this manner because the point of the journal was to monitor their ideas and to use them to plan for class discussion. Furthermore, I was not prepared to just "tell" them everything, so I often made suggestions as to how they might find out the answers to their questions for themselves if I was not going to deal with it in class time. The recognition
that I had read the journal was what seemed to be the most important. The practice of commenting in the journals in a non-evaluative way had the added value of personalizing our teacher/student relationship. However the time factor involved would not make it practical for a teacher to do this after every lesson for every child.

The journal was also useful in having the students reflect on their past ideas before adding new ideas to it. This was very difficult to do because most students did not like reviewing their past work particularly if they were not proud of their original idea. This situation slowly gave way to a feeling of "ownership of ideas" which will be discussed in another section.

The whole idea of reflecting was difficult not only for the students but for me. Reflecting takes time, energy and practice and only when it becomes evident that reflecting will produce something fruitful do you begin to realize the value in the process. It was quite evident during the post-test, when students were encouraged to use their journals to answer questions, that many students were not prepared to take the time to use them. Their journals did not contain enough of their ideas to really make them useful. I believe that keeping a science journal that will be really useful for the student will take much practice and, in fact, is difficult for many grade five students.
However, the journals were very useful to me in lesson planning.

3. Class discussions

Discussion played a very large role in the development of the unit in magnetism. It was important to know how the students were thinking not only at the beginning of the study but throughout the unit. Additional student beliefs in magnetism were uncovered and the monitoring of new or changed thinking as it surfaced was made explicit during our many discussion times.

A concerted effort was made not to allow discussions to become question and answer periods but to encourage interpretive or reflective conversation. This was hard for me because I had been used to asking questions in order to help students begin working with materials and then to circulating among the groups to ask individuals specific questions about their work. The aim of the discussions for this study was to begin with some sort of problem or event that encouraged students to express their ideas not only to me but to engage in discussion with their peers before their ideas were tried out with materials.

I did not stop asking individuals specific questions about their work but the questions sought out opinions as well as directing experimenting. For example the question,
"What do you think will happen when the magnets N poles are pointed at each other?" was more common than, "What happens when you point the magnets N poles at each other." Both are good questions and both should be asked but the first question tries to encourage the student to think about what she already knows then she is ready for question number two. I found that I spent more time and effort on prediction than I ever had before and with a greater understanding of why I was doing it.

To keep track of student beliefs and to allow those beliefs to be recorded visually large chart paper was hung on the wall in the discussion area and individual names were written beside the owner's idea as it was presented. The students were then able to refer to specific ideas by name when they were speaking. Sometimes during discussion we would refer to previous thinking and the charts were valuable in allowing us to look back on prior discussions.

B. Restructuring of ideas

1. Conflict situations

The restructuring of student's ideas began with the type of interpretive discussion as described in the previous section. But it was not just discussion that brought about a change in thinking in many cases. Students that did not have a strong belief of their own were quite prepared to listen to discussion and accept the new ideas with little thought
as as they did in Marias' case where she made a magnet instead of a shield. If there had not been a follow up to that experiment in the form of a conflict situation, (Maria and James shared their opposing ideas by demonstrating to the class) I am sure many students would have continued to believe her results because they "saw" it happen. They may have listened to my explanation of what happened and understood but I wonder what would have been the most powerful influence - what they heard from me? or what they saw Maria do?

The introduction of the particle model diagrams after the incident with Maria widened the study of magnetism beyond my original intent but the students were interested in taking this direction and the problems that the diagrams instigated were interesting enough to explore.

The conflict situation presented with the propane torch and the paperclip to show that heat could weaken a magnet certainly led to frustration on my part but it did show me quite clearly that aside from the heat problem the students still believed that a "real" magnet was bar shaped and commercially made. Knowing this made it easier to understand why they may have had difficulty understanding that the heat from the torch did weaken the paperclip magnet. The "red hot" heating of the "real" magnet at the forge was necessary before the students would believe that heat really could weaken a magnet.
Presenting a problem in some form that conflicted with the current idea gave the students a chance to see and to hear about something different. Then the students had an opportunity to "do" by applying new conceptions in a variety of ways. Hopefully new ideas were consolidated with this approach. Perhaps this happened at the forge.

It was often necessary to introduce some sort of conflict situation or problem during the discussions in order to keep them from becoming question and answer periods. Unfortunately knowing what challenge might be needed ahead of time was not always possible because I never knew how the students would be thinking ahead of time or the direction the discussion might take.

The introduction of conflict situations was where reflection -in- action was often necessary and important - but difficult. I think that teachers probably reflect -in-action frequently when they are circulating in the classroom and see a need for redirecting an activity but the situation is different when you are confined in a discussion situation with thirty students trying to redirect a conversation with a "problem on the spot". Many times a discussion was brought to closure because I was not sure of what I should do next. I am convinced that practice in reflecting and familiarity with student's common alternate ideas of magnetism will make the inclusion of conflict situations
easier in the future although trips to the forge are rarely possible.

2. Sharing ideas

Some of the most interesting situations, that encouraged the students to restructure their ideas, took place during discussion times when the students shared their ideas in a variety of ways. For example Beodl used a set of floating magnets to explain attracting and repelling to the class and then compared her idea to others that she saw listed on the chart paper. Emma used an overhead projector to explain her ideas of a magnetic field. Lana helped to demonstrate her idea of heat weakening a magnet by helping with the propane torch. Roger explained his island theory using a map of Canada. Maria, who was very daring and demonstrated her idea of a magnetic shield, caused a number of students to get involved in a variety of demonstrations. I would like to have seen a great deal more of this kind of sharing but like many of the other activities used during the study it required practice and patience on the part of the teacher to allow for it and an understanding of its' role on the part of the students.
3. Coming to consensus

Trying to come to consensus on an issue was always interesting and provided for the most exciting kind of sharing and potential restructuring of ideas. After the students had had an opportunity to work with materials the group leaders would be asked to present the results that their group members had agreed upon (or not agreed upon in some cases). After the first group explained their findings the class would be asked how many other groups confirmed the results. Those groups that did not would be asked to demonstrate their own findings and we would enter into discussion until we came to some kind of closure. If the entire class was on the wrong track it was time for me to present a conflict situation.

For example we did not come to consensus with the magnetic shield experiment until after Maria, James and several others had demonstrated their findings. But eventually everyone was satisfied. The concept of heat weakening a magnet took days to be resolved but again we came to consensus after the torch experiment and the trip to the forge. I am not convinced that we ever really came to consensus on the idea of why compasses point north and the post-diagnostic test certainly showed that some students still believed in Rogers' magnetic island theory.
The aim was to come to consensus with the results from activities and experiments but if we did not as in the case of heat particles, magnetic north, and the three pole magnet I simply went on with the next lesson.

When the students were drawing magnetic fields there was very little discussion other than confirming instructions or arguing about who was going to sprinkle the iron filings next but once the class was told to discuss results to see if the group could come to consensus they began to share their ideas. These conversations often ended up in arguments until the ideas were presented to the class. The majority of students did need teacher direction when trying to come to consensus.

C. Application of ideas

When working with materials the students were grouped into fours so that they could work with a larger number to share equipment, work with a partner, or work as individuals as the need arose. I found that many students did not carry on a productive discussion when working with the larger group but were quite capable of sharing results once they had had the opportunity to work alone or with a partner. Working with a group also took practice. There was improvement over the course of the study but at first there was more gossip than anything else except when the conversation was directed by me as I mingled with individual
groups or during the discussions when we were trying to come to consensus.

The students needed the time and opportunity to apply the ideas that we had been discussing on the various topics presented. Sometimes that application took the form of problem solving as in identifying mystery field patterns after working with magnetic fields. The students demonstrated their beliefs of poles and repelling and attracting with this kind of activity.

Every lesson included work with materials and an opportunity for personal enquiry. For example the students were encouraged to make their own compasses, they were not given a specific procedure for doing so. They experimented with many different ways to weaken a magnet even though they had had a class discussion and had heard their friends ideas. They were eager to try out these ideas as well as their own. Since the students were not sharing their ideas while they worked with materials and because many students simply did not know how to get started having discussions about what you could do ahead of time was usually productive. However, there was plenty of time set aside for "messing around" (Hawkins, 1965).

**D. Reflection**

Trying to get my students to reflect was the most difficult part of the constructivist teaching sequence. The
students were most anxious to keep doing new activities. They did not want to "look back" to see how their thinking had changed. Except for the occasional referral to an idea by name from the charts, or reading the last entry in their journal and comparing it to previous entries, or looking at the results from a previous experiment, they saw no value in reflecting. Even during the post-diagnostic test where they were encouraged to use their journals the majority of the students did not want to do so.

The most valuable part of reflection, however, happened without the students realizing what they were doing. This happened when they were encouraged to talk or write about their beliefs. The students already had a framework of beliefs built from experiences. It was this framework upon which they reflected. Any opportunity that allowed the students to express their old beliefs, new beliefs, or changed beliefs required them to reflect, which they were doing unconsciously.

E. The Notion of Ownership

The students were encouraged to express their ideas freely during discussion periods. Previous experience had taught me that ten year olds can express themselves much more clearly orally than on paper and a great deal of information about what they were thinking would have been lost to me unless an attempt had been made to record it.
Large lined chart paper was hung up in the discussion area and when students were sharing ideas they were noted on the chart (very similar to what an elementary teacher might do when brainstorming for ideas) only the students' names were placed along side their idea. Later, when the discussion was over the charts were then left hanging on a bulletin board. The display boards filled up with charts and eventually had to be stacked together but they were a valuable source of ideas that were used for reference on a number of occasions.

Very quickly after the idea of recording ideas became established the students began to take ownership of their ideas. During a discussion students would use each others names when referring to a certain activity or idea. For example the students were quite clear on who wanted to heat the magnet - Lana - and who wanted to melt it - James -. During the experiment with Maria, Beodl tried to explain a point by referring to "Marias' way".

Eventually the students would stop and wait to see that I had in fact remembered to write a name down beside an idea on the chart. The effort was always made to get down the exact words of a student response rather than rewording thoughts for the sake of speed or correct English. This small act did not go unnoticed by the students and they would assist in making sure that I had heard the words
correctly, not just for their own ideas but for their peers as well.

Several months later, after I had returned to the classroom, the students and I were studying a unit in astronomy and I asked a question about how they believed galaxies were formed. There was a buzz of interest as the students thought about this then I asked a female student to give a response. I wrote the idea down and then asked a second student to respond. The classroom became very quiet and when I asked what was wrong the second student said, "You forgot to write her name down beside her idea."

The students liked being recognized for their ideas. They were quite free to change them but in the mean time their thoughts were treated as important discussion items. At the beginning of the study the students were often taken aback when I would say, "John had an interesting idea yesterday about how to make a compass. I have the materials here John come up and show the class what you were talking about," or "Wesley gave a very interesting analogy about broken magnets in his journal. I've put it on a poster on the bulletin board have a look at it when you have a chance."

Generally the students gave thoughtful answers to the questions asked. I believe that for the most part the students were proud of their ideas. They often pointed out their names on the charts to other students and would
occasionally remind me that we had not tried their idea out with the class. Students who were shy always had their journals to write in later but there were very few students who did not feel that they could share their ideas by the end of the study.

The idea of ownership did not occur just with the students' ideas. They also recognized they were part of the study. Students would line up at the classroom door before the lessons to help set up the video camera and to assist in any way they could. They were also excited about watching a video made from excerpts of lesson tapes entitled Childrens' Ideas About Magnetism shown to them after the study was completed. Many queries have been made about when the "book" would be written, as the thesis became known. The students' involvement enhanced the idea of teacher and students working in a partnership.

III. Influence of the constructivist perspective on the teacher

A constructivist perspective toward teaching has influenced my teaching in two ways. Firstly, it has given me an opportunity to reflect on my teaching style and to assess it and secondly, it has helped me understand my students thinking in a way that I never have before.

Looking with a new perspective at what I had been doing for a long time was very exciting as I say new possibilities
arise, but it was also frustrating and fraught with problems.

A. Adopting a New Approach

When I first began the study I believed myself to be a "guided discovery" teacher. To me that meant that my students worked with materials, I asked questions to guide them, we had discussions when appropriate, and I presented information when I felt it necessary. I assumed that if the information was interesting and intelligible to my students they would understand. I felt comfortable with that approach to teaching and I did not want to change but there were some topics in science, magnetism for example, that I never seemed to be able to present successfully. The overwhelming evidence of my students' prior beliefs in magnetism that I received after a prior study in my own classroom convinced me that they had many ideas about magnetism that had influenced their learning and started me thinking about how I could meld constructivist theory with a discovery philosophy.

Much of the literature on conceptual change theory (eg. Hewson, 1981) gave the impression that applying constructivist theory to the classroom meant that the teacher should persist until each child had demonstrated understanding. This seemed like an unreasonable task for the teacher of a large classroom so even though researchers like Driver (1986) did not make the same assumptions as
Hewson I was unsure of what a constructivist teacher should do in terms of a teaching method.

My initial attempt to use a constructivist approach consisted of following the model of a constructivist teaching sequence that Driver (1986) and other researchers in the Children in Science Project at Leeds had developed. The idea that a discovery approach could not work in conjunction with this constructivist model, even though I wanted it to, evolved during the planning stages of the unit. For several weeks I tried to follow someone else's model of teaching and failed to recognize the value in what I had already been doing. While the model appeared to be different from my own teaching style it was, in fact, only different in certain aspects. For example, there was the stress on activities to monitor student thinking, more of an emphasis on challenging ideas, and no expectation that students should discover everything for themselves. In reality this teaching model, which was intended by the researchers to be flexible, was quite compatible with my own thinking. Eventually I felt confident enough to adjust my teaching to suit myself and my students and I realized that I had not really changed my ideas about discovery - I just enriched my teaching.

After the first three lessons presented to the class I began to realize that very little of what I had planned ahead of time was actually being done when I wanted to do
it. That when consciously considering students' understanding of events, on a continuing basis, I had to be prepared to change a presentation, demonstrate a discrepant event for just "talk it out", in order to have more students come to a better understanding of the concept being considered. I was prepared to be flexible prior to the study but the deeper understanding of the students thinking made changes in plans and direction constant. Gradually what I realized was happening was a partnership. I would present a concept, the students would work with materials, and then they would present their ideas during discussion. But someone would invariably have an idea that just didn't "fit" with everyone else's. So I would then try to adjust the lesson or take the new idea into consideration during the next lesson. Eventually the unit came to a conclusion but with both teacher and students guiding the way.

One of the most difficult stages of adopting this new approach occurred when I was trying to work out how much I had to do to change or redirect my current teaching practice. I became so caught up in trying to figure out how a constructivist perspective translated into classroom practice, in my own instance, that I lost sight of what I was already doing well. For the first two weeks of the study I felt lost and frustrated because I thought that the two perspectives, discovery and constructivist were not compatible. I had no evidence that they were not but that was how I was thinking. Then one day when the class was very
busily and noisily engaged in about fifteen different activities I realized I was feeling very comfortable with the teaching atmosphere. I'm not quite sure what happened but a constructivist perspective seemed to be just part of my teaching not dominating it.

A constructivist approach did not have to assume that I must "flog a concept to death" (which was quite contrary to my personal belief of how to present a concept), it simply made me more aware of where to put the emphasis to encourage conceptual change. In other words the constructivist model encouraged me: to monitor student's ideas; to ask better questions in a variety of ways that were the most beneficial to the majority of students; to challenge students ideas that seemed to be confused; to encourage the development of consensus and the sharing of ideas; and to compare new ideas with old ones to see how we were progressing.

B. Problems of the constructivist teacher

1. Challenging ideas

Challenging student's conceptions was never an easy task because conflict situations to challenge ideas were usually required at unexpected times and required reflection - in - action. I could not always think of how to respond on the spur of the moment and often I had to return to a problem at the beginning of the next lesson. Sometimes the conflict had been forgotten by the students but most of the
time coming back to a problem with an interesting challenge after a break had given me time to reflect and the discussions were often richer because of it. Presenting conflict on the spot will come with practice and determination but would be particularly hard for a teacher with little background knowledge of a specific topic.

2. Time

One of the frustrating aspects of any activity oriented teaching programme is always time but a constructivist approach lent new meaning to the word. Not only was time a problem on a lesson basis but also on a unit basis. As an elementary teacher in a school where the teacher has control over time and where a certain degree of leeway is given over the development of a unit I generally do not feel restricted. However, during the study I had to co-operate with another teacher and the class had to leave for another class at a specified time. I am convinced that teachers can overcome the time problem with most of the activities used in the constructivist teaching sequence.

3. Lack of resources

The lack of background information about magnetism in the teachers' guide for the textbook used in the study sent me searching for additional resource material. As the science resource teacher in my school I had access to other books and activity ideas about magnetism but I did not have
an up to date physics text that I could refer to. The fact that I had the time to search for and find the information I needed does not minimize the problem for other teachers who do not have resources beyond their teacher guides. In order to be able to understand the problems that my students were having understanding the concepts of magnetism and to be able to offer challenges it was necessary to have this additional information. I found that it was not enough to have "messed around" on my own before a lesson.

C. The role of reflection

Adopting a new approach towards the teaching of magnetism depended greatly on reflection. Sometimes the reflection took place during the lesson and required "on the spot" decisions about how to deal with a problem. Usually the reflection took place after the lesson and assisted in lesson planning. The reflection that took place in action was the most difficult to engineer.

Dealing with problems in action is something that I do all the time for many different situations but it took a different kind of skill to challenge students' ideas as a result of immediate reflection. This required knowing when to introduce a discrepant event or when to introduce a new idea in such a way that it encouraged conceptual change such as having a student expand on an idea as James and Maria did with the magnetic shield or demonstrating a discrepant event such as floating magnets.
I found that reflection - in - action was difficult because my own knowledge of magnetism was elementary and because I had been used to dealing with students as individuals within their small groups and to trying to get them to solve their own problems. I continued to deal with the students in this manner much of the time but I felt that more input was needed from me when we had common problems that were not being solved. The class discussions occurred more often as a result and it was during those discussions that the reflection - in - action was needed most.

Many of the activities that I instigated in this study occurred as a result of the reflection - on - action. This made planning very time consuming although it resulted in lessons that were not only of interest to the students but reflected their current problems with conceptual understanding.

As I look back on the study now the most important influence of the constructivist perspective on my teaching was the emphasis on reflecting. That had not been a conscious part of my "guided discovery" because I was often content to learn with the students and I believe that it has made me much more aware of not only my student's thinking but my own as well. I am particularly pleased with the partnership that developed between my students and I as the result of reflecting.
IV. Conclusions

Eliciting of students' ideas was the primary activity used to adopt a constructivist perspective toward teaching magnetism to this grade five class. Effective methods of eliciting students' beliefs were:

1. class discussion
2. diagnostic tests
3. the use of journals
4. small group work on a one to one basis

Class discussions were the most effective and the easiest way to find out how the students were thinking. The following are some strategies that encouraged discussion:

1. reviewing the importance of respecting the views of others
2. placing non-evaluative judgements on students' ideas
3. inviting volunteers who were likely to present more primitive or naive views first, then calling on those who were more advanced in their thinking
4. listing of ideas on charts for future reflection
5. referring to contributors of ideas by name when discussing or comparing models
6. asking specific questions but then allowing the students the time to answer them and to share their ideas.
Once some of the students' beliefs of magnetism were uncovered there was a variety of activities that allowed them to change their views. The following activities presented the opportunity for change to occur.

1. discussion
   a. sharing of ideas
   b. coming to consensus
2. use of models and analogies
3. conflict situations
   a. discrepant events
   b. problem solving

The students had a focus for the "hands on" part of the lessons as they were encouraged to apply the ideas from discussion. I chose not to direct the activities to exclude their own "messing around" but allowed them the opportunity to try their own ideas as well as the ones suggested by me.

Group discussion of ideas during these times was not productive for most students unless it was teacher directed. Partners however did share ideas and did try to come to consensus. This situation is perhaps indicative of the socializing of grade five students in that they would often argue about whose turn it was next when in a larger group but were able to share and talk quietly with one other person.
The students found reflecting to be unnecessary although they did refer to their peers ideas in discussion. I found that reflection was an integral part of the constructive perspective but that reflection -in- action was very difficult and in retrospect see that most of my reflecting took place on action. If teachers are to allow their students' beliefs to direct lesson planning reflection - on - action must be practised at the very least.

The students took an interesting view of their ideas in the notion of ownership. It would appear that these students were more interested in expressing their ideas when they were acknowledged publicly and their ideas accepted at face value rather than corrected with the scientific definition.

Teaching with a constructivist perspective is a time consuming task both in the planning and in the executing. The teacher must make the effort to be well informed about the subject to be taught as there is not always the same opportunity to learn with the students as there is in a discovery approach. Much time however is needed to "mess around" or try out activities that could be used during a lesson. The teacher not only needs time to consider activities prior to a lesson but needs the opportunity to consider students' beliefs that may be causing difficulty with conceptual understanding.

Teachers must consider the class time involved in using a constructivist perspective. The constraints of a set time
period for teaching science or a set period of time that a unit may take will require some careful planning and decision making about what concepts to teach and what activities to introduce.

The process of adopting a constructivist perspective towards teaching magnetism has only just begun for me. There are many new ideas to consider, many strategies that require practice, and problems to overcome. I believe that the effort was worth the time required to teach magnetism from a constructivist perspective and hence to use a constructivist teaching sequence that will assist in the adopting of this perspective. Some of the reasons for my belief are that I gained:

1. a knowledge of the students' beliefs of magnetism that enabled better preparation of lessons
2. a heightened understanding of the difficulties in learning that the students' faced when presented with the concepts of magnetism
3. a clearer understanding of my own beliefs about magnetism and how it should be taught

There appears to be a number of activities that elicit students' ideas about magnetism and that help to restructure their thinking. Some activities seem to be more affective than others for elementary students for example the group discussion charts and the introduction of conflict situations.
The role of reflecting, while a difficult one for both students and teachers, is important in considering a constructivist approach to teaching.
V. Implications of the study

A. Implications for teaching

In planning to adopt a constructivist approach to teaching magnetism a teacher will have to give careful consideration to the following points:

1. Re-thinking of the teaching style and the focus of lessons when alternate frameworks are encountered

Having to consider a new teaching style is disconcerting for any practitioner, particularly for someone who is comfortable with their present style. However, when students' alternate frameworks surface and are then acknowledged to be important, there is an obvious need for some redirection of thinking. The time must be taken to question what your goals really are for completing both lessons and units.

2. Reflection-in-action

The words reflection-in-action and reflection-on-action were new to me before the study although I know as a teacher I do reflect on many occasions, both in class and after, in other subjects such as language arts and arithmetic. However, conscious reflecting, particularly in science, was another matter. I found it difficult to make it happen while teaching a subject like magnetism when I was not always sure myself if I thoroughly understood the concepts as a
physicist would. Teachers need to understand the nature and importance of reflect-in-action.

3. The time factor involved in finding resource material other than the textbook

The textbook clearly did not provide the information that I needed to be informed about magnetism nor did it give me a source of activities that I could use as discrepant events. The time spent in finding information and then trying out the activities before a lesson was perhaps too long. I was fortunate to have many resources available to me but I know that many teachers will face the problem of resources and this factor needs to be considered seriously.

4. Learning how to encourage/motivate conceptual change

As with all new ideas in teaching, they take time to become useful. Teachers who attempt to use a constructivist teaching sequence in their classrooms need to examine closely the activities that encourage conceptual change and expect that some of them may not work with a certain age group or a particular group of children. However, some of the activities, such as journal writing and reflecting, need to be practiced by both students and teacher over time. Success will not necessarily happen after one try.
5. Accepting students' beliefs at face value

This point is of paramount importance. If the teacher and the students' peers do not accept ideas at face value and do not respect the others' viewpoints the sharing of ideas will not happen. Teachers need to take the time to assure students that their journal writings are not for evaluation and that their classroom discussions are important. One way to ensure that students believe you is not to reword their ideas in "teacher language" when recording ideas.

6. Perfecting questioning skills that will motivate students' to express their thoughts.

Much research has been done on the role of questioning and its' importance in teaching a good lesson. Much of this research, however, has focussed on questioning styles and techniques and their relationship to students' "right answers". Teachers need to consider how they question the students so that the discussion periods do not become question and answer periods. From a constructivist stance one of the primary purposes of discussion is to elicit students' ideas, not for teachers to list their own. So, for example, the question "What if" is preferable to "What is it?"
7. The role of language

Teachers need to consider how they respond to a student's idea both in what they say and in how they look or gesture. For example, during the first lesson in magnetism I got very excited about the ideas I was hearing and often responded with words like "wow", "terrific", and "what a neat idea" perhaps giving the students the notion that their beliefs were scientifically correct, whereas I really just wanted them to know that I found their responses interesting. I found it difficult to remain silent when the students were speaking but found later that responses such as "that's an interesting idea" or "thank you for your thought" said calmly, was more appropriate.

The misinterpretation of language from both the teachers and students' point of view is worthy of great consideration. Many times throughout the unit the students and I did not "connect" because of the difference in interpretation. The "tin can" lid demonstration with Maria is one good example of how careful a teacher needs to be with language. That lid was not made of tin but the average person refers to a can that contains food as a "tin can" and I believe that the students took me literally. Lana's journal and post-test both were filled with spelling errors and awkward sentences that on first glance were confusing but a second look at her drawings combined with her words
made me believe that she really knew much more about magnetism than what appeared to be the case.

8. Controlling ones' impatience when students' ideas seem to be leading "nowhere"

It is very easy to give up when things go wrong in the classroom and to just tell the student what they should know and get it over with. For example, the students will not always respond the way you planned. The incident between James and I during the propane torch demonstration served as a reminder that it takes time for conceptual change to happen. Teachers need to look at their apparent failures with a positive view and consider carefully why it might have happened.

9. The unit in magnetism

In the teaching of magnetism teachers need to be aware that the many problems surrounding the particle theory of matter may arise and decisions must be made as to how their ideas about matter should be dealt with. Because of the nature of the constructivist approach it was difficult to stay within the confines of the grade five curriculum. Teachers will have to be wary that many of the concepts presented may have to be dealt with more broadly than planned. Perhaps introducing fewer concepts than the textbook suggests would be appropriate.
10. Student/teacher partnership

A teacher who takes children's beliefs into consideration in planning lessons will, in effect, be forming a partnership with the students and must be prepared to consider these beliefs throughout the unit not just in the beginning. The students' ideas grew and changed continually as was evident in both journals and discussions. These ideas must be constantly monitored and discussed throughout the unit.

B. Implications for research

The aim of this research project was to document the implementation of a constructivist approach in teaching magnetism and my own reflections of that implementation in a fifth grade classroom. From this endeavour there has emerged four major ideas for future research.

First, it is quite evident from prior research that children have many ideas about science before being formally taught and that they get these ideas from their personal experiences outside the school as well as from previous schooling. Future studies need to be done to investigate the students' most common beliefs about magnetism that could be used by textbook authors to assist teachers in pre-planning, in presenting background information and in providing a wider variety of activities for use as discrepant events.
Secondly, the question "Do the students undergo a greater degree of conceptual change when taught by a constructivist approach than with other approaches?" will have to be investigated. Because a constructivist approach will require changes to be made by a teacher and initially increase their planning time and class time, it may have to be proven that a constructivist approach will result in an academic gain before it will be accepted by teachers.

Thirdly, the whole question of making one's reflections explicit will have to be considered. More work will be required on how to communicate to teachers, at the preservice and inservice levels, some methods to encourage reflection. Researchers will have to experiment with how this can best be done.

Finally, further studies need to be done with teachers using a constructivist teaching approach in the elementary grades. There are many considerations that are different from those faced by a secondary teacher – such as the students' ability to reflect and to write coherently in their journals. Much of the writing and preliminary work on constructivist teaching has been done primarily at the junior secondary level and the activities may not be as appropriate for elementary students.
References


Diagnostic test

1. Circle the objects below that might be attracted to a magnet.

   aluminum foil candy wrapper    gold ring
   brass plate                    rusted wrench
   copper pot                     steel needle
   Canadian nickel                paper clip

2. John made a compass by floating a magnetized needle in a steel bowl full of water. The compass didn't work explain why?

3. A train is to move by a magnet along a track made of wood, plastic, iron, glass, brass, copper. Place an X under the section the train cannot run over.

   Explain your answer.
4. Label all the poles with an X.

   A. Horseshoe Magnet         B. Bar Magnet
   
   C. Broken Magnet

5. Label the poles with N or S

   A. 
   B. 

Explain why the magnets are floating in B.

6. Explain how a broken magnet works. Draw a diagram if it helps you explain.
7. A. Are these magnets repelling or attracting?

B. Explain why this happens.

8. Will the scissors stay closed or open?

Explain your answer.

9. A. Circle the pole you think the compass points to.
B. Explain why the compass points in the direction that you chose.

10. Label a model of the atoms in a compass needle with N and S to show why the needle is attracted to earths' N pole.

11. Draw a model of the atoms in a magnet to show what when it becomes:

   A. magnetized:

   B. weakened by banging or high heat:

   C. broken: