THE DEVELOPMENT OF A MODEL OF TINKERING: A STUDY OF CHILDREN'S SCIENCE

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ABSTRACT

This study on tinkering evolved out of a review of literature on females and science. A review of this literature revealed a consistent conjecture raised by researchers to explain why females underachieve and also why they are underrepresented in the physical sciences field. The conjecture was that females do not tinker. Prior to undertaking an investigation into the nature of tinkering and how it might be related to this conjecture, it was necessary to clarify the nature of tinkering and how it might be related to the development of an understanding and interest in science. The present study offers this clarification by the way of proposing a model of tinkering.

A children's science perspective was chosen as a theoretical framework for the interpretation of tinkering. Osborne & Freyberg (1985) describe *children's science* by noting that some children's views of the world and meanings for words are unexpectedly different from those of adults in general and scientists in particular. Those views and different word meanings influence children's subsequent learning in science. Most studies investigating children's science have focused on children's conceptualization of scientific phenomena. The present study however brought a wider perspective to children's science by seeking to describe it as the intuitive methods which children learn from everyday experience. The findings therefore add a new dimension to the study of children's science by providing insight into the methods by which some children may acquire their intuitive knowledge of selected science concepts.

Based on the results from preliminary and pilot studies ten target students were selected for the purpose of data collection. Subsequently six

target subjects, representing a variety of levels of tinkering, were selected for final analysis. The analysis utilized a variety of data sources (survey, interview, and classroom observation) collected over a three-month period.

The model of tinkering which was constructed conceptualizes tinkering as consisting of three general sets of characteristics. These characteristics were described in terms of the different types of tinkering observed, the different phases entailed in the tinkering process, and finally the different types of knowledge generated by this activity. The first characteristic, called the "a typology of tinkering", maps out the "purpose" and the "proficiency" of tinkering as it was observed in the target subjects. Four purposes were described: utilitarian, technological, scientific and pragmatic. The proficiency of tinkering was described in terms of categories: master, professional, amateur and novice. The second characteristic focussed on the nature of the process of tinkering. Since tinkering was conceptualized as a form of problem-solving, four different phases of tinkering activity were identified. A third characteristic identified the kinds of knowledge bases that appear to be constructed from tinkering activity. These were described in terms of verbal and actional knowledge.

This study also constructed three sets of factors which influence tinkering: experiential, social and personal. These factors were metaphorically described as an apprenticeship. The experiential factors were noted as ranging from low to high levels. The social factors were described as having three levels of influence, namely mentor, family and friends, and school and other agencies. The personal factors were described as ranging from low to high levels of interest.

Since the problem initially arose from the literature on females and science a discussion of gender differences in tinkering was also undertaken.

This discussion utilized "women's ways of knowing" (Belenky, Clinchy, Goldberger and Tarule, 1986) to interpret the extensive data. The focus of the discussion was that tinkering is "disconnected knowing" for females and "connected knowing" for males. On the basis of this argument tinkering can be viewed as an activity which favors males.

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Once in a lifetime one stumbles onto a problem which is so rich that even the most gifted mind would find a challenge. When a novice discovers such a problem the task is overwhelming. Still, if the spark of curiosity and excitement is there one naively attempts this most difficult task, with hopes that upon conclusion to have made some small contribution to the interpretation of knowledge. Although to most people reading this still somewhat crude and unfinished work it might appear to be just another routine document, for me it has been a 'process of discovery'.

I have been most most fortunate in my undertaking to have had a supervising committee who provided the right kind of support. Dr. Gaalen Erickson, my dissertation supervisor provided me with competent guidance and encouragement. His mentorship was critical for he believes that all his students can be a success and is willing to pains takingly edit crude writings and ideas. I thank you. Gaalen, for your patience, kindness and moral support. I am most grateful to Dr. Jane Gaskell for helping me to bring a feminist perspective to my study. I also thank you for posing the right question or appropriate comment (those broad conceptual glasses) to make me look just that much further, and refocus when needed. Special thanks to Dr. Ron McGregor who heard me through from my crude beginings in the doctoral seminar to the final defense. You provided direction when needed then left me alone to discover on my own. Again thank you.

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CHAPTER I: INTRODUCTION TO THE PROBLEM

Background

Children's science is an active area of research today as indicated by the international attention it has received in recent years (Driver, 1983, 1989; Helm & Novak, 1983, 1987; Osborne & Freyberg, 1985). Osborne, Bell, and Gilbert (1983) describe *children's science* as:

> The views of the world and meanings for words that children tend to acquire before they are formally taught science. Children's science develops as children attempt to make sense of the world in which they live in terms of their experiences, their current knowledge and their use of language. (p. 1)

Children's science is a term coined to describe the intuitive scientific concepts that children learn from their everyday experiences. A variety of other terms have been used to describe the cognitive constructions developed from these everyday experiences. These terms, although not synonymous, include: alternate frameworks, prior knowledge, preconceptions, misconceptions and commonsense knowledge. The *children's science* research has all taken place under one general theoretical framework, which has been called by some, "constructivism" (Driver & Oldham 1986; Magoon 1977). The findings of such research (Driver, 1981; Erickson, 1983) suggest that children's understanding of physical phenomena within the context of science instruction is influenced by prior experiences with their own physical and social worlds.

Central to the discussion of *children's science* has been the role of prior experiences. Ausubel (1968) noted: "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him [sic] accordingly" (p. vi). There is also evidence in the science education literature (Driver & Easley, 1978; Novak, 1977; Osborne & Gilbert, 1980; and others) which suggests that the role of students' existing knowledge in lêarning science is a central issue. Specifically, Driver (1981) argues:

> Far from being "tabula rasa" of repute, pupils bring to their school learning in science ideas, expectations and beliefs concerning natural phenomena which they have developed to make sense of their own past experiences. These alternate frameworks, in some cases strongly held and resistant to change, in others flexible and with many internal inconsistencies, have their influence on the effectiveness of formal school science programmes. (p. 93)

Kass and Lambert (1983) note that a significant factor in teaching science is that students come to many learning situations with some previously formed ideas or preconceptions about the topic. They claim these preconceptions can either interfere with the teaching process or enhance it.

What has been argued in relation to children's conceptualization of scientific knowledge also applies to children's methods and attitudes according to Hewson (1980), Osborne, Bell and Gilbert (1983), Perez and Carrascosa (1985), Tasker (1980, 1981), Stead (1981), and others. Specifically Osborne, Bell and Gilbert (1983) emphasize that:

> Children bring to science lessons not only their views of the world and their meanings of words but also their own methods of investigation, their own ideas about what constitutes adequate explanations and their own outlook on science. (p. 5)

While researchers within the area of *children's science* note that children bring their own methods and attitudes to the study of science, a review of literature shows that such research has focused mainly on children's understanding of scientific concepts. My study is an attempt to understand *children's science* by focusing on one method through which some children acquire their prior experiences, namely tinkering. "Tinkering" has been defined, at a commonsense level, as an informal method by which we explore the properties of physical objects such as mechanical and electrical devices. An illustration of what is commonly referred to as tinkering is when males are asked repeatedly to take care of minor household or car repairs.

If tinkering is one type of prior experience which influences preconceptions that students bring to science instruction the question is: What are the influences of tinkering on instruction? Before we can examine such a question tinkering needs to be clarified and elaborated. The primary aim of my study is to undertake this task of analyzing more carefully what might be entailed by the notion of "tinkering". Specifically I have explored the nature of tinkering within the context of one area of physical science, namely electricity. This exploration has resulted in the development of a model of tinkering.

The appearance of tinkering as a potential issue in the science education literature centers around the gender imbalance of females in science-related careers, especially the physical sciences. Within this context the role of tinkering as a significant prior experience has become an issue. In fact, one conjecture that has been advanced to partially explain female underachievement on such science measures as: International Association for the Evaluation of Educational Achievement (IEA) in the 1970's (Kelly, 1978); National Assessment of Educational Progress (NAEP) (Heuflte et al., 1983; Kahle & Lakes, 1983); Assessment Performance Unit (APU) (Johnson & Murphy, 1986); and British Columbia Science Assessments in 1978, 1982, 1986 (Bateson et al., 1986; Hobbs et al., 1978; Taylor et al., 1982) is that females lack prior experiences with physical objects (Bateson & Parsons-Chatman, 1989; Erickson & Erickson, 1984; Johnson & Murphy, 1984; Kelly, 1981; Lie & Bryhni, 1983). Some researchers have described such prior experiences as tinkering (Cooley & Reed, 1961; Johnson & Murphy, 1984; Kelly, 1981; Kelly, Whyte & Smail, 1983; Wahlberg, 1967). Specifically, such discussions have focused on specific topics within physical science such as electricity, where the claim has been made that the greatest gender difference in science occurs in achievement on standardized achievement tests. Clearly, before one can investigate such a claim these notions of tinkering need to be clarified. Therefore I have attempted to develop a model of tinkering based on a case study of grade nine students engaged in an hands-on study of electricity. While the primary focus of my study was tinkering, a discussion of the gender differences in tinkering was also undertaken.

Statement of the Problem

The assumption is made that we can better understand something about the methods children bring to science through a study of tinkering. The focus of my study was the following problem: "To describe and interpret tinkering as a phenomenon or practice, within the context of the study of electricity at the grade nine level."

The broad aims were to develop a model of tinkering through the description and characterization of students' demonstrated ability to tinker, to explore some of the factors which relate to tinkering, and to examine the underlying processes related to tinkering. The following research questions were addressed:

1. What are the characteristics of tinkering?

    1.1 Can we identify a typology of tinkering?

    1.2 What are the knowledge bases of tinkering?

    1.3 Can we identify phases in the tinkering process?

2. What are the factors influencing tinkering?

    2.1 What role do prior experiences play in tinkering?

    2.2 What role do social relationships play in tinkering?

    2.3 What role do personal interests play?

Since the origin of the above problem had its roots within the "females and science" literature (Johnson & Murphy, 1984; Kelly, 1981, Kelly, Whyte & Smail, 1982; Kelly & Smail, 1983), my study therefore had a secondary focus on the possible relationship between gender and tinkering.

A Preliminary Conceptualization of Tinkering

One useful strategy for dealing with the conceptualization of a complex process such as tinkering is through the development of a model. A model can serve as a useful guide for future investigation. As a basic research strategy, model building is not simply an outgrowth of factual or logical considerations. Instead, it offers one approach for establishing conjectures from which to explore a process, such as tinkering. There are many approaches one could take in model building. The approach taken here is the "theory models approach." The theory models approach is neither reductive or deductive but retroductive, meaning ideas must be derived because not all ideas are ready made and waiting (Steiner, 1976). Researchers can evaluate the fruitfulness of any particular model by assessing its theoretical and practical implications. The model of tinkering developed as a result of my study can serve as a possible framework to provide action plans for further investigations.

The model was gradually constructed through the ongoing process of data analysis and interpretation. This is called an "actional approach" (Gilbert & Watts, 1983), within the "verstehen tradition" which according to Gilbert and Watts:

> . . . is relativist in outlook, showing the influence of post-inductivist views of knowledge, with a belief in the value of an holistic approach to phenomena, seeking to perceive understanding as shown by the individual actors in any human situation without the overt pursuit of generalizations. (p. 63)

Prior to undertaking the study of tinkering my attempts to define tinkering included:

1. a survey of dictionary definitions,
2. a survey of science education literature,
3. computer searches such as ERIC, and
4. pilot studies.

I realized that any model of tinkering developed would need clarification by further research. That is, in contrast to the deductive researcher starting with a preliminary causal network, the researcher with an "actional approach" ends up with one that has been built-up by the end of the data gathering. Therefore, at the end of a gradual series of progressive refinements, a model of tinkering was constructed.

The tentative model of tinkering proposed at the beginning of my study based upon literature review and pilot studies defined tinkering as:

> **A process of acquiring commonsense knowledge which is a practical or hands-on activity that involves prior experience with manipulating physical objects, such as mechanical and electrical devices. It consists of interactive - affective, psychomotor and cognitive dimensions. Those three dimensions consist of low to high stages. The transition from the sphere of commonsense knowledge to the sphere of scientific knowledge occurs when the cognitive dimension reaches its higher stages.**

This definition is a synopsis of the model of tinkering that was initially proposed. It was also recognized at the time that such a model served as a starting point for inquiry into the nature of tinkering.

Rationale for Study

Some of the general arguments for a study of tinkering can be summarized as follows:

1. Commonsense knowledge which children bring to science instruction has been virtually unexplored. While we know a lot about the structure of knowledge and the structure of scientific knowledge in particular we know much less about how children obtain the knowledge which they bring to the classroom. It has only been within this past decade that *children's science* has become popular as the focus of research. Much of this research however tends to focus on specific concepts within science, with little attention being paid to how children develop such concepts.
2. Researchers have argued that prior experiences are important in the understanding of science. Tinkering is one type of prior experience

which may be relevant to how children learn science. Therefore my study attempted to develop a model of one type of prior experience, namely tinkering.

3. Tinkering is a type of activity which some students appear to engage in while others do not. Clearly the role that such prior tinkering experiences may play, with regard to science instruction in particular and learning theory in general, is important to explore.

In addition to the above general arguments there are some specific reasons for a study of tinkering such as:

4. The Science Council of Canada (1982) and Erickson, Erickson, and Haggerty (1980) have suggested that the influence of students' commonsense knowledge on achievement be studied. Specifically, one area for research identified by both of these large scale assessments is "to identify the kind of commonsense knowledge that boys have and girls lack." Therefore if tinkering is a form of commonsense knowledge there is strong support for it to be studied.
5. The physical sciences have been identified as posing the greatest problem for females as measured on standardized science achievement tests. Within physics, electricity is the topic which seems to cause the most difficulty for females on such tests. A study of tinkering within the context of electricity therefore may provide further insight into this problem.
6. The Science Council of Canada (1984) has deemed the issues associated with female underachievement in science to be a priority area for research. While the primary focus of my study is tinkering I will also discuss the gender differences issue as it is related to tinkering.

Overview of Methods

The state of current research in this area of inquiry did not provide any direction for the specific selection of critical factors related to a student's ability to tinker. For this reason the method employed can be characterized as exploratory. The specific form of my exploratory study was multiple case studies.

The initial sample included 27 subjects at the ninth grade level. From this sample a smaller sample of six target students (three female, three male) was selected for detailed analysis. This sample was selected to provide as diverse a representation of tinkering activities as possible.

While the study compared male and female subjects to each other, the ultimate aim was to use the data collected to generate a model of tinkering. The investigator's goal was to formulate a model (analytic generalization) and not to enumerate frequencies (statistical generalization). The results will therefore be generalizable to theoretical positions and not to populations or universes (Yin, 1984).

Grade nine students were used because grade nine is prior to the point where students decide whether or not to study physics. It is also a level at which electricity is taught. Moreover based on the results on achievement tests, it was felt that differences in tinkering should be more visible at the junior high level than it would at the elementary level. Electricity was selected because it is a topic which all junior high students must study and which all students have been exposed to in earlier sciences. It is a topic where tinkering has potential influence, and it is also a topic on which males and females have shown the greatest discrepancy in achievement in physical science.

Multiple sources of evidence were used to collect data on tinkering. The specific events documented and analyzed were a survey, a clinical interview, and classroom observations. The survey focused on students' science-related experiences with electricity. The clinical interview required students to engage in a series of tasks. While performing these tasks students were asked a series of questions. These questions focused upon their responses to the survey and on the actions they displayed during the completion of the tasks. The focus of classroom observation was on describing the target students' tinkering activities during the electricity unit.

The data obtained from the above events included:

1. Written responses from the survey of the students' prior experiences with the topic electricity.
2. Videotapes of the target subjects engaged in tasks in the interview setting.
3. Audiotapes of large and small group discussions in the classroom setting.
4. Field notes based on classroom observations of target subjects.

Prior to the study, the survey, tasks and interview protocol were piloted, and revisions were made as a result. Based on the results of these pilots the final pilots were conducted with ninth grade students. Although grade nine students had previous exposure to electricity the specific tasks selected had not been presented in earlier grades.

The data analysis used qualitative methods and included:

1. Coding and analysis of the language and behavior displayed by target subjects during the interview, and in the classroom and laboratory

activities. This analysis yielded a series of dimensions which formed part of the model of tinkering.

2. Categorization and analysis of the social, experiential, and personal contextual factors of tinkering as revealed by the survey, interview and classroom observations.

After the above analysis was complete gender differences in tinkering were noted for discussion purposes.

Limitations of the Study

The present study is an exploratory study of tinkering and as such will not test any hypotheses. The size and nature of the sample will not permit generalization to a larger population. The delimitations included a very limited set of students in one region of the country at one grade level studying one topic area. The intent, then, was to develop a conception of tinkering, through building a tentative model, rather than validating it across a population. It will be necessary to examine the utility of the model in other contexts, at different age levels, and in different regions.

The utilization of qualitative measures (interview, participant observation) have been criticized for being potentially subjective. The problem of subjectivity in an interview setting was addressed to a limited extent by using a semi-structured protocol for all subjects, and videotaping of the interview. For participant-observation during classroom instruction field notes and audio tapes were used. The use of audio tapes, videotapes, and fieldnotes to collect data from a variety of sources allowed for triangulation during analysis. The analysis of such data was made more trustworthy because multiple sources of evidence were used to support the claims being made.

CHAPTER II: CONTEXT OF THE STUDY

Introduction

This study can be framed in terms of three contexts: theoretical, empirical and educational. Each of these contexts will be examined in turn in this chapter. The relevance of each of these contexts will be discussed in terms of the problem area being addressed.

Theoretical Context of Study

The Constructivist Perspective

One perspective for the interpretation of the influence of everyday experiences on development of scientific knowledge is "constructivism" (Nussbaum, 1989; von Glasserfeld, 1989). A basic premise in constructivism is that individuals construct a variety of cognitive entities in order to explain and predict natural phenomena and to reduce observed ambiguities. That is, constructivism recognizes that it is important to take into account the many ideas, experiences, and images that children bring to science instruction. This perspective provides a basis for interpreting tinkering as part of this process.

Constructivism is not a single theory, but rather it is a cluster of theories which are united in their view of the world (Candy, 1987; Erickson, 1987). Driver (1987) also notes that contemporary developments in a number of fields are seen as contributing to the constructivist perspective. She offers evidence from cognitive psychology, philosophy of science and social context of learning. Magoon (1977), in completing a review of the constructivist perspective from a wide variety of disciplines, notes the following assumptions which underlie constructivist research:

1. The subjects being studied must be considered as knowing beings whose knowledge has important consequences for how their behavior or actions are interpreted.
2. The locus of control over intelligent behavior resides initially within the subjects themselves, although this capacity for autonomous action is often severely constrained, for example by either explicit or tacit recognition of social norms.
3. The human species has a highly developed capacity for:
   a. constructing knowledge by organizing complexity rapidly;
   b. attending to the meaning of complex communications rather than the surface elements; and
   c. having individuals take on complex social roles and reconstruct elaborate social roles.

Magoon concludes by noting that educational phenomena are unavoidably sophisticated and highly organized. A constructivist approach according to Magoon must therefore refocus educational research towards an extensive descriptive and interpretive effort at explaining the complexity of educational phenomena.

Candy (1987) drawing upon Doyle's work summarized the constructivist theme in education as having the following characteristics:

> 1. Comprehension of texts is an active constructive process, not merely reception or rehearsal of information. Personal knowledge of the world is organized into associational networks or schemata;
>
> 2. Prior knowledge plays a significant role in this process of construction, in problem solving, and in learning. One of the major findings of research in this area is that domain-specific knowledge plays a central role in problem solving and learning within a content area;
>
> 3. Solution strategies are learned 'naturally' through experience; from these natural strategies, learners invent procedures for solving routine problems. Sometimes these problem-solving strategies are systematic, but wrong;
>
> 4. Academic work requires both domain-specific knowledge and complex solution strategies;
>
> 5. Age and ability of the learner influence subjective complexity of academic tasks. Mature learners are selective and efficient in extracting information relevant to a task, less mature learners attend to a broader range of stimuli and are less likely to select and process information to fit the demands of a particular task. (p. 265)

Candy further argues that people are 'self constructing' and then proposes corollaries which would follow from such an assumption.

While Magoon (1977) and Candy (1987) talked about the implications of constructivism for education, Driver (1987) notes that constructivism has the following implications for science education:

> 1. **Learners** are not viewed as passive recipients of an instructional programme.
> 2. **Learning** is seen as involving a change in the learner's conceptions.
> 3. **Knowledge** is not 'objective' but personally and socially constructed.
> 4. **Science as public knowledge** is also a product of human corporate endeavors.
> 5. **Teaching** is not the 'transmission' of knowledge but the negotiation of meanings.
> 6. **Curriculum** is not that which is to be learned, but a programme of learning tasks, materials and resources which enable students to reconstruct their models of the world to be closer to those of school science. (pp. 7-8)

The constructivist position taken by researchers such as Driver has received support within the science education community. This support is evidenced by international conferences and the volume of research in recent years that have focused on this theoretical framework.

Using the constructivist approach, one is also able to draw upon learning theorists such as Ausubel (1968) to focus on the construction of knowledge. This approach to investigating learning in science has focused on the examination of knowledge children bring to the classroom. Such an approach is often associated with Ausubel's concept of prior cognitive structure. That is, existing knowledge determines what knowledge individuals can acquire. Ausubel claims that meaningful learning involves the integration of new knowledge with existing knowledge where a reconciliation between the two is required. Ausubel's (1968) assimilation theory of cognitive learning and its subsequent elaboration by Novak (1977) is founded on the principal assumptions that concepts are regularities among facts that are designated by a symbol or sign; that meaningful concept learning will occur only when the learner consciously tries to relate new knowledge in a substantive way to concepts which already exist in the learner's cognitive structure.

The question is "What implications does this have for actional knowledge, such as tinkering?" Before we can discuss such implications we need first to develop a clear conception of tinkering. A model of tinkering might tell us something about how such actional knowledge relates to the formation of concepts in an area of physical science such as electricity.

Two psychologists, Feldman (1980) and Claxton (1982, 1984), who can be described as constructivists, are helpful for the interpretation of tinkering as a method of acquiring commonsense knowledge. The remainder of this section will be devoted to a review of their work and the location of tinkering within such constructivist perspectives.

Feldman (1980) proposes that knowledge acquisition follows a continuum from universal to unique. He views the domains of knowledge acquisition as developmental because they are neither universal nor spontaneously achieved. Specifically, the nonuniversal domains of knowledge are not necessarily mastered at the highest (or even initial) levels by all children in all cultures, nor are they acquired spontaneously, independent of environmental conditions prevailing in a particular culture at a particular moment in time. This certainly provides a strong psychological base for examining tinkering. Obviously the knowledge acquired through tinkering is not universal knowledge. It is, however, cultural to the extent that it has been conjectured if certain processes of learning are promoted for males and not for females that males may develop superior knowledge and skills in a specific content area, such as electricity. If we extend the argument to discipline-based knowledge we would, therefore, anticipate fewer females studying the physical sciences in cultures which do not encourage this area of learning for females.

Claxton (1982, 1984), also working within the constructivist framework, examines the nature of what science students learn from their everyday and school experience. His claim is that children develop their own mini-theories or personal constructs from their direct experience with the physical world and informal social interactions. Table 2-1 displays the way in which Claxton categorizes these experiences: gut science, lay science and school science. Claxton's premise is that we learn about the world from the moment we are born and in the process of interacting with our physical and social worlds we develop mini-theories. These mini-theories are developed through experience and use of language. We subsequently learn to make sense of these experiences. He sees three distinct clusters of mini-theories. Two of these clusters--gut science and lay science--can be defined as being within *children's science*. The third cluster, school science, is learned in school and has a linguistic and mathematical superstructure of its own. Claxton suggests that we should examine how school science interacts with "gut" and "lay" science. That is, we should first investigate the extent of overlap of school science with the child's pre-existing scientific knowledge or mini-theories. Claxton argues for the importance of acknowledging and building on these mini-theories in science classes. He also cautions that conceptual change can be potentially threatening to the individual and that restructuring conceptions will require a supportive classroom environment. Tinkering, as a process of acquiring commonsense knowledge, is obviously within the realm of gut science and lay science and should therefore be investigated. This is not to suggest that all students who have not tinkered will come to physical science with no prior knowledge of electricity, but rather their mini-theories may be more naive than subjects who have had such experiences. Also, it does not suggest that all subjects need practical experience before being successful at comprehending physical science concepts. Yet I would argue that it appears that there are few children who can comprehend such concepts without some practical experience.

Clearly the constructivist perspective provides a viable theoretical framework for the development of a model of tinkering. While the works of Feldman and Claxton offer some insight into tinkering, from a constructivist perspective, it is works like Candy's that provide further clarification for the viewing of the notion of tinkering. Specifically Candy's (1987) description of people as being "self constructing" provides further argument for the

Table 2-1: The Features of Gut Science, Lay Science and School Science

	Gut Science	Lay Science	School Science
Situation	Domestic	Domestic Media Science fiction	Laboratory
Prediction	about the tangible world	about real and fantasy worlds	about outcomes of "experiments"
Action	perceptions, motor habits	attitudes, play	scientific thinking and skills
Description	"experience"	"beliefs"	"facts"
Explanation	"because I know it"	"because they say so"	"because it follows
Language	everyday	everyday sci-fi	technical symbolic
Learning	trial and error	receptive	receptive illustrations

(Claxton, 1982, p. 9)

interpretation of tinkering as being a "self constructing" process. This self constructing process, as defined by Candy, views personal autonomy as being a process rather than a product which is influenced by personal and social circumstances and has both cognitive and affective dimensions. The next section will extend the constructivist perspective even further by discussing the social construction of knowledge as a theoretical basis for interpreting gender differences in tinkering.

The Social Construction of Knowledge: A Constructivist Framework for the Discussion of Gender Differences in Tinkering

While the primary focus of my study is the development of a model of tinkering, the secondary focus is a discussion of gender differences that have been associated with tinkering. In examining this secondary focus it has been helpful to draw upon a sub-section of the more general constructivist position, the social construction of knowledge. This position is that knowledge is socially constructed constructed rather than that there is an objective reality to be discovered.

The view that knowledge is socially constructed provides a viable theoretical framework for the viewing of feminist theory. Feminist literature has been highly critical of early studies which focused mainly on male subjects in the formative stages of the construction of psychological theories. One such critic is Carol Gilligan (1982) who has argued that the woman's voice should be included in the study of developmental theory. The basis of her argument is that when women's lives and qualities are revealed we can observe these same qualities in the lives of men as well. Such researchers have contributed to the construction of psychological theory which include the female perspective.

Feminist scholarship has not only challenged the construction of psychological knowledge but also the construction of scientific knowledge. Evelyn Fox Keller (1985) in her book on *Reflections on Gender and Science* argues that not only are gender and science socially constructed but that science is socially constructed in a masculine image. Specifically in her introduction to her series of essays on the subject she notes:

> The widespread assumption that a study of gender and science could only be a study of women still amazes me: if women are made rather than born, then surely the same is true of men. It is also true of science. The essays in this book are premised on the recognition that both gender and science are socially constructed categories. Science is the name we give to a set of practices and a body of knowledge delineated by a community, not simply defined by the exigencies of logical proof and experimental verification. Similarly, masculine and feminine are categories defined by a culture not by biological necessity. Women, men and science are created, together, out of a complex dynamic of interwoven cognitive, emotional, and social forces. The focus of these essays is on that dynamic and the ways it supports both the historic conjunction of science and masculinity, and the equally historic disjunction between science and femininity. My subject, therefore, is not women per se, or even women and science; it is the making of men, women, and science, or more precisely, how the making of men and women has affected the making of science. (pp. 3-4)

Beyond bringing a feminist perspective such arguments offer support for the social construction of scientific knowledge.

If we view knowledge such as scientific knowledge as being socially constructed the question is: Do females and males construct knowledge differently? Some theorists claim that males and females have different ways of knowing. A recent study which has received considerable attention was done by Belenky, Clinchy, Goldberger and Tarule (1986). In this case study of

135 female subjects the following five epistemological categories were developed to describe views of knowledge held by the subjects:

> 1. **silence**, a position in which women experience themselves as mindless and voiceless and subject to the whims of external authority;
> 2. **received knowledge**, a perspective from which women conceive of themselves as capable of receiving, even reproducing, knowledge from the all-knowing external authorities but not capable of creating knowledge on their own.
> 3. **subjective knowledge**, a perspective from which truth and knowledge are conceived of as personal, private, and subjectively known or intuited;
> 4. **procedural knowledge**, a position in which women are invested in learning and applying objective procedures for obtaining and communicating knowledge; and
> 5. **constructed knowledge**, a position in which women view all knowledge as contextual, experience themselves as creators of knowledge, and value both subjective and objective strategies for knowing. (p. 15)

These categories, they felt, were appropriate to describe the ways of knowing for the women in their study. Although their study focused on women they did not claim that these categories were only applicable to women. Their work, in fact, assessed Perry's (1970) epistemological positions which was largely based on a study of the male population that he had generalized to the female population. The result was they rejected Perry's categorization and proposed instead a different category system which they felt more appropriate to describe the females in their study. Their work further illustrates how inappropriate it is to use knowledge that has been socially constructed to describe the male population to generalize to the population as a whole.

In conclusion, the view that knowledge is socially constructed offers a viable framework for the interpretation of gender differences. Following from the social construction of knowledge, from a gender perspective, different ways of knowing provides a specific focus for the viewing of gender differences in tinkering.

The Construction of a Definition of Tinkering

My first attempt to define tinkering was a survey of dictionary definitions (Oxford English, 1933; Scottish National, 1974; and Webster, 1966) of tinker (in verb form) which revealed such descriptions as:

1. to make clumsy attempts to mend something;
2. to putter aimlessly or uselessly;
3. to work as a tinker; to mend metal utensils (and hence generally any material object), especially in a clumsy, bungling or imperfect way;
4. to work at something (immaterial) clumsily or imperfectly, especially in the way of attempted repair or improvement; also more vaguely, to occupy oneself about something in a trifling or aimless way; to trifle, potter; and
5. to mend as a tinker; to repair or put into shape in an imperfect or makeshift way; to patch up.

From such descriptions I identified two dimensions of knowledge associated with tinkering--psychomotor and cognitive. However, what was immediately obvious was the level of cognitive functioning was defined as being at a low performance level. I then felt that a survey of science education literature was necessary in order to provide a description of how the concept of tinkering was used within the context of science education.

A review of science education literature disclosed that one of the first references to tinkering was made by Cooley and Reed (1961) who, in their development of the Reed Science Activity Inventory, proposed an instrument to measure science interests. Cooley and Reed included a tinkerer factor which they described as "working with mechanical things and a curiosity about how 'gadgets' work. Examples are: repairing electric lamps and cords, investigating electric appliances, working with home chemistry sets and devising new inventions" (p. 325).

Wahlberg (1967), in a study of the interests of male and female grade 12 physics students, using the Reed Science Activity Inventory, described tinkering as an activity which "seems much more practical and experimental: for example, repairing electrical appliances and experimenting at home in physics and chemistry" (p. 114).

The "Girls into Science and Technology" (GIST) project has probably drawn the most attention to tinkering as an issue. Judith Whyte (1984) working on a GIST action research project referred to tinkering in the following context: "For example, the evidence we gathered about girls' poorer opportunities to engage in 'tinkering activities' such as using a saw, mending a bicycle or playing with Meccano . . ." (p. 76). Later on she noted "Girls are far less likely than boys to find at home the kind of practical 'tinkering' experiences which may contribute to the development of three-dimensional skills and visuo-spatial competence" (p. 82). In another paper, Smail, Whyte and Kelly (1982) referred to tinkering activities as: "Using tools, taking things apart and mending them, playing with construction toys" (p. 626). They also suggest that such activities may develop mechanical and spatial reasoning abilities.

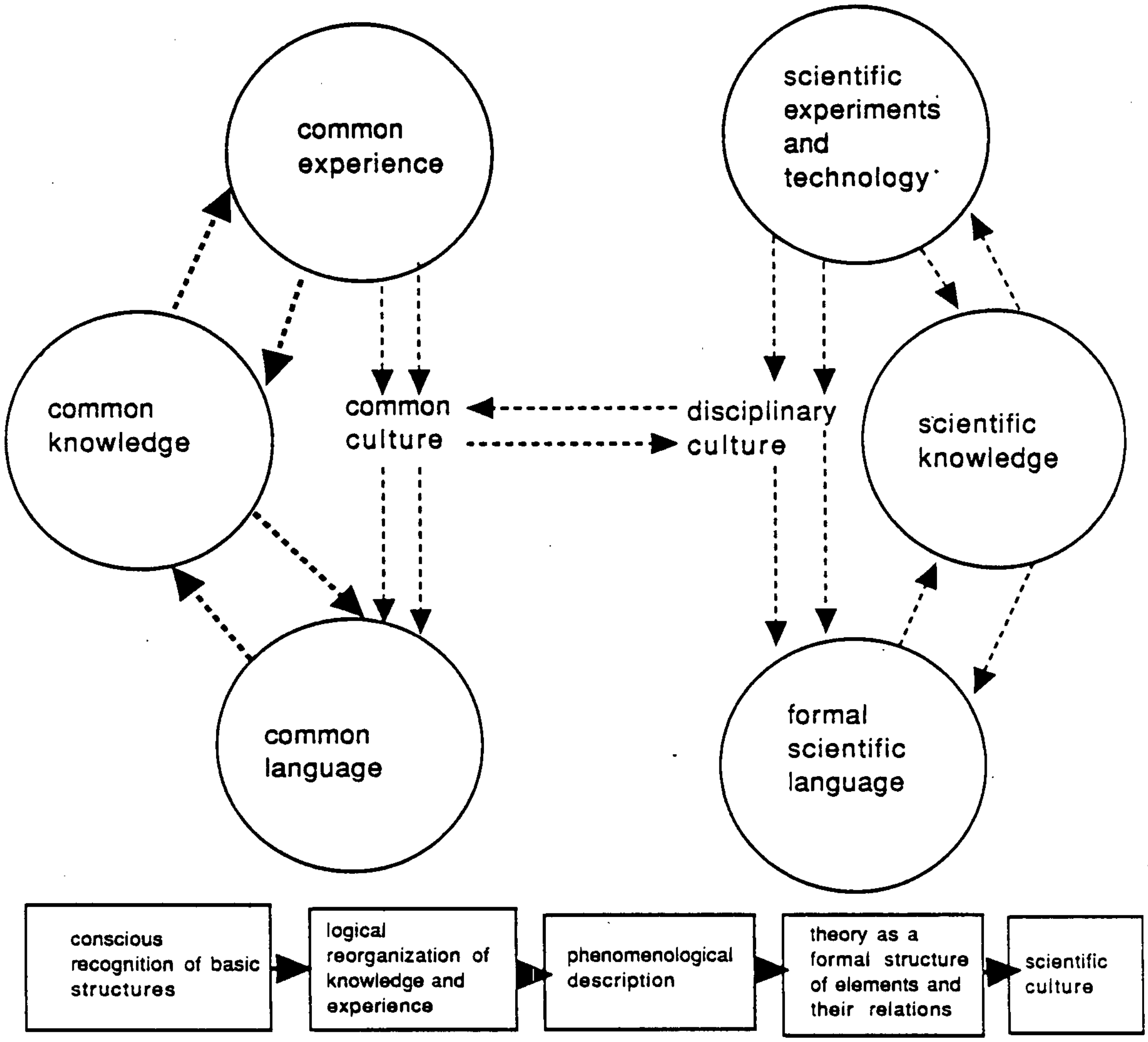
Johnson and Murphy (1984) referred to tinkering by example. Specifically they noted: "A number of studies have reported that young boys have much greater experience of 'tinkering' activities in their leisure time. Examples of such 'tinkering' activities would be dismantling mechanical objects, assisting with car maintenance, playing with construction toys" (p. 406).

The review of science education literature revealed a discrepancy between the dictionary definition and what science educators identified as tinkering. To provide some conceptual framework for the study I therefore proposed a definition which encompassed what science educators saw as tinkering. The definition proposed viewed tinkering as yielding a subset of commonsense knowledge which involved "hands-on" or practical experience. Here commonsense knowledge defined as an intricate net of experience and interpretations constructed from everyday experience (Vincentini-Missioni, 1980). Figure 1 presents Vincentini-Missioni's theory on the development of commonsense knowledge and how it is related to acquisition of scientific knowledge. However, my preliminary definition of tinkering tried to incorporate the meaning of the French term for tinkering, "bricolage." Levi-Strauss (1972) defined "bricolage" as prior science. Specifically he noted:

> There still exists among ourselves an activity which on the technical plane gives us quite a good understanding of what a science we prefer to call "prior" rather than "primitive," could have been or the plane of speculation. This is what is commonly called "bricolage" in French. In its old sense the verb "bricoler" applied to ball games and billiards, to hunting, shooting and riding. It was however always used with reference to some extraneous movement: a ball rebounding, a dog straying or a horse swerving from its direct course to avoid an obstacle. And in our own time the "bricoleur" is still someone who works with his hands and uses devious means compared to those of a craftsman. (p. 16)

Levi-Strauss (1972) also made a clear distinction between "bricolage" and science when he described how the scientist and "bricoleur" function:

Figure 1: Vincentini-Missioni's View of Common Sense Knowledge



The passage from a closed coherent structure of cognitive culture (the example shows explicitly the one from common culture to a disciplinary culture) involves a radical change in the structure: for instance in the meaning of what is defined as "evident", "simple", "possible"... The passage from common culture to a specialized culture may be articulated in a series of logical steps (and the same is true for passages between specialized cultures). The gap or critical barrier from common sense culture to scientific culture may be identified in the fact that science books and science education usually take as a starting point the phenomenological description of "simple" scientific facts and phenomena overlooking the first three logical steps from common culture to conscious recognition of the structure of common culture to its logical reorganization to the choice of the phenomenology. (Vincentini-Missioni, 1980. p. 280)

> Both the scientist and "bricoleur" might therefore be said to be constantly on the look out for "messages." Those which the "bricoleur" collects are, however, ones which have to some extent been transmitted in advance--like the commercial codes which are summaries of the past experience of the trade and so allow any new situation to be met economically, provided that it belongs to the same class as some earlier one. The scientist, on the other hand, whether he is an engineer or a physicist, is always on the look out for "that other message" which might be wrested from an interlocutor in spite of his reticence in pronouncing on questions whose answers have not been rehearsed. Concepts thus appear like operators "opening up" the set being worked with and signification like the operator of its "reorganization," which neither extends nor renews it and limits itself to obtaining the group of its transformations. (p. 20)

Lawer (1985) drawing upon Levi-Strauss's work defines the bricoleur as a person who undertakes odd jobs, a sort of jack/jill-of-all trades or more precisely a committed do-it-yourself person. Lawer also views the "bricolage" description by Levi-Strauss as a metaphor for the process of mental self-construction. Specifically Lawer referred to bricolage in terms of this mental process by using the following analogy:

> Students of anatomy have named the adaptiveness of structures to alternative purposes functional lability. Such functional lability is the essential characteristic of the bricoleur's use of his tools and materials. I propose that bricolage can serve as a metaphor for the relation of a person to the contents and processes of his mind. Bricolage, as a name of the functional lability of cognitive structures, emphasizes the character of the processes in terms of human action and can guide us in exploring how a coherent mind could rise out of the concreteness of specific experience. (pp. 41-42)

The notion of bricolage used by Levi-Strauss and elaborated upon by Lawer provides further insight into what science educators appear to be talking about and what my preliminary studies tentatively described as tinkering. The viewing of tinkering as prior science also allowed for the labelling of gut science and lay science proposed by Claxton to be encorporated within a preliminary model of tinkering. Therefore, during the preliminary phase of my research I drew upon Claxton's definition of gut science and lay science, Vincentini-Missioni's idea of commonsense knowledge and Levi-Strauss's notion of "bricolage" to further develop a model of tinkering. Figure 2 presents a concept map of the preliminary model of tinkering which was proposed after the pilot studies were complete. Drawing upon primarily Levi-Strauss's work, I further proposed a connection between tinkering and science as outlined in Figure 3.

Empirical Context

To date I have not discovered any studies which focus on tinkering. However, a survey of literature did reveal a limited number of studies done on the differential experiences of males and females. A survey of such studies is relevant because it is on the basis of differential experiences reported in such studies that some researchers have argued that males have acquired superior knowledge in the physical sciences. Also, these researchers have described the out-of-school science experiences attributed to males as predominantly tinkering activities.

Wahlberg (1967), in a study of 1057 grade 12 physics students (332 females, 725 males) participating in Harvard Project Physics curriculum, found that on the Reed Science Activity Inventory girls scored significantly higher on factors termed academic, nature study, and applied life; whereas boys scored higher on factors labelled tinkering and cosmology. The sharpest difference was on tinkering, where girls had extremely low scores. Wahlberg speculates that this might explain why girls are hesitant to engage in the

Figure 2: Concept Map of Tinkering

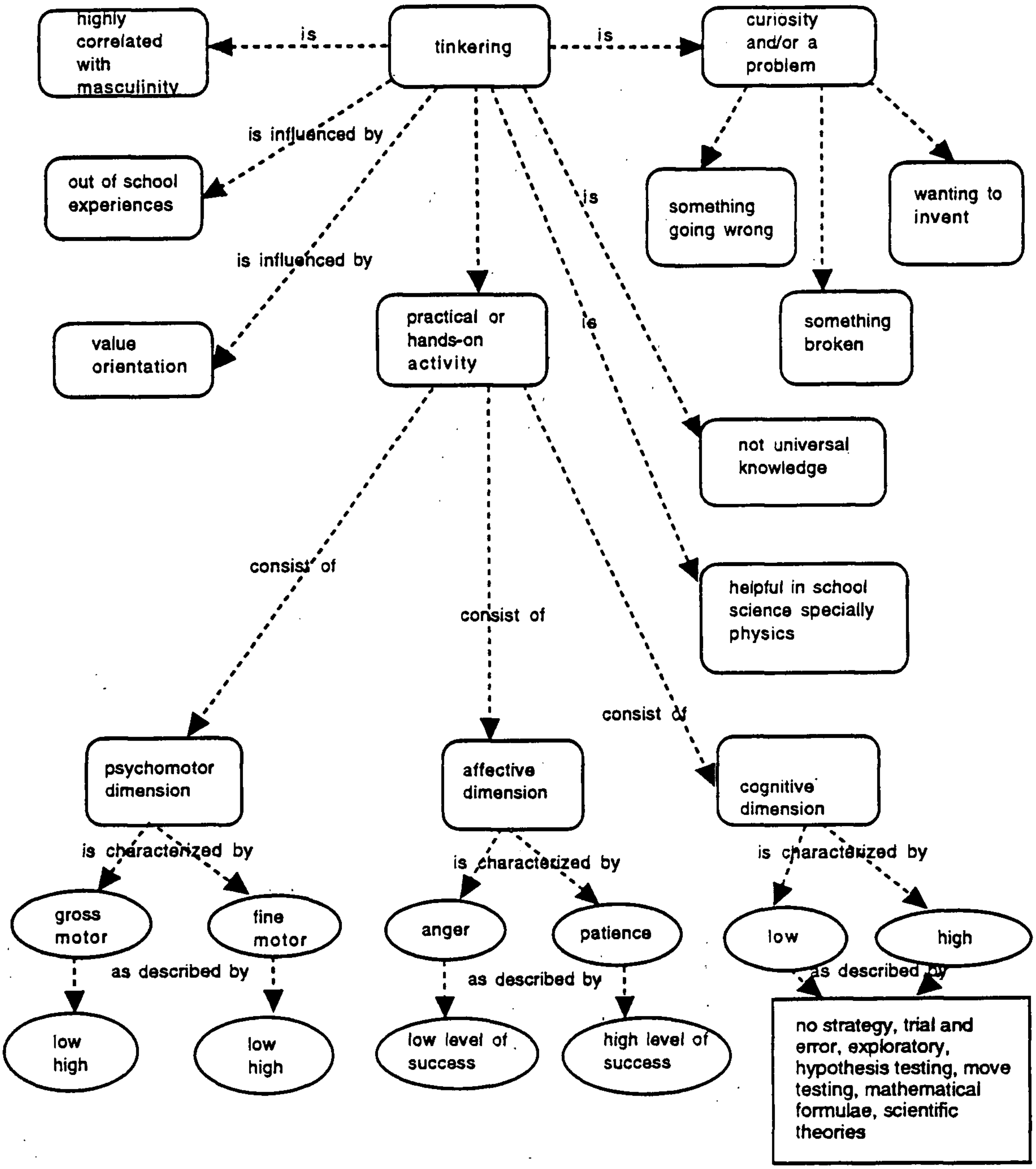
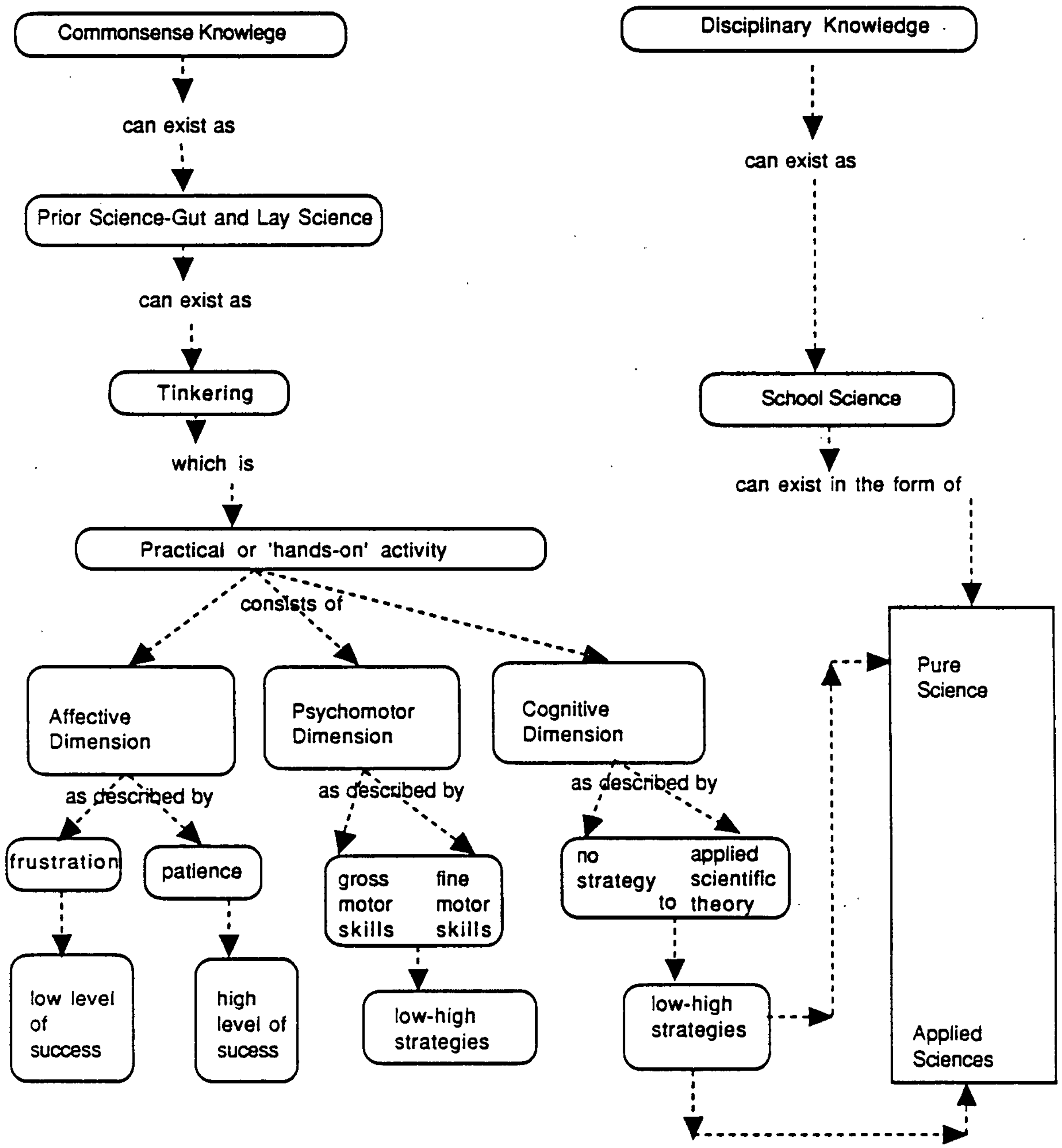


Figure 3: Concept Map of the Transition from Tinkering to Science



"tinkering" aspects of physics, that is, preparing and executing laboratory experiments. Wahlberg's conclusion was that the differences appear to be consistent with cultural stereotypes of masculinity and femininity. He notes that despite the fact that girls taking physics are more interested in science than are other girls, and that they scored higher on more dimensions of science interest than did boys in physics classes, the score pattern for girls did not appear to be in as sharp conflict with the feminine role as it might be. Specifically, Wahlberg noted that the score pattern for girls showed that they were more interested in animate aspects of science such as nature study and in applied life, whereas boys express more interest in inanimate aspects: tinkering and cosmology.

The instrument used by Wahlberg in his survey of science activities was developed by Cooley and Reed (1961). It should be mentioned that no specific reference was made to tinkering by Cooley and Reed except to define it as a category of science interest. The prime focus in their study was the validation of an instrument to measure science interest.

One of the most concentrated efforts to address the issue of girls' underachievement in the physical sciences has been the Girls Into Science and Technology (GIST) action research project. In particular, one of the GIST studies (Kelly & Smail, 1983; Kelly, Whyte, & Smail, 1982) was a three year study of 2065 eleven year old children entering first year at ten co-educational comprehensive schools in Greater Manchester. This study included the administration of a range of attitude, achievement and sex stereotyping tests. The project surveyed science activities in three areas: biological science, theoretical science and tinkering. GIST noted that in the survey of science activities deemed to be appropriate by the students for each sex masculinity had the largest correlation with tinkering and femininity with biological science. Also, in the survey of student activities they noted that boys had a lot more experience with tinkering activities--using tools (for example, in their study 55% of the boys and only 22% of the girls had used a screwdriver "quite often"), playing with construction toys, taking them apart and mending them. They pointed out that the importance of tinkering experience is borne out in two cognitive tests they administered (the mechanical reasoning test on gears, pulleys, screws, etc.; and the spatial test involving the ability to visualize and mentally manipulate objects in three dimensions). The explanation, they suggest, is that boys' greater prior experience in technical matters outside school may be a contributing factor to superior achievement in the physical sciences, as measured on standardized achievement tests.

Kelly (1981) noted one very important way in which secondary school boys and girls differed was in prior science experiences. Her claim is that girls and boys typically play with different sorts of toys and have different hobbies and household tasks, with the boys' mechanical and electrical toys enabling them to develop greater physics-related and spatial skills. Specifically she emphasizes the fact that boys have much greater experience with "tinkering" activities such as dismantling objects, assisting with car maintenance or playing with construction toys in their leisure time than do young girls. She further notes that girls are socialized away from science at an early age by virtue of the toys they are encouraged to play with, the household jobs they are assigned, and the masculine image of science and scientists in books, films, and television. These factors would seem to have the potential for operating more strongly in the physical sciences than other areas of science.

Johnson, Murphy, Driver, Head and Palacio (1983) in reviewing the performance of students on the IEA, NAEP, British Columbia Science Assessment, and APU studies note the significantly lower performances of girls on tests dependent on physics knowledge. They offer as a possible explanation the differential experiences of boys and girls. In particular they highlight the fact that leisure activities and science interests of boys and girls have been identified as already divergent by the age of eleven. They emphasize that boys' activities afford greater opportunities, or at least a broader range of concepts than do girls' activities; boys would have much greater opportunity of accumulating knowledge of mechanics and of gaining familiarity with electrical circuits. Elsewhere, Johnson and Murphy (1984) point out that the extreme discrepancy in the performance of girls and boys on questions featuring electricity appears to be a firmly established phenomenon with this being confirmed by all the international studies undertaken to date.

Johnson and Murphy (1984) also note that the discrepancy in physical science is visible at such an early age, as eleven when pupils have received relatively little direct science teaching, particularly in the physical sciences. They suggest the differential experiences of students in their everyday out-of-school activities must therefore be influential.

A further conjecture advanced by Johnson and Murphy (1984) is that society's role expectations for men and women result in the kinds of differences in the early socialization of boys and girls. These differences they claim are reinforced by role models from real life, in the media, in textbooks and the hidden curriculum. They emphasize that it is not only noteworthy that males and females are involved in different leisure time activities but such activities might also lead to a greater motivation to seek relevant factual knowledge from books. They believe this might explain why boys have an early established preference for non-fictional reading material whereas females have a greater preference for fiction.

Based upon the above arguments one conclusion that could be reached is the outcome of such experiences for males is greater opportunities to explore the physical sciences in their out-of-school activities. This, combined with their predilection to gather information from reference books might partially explain their superiority in factual knowledge and understanding within physical science.

Erickson and Erickson (1984), in examining the British Columbia Science Assessment Study, note that the enrollment patterns in science courses may partially account for the gender differences on science achievement tests. They note that boys do better than girls on items which deal with objects and events drawn from their "sphere of experience." They emphasize that this is most clearly illustrated in physics where there is a tendency for more males to enroll than females.

Kahle and Lakes (1983) report that an analysis of a 1976-77 NAEP survey of attitudes of subjects aged nine, thirteen, and seventeen reveals that by age nine females, although having the same or greater desire to participate in science activities, reported fewer experiences than boys of the same age. These experiences included the use of common experimental materials (magnets, mirrors, electricity, heat and solar energy) and instruments, observation of scientific phenomena and field trips. This situation, according to their analysis, worsened by ages thirteen and seventeen, with girls reporting fewer classroom and extra-curricular science activities (TV science shows, reading books, magazines, newspaper articles, working with science projects and hobbies) as well as a negative attitude toward science and science careers which was not present at age nine. Their conclusion was that the data showed that most girls participated in traditionally feminine tasks and not in traditionally masculine tasks.

In a study of 500 grade five pupils in a Norwegian school, Lie and Bryhni (1983) found a striking correspondence between experience and test scores in science. Specifically, they note that the general trend is that the two sexes have very different experiences. Boys are more interested in technical aspects of science and physical science topics such as optics and electricity whereas girls are more interested in the connection of science to the human being, to society and to ethnic and aesthetic aspects. They also note that the interests of female and male students are reflected in areas of science where they have obtained out-of-school experiences at an early age.

Rennie (1987), reporting on a study of 390 13-year-olds, found that the out-of-school science-related activities of Australian students were similar to those reported in other studies. That is, males enter high school with more science-related experiences than do girls, especially in the physical sciences. Her study however, unlike other studies, reported that the greater experience by males in science-related activities did not necessarily lead to higher achievement. She attributed this difference in findings to the activity-orientated style of science teaching which students in the study had experienced. One important variable which she did not consider was that her study defined achievement based on school tests whereas other studies used standardized achievement tests.

In summary, a review of the literature shows that there is an obvious discrepancy in the out-of-school experiences of male and female students from an early age. Some researchers have tended to label the type of out-of-school physical science experiences of males as "tinkering." Tinkering has been labelled as a specific type of experience but has not been studied. The question is: "Does the lack of access to situations where tinkering may be practised account for gender differences on science assessment tests?" Clearly before one can make such claims the notion of tinkering needs to be clarified. Although consistent sex differences have been reported from studies which consider spare time hobbies, etc., the questions that still arise out of this review are: "If some students have greater experience with tinkering activities what does this mean for physical science instruction?" and "What role would such commonsense knowledge play?" In an attempt to get some preliminary insights into such questions I will focus on the development of a model of tinkering.

Educational Context

Junior high school students in Canadian schools usually have to complete at least one unit in electricity as part of their science curriculum. Electricity is often a required component of all junior high school science programs. Since most of these programs require a hands-on approach what does this mean for students with varied experiences, such as tinkering? Do science curricula make provisions for dealing with students with such varied prior experiences? The Science Council of Canada (1984), after a four year study of science education in Canadian schools, stated:

> Students bring to school a wide variety of experiences and these, in turn, affect what they learn from the school curriculum. Girls' experiences unfortunately are usually not those that the science curriculum takes for granted. Many girls lack the practical, mechanical experiences that are commonplace in the lives of boys. . . . Girls must be able to identify with science and technology as much as boys, and herein lies a practical dilemma. (p. 35)

While such statements as the above are very encouraging, as yet only few Canadian junior high science curricula address this concern.

The junior high science program is a very crucial time for most students since it is after this point that students are directed to future career options at the senior high level. That is, students are forced to make choices about science and non-science streams. Should they decide to eliminate science subjects, such as physics, at the senior high level then many career options at the post-secondary level are also automatically eliminated. The Science Council (1984), in its discussion of what science education is supposed to achieve and what it actually achieves, notes that many girls unfortunately do not see scientific or technological careers as being relevant to them, and hence they turn away from science. This is not to suggest that science is only important for career preparation: Education in science should be perceived as part of a lifelong learning process to give students the ability to examine their own knowledge critically. The transitional period from junior high to senior high science is very critical. Therefore, based on the above rationale, junior high science should receive critical attention in considering the prior experiences of students as well as paying special attention to the gender issue.

It is well documented both at the provincial and national levels that the participation rates of females in the physical sciences are much lower than for males. The Science Council of Canada (1984) notes:

> The tendency is for girls to opt out of science, especially physical science, as soon as they are permitted to do so. . . . Certainly, girls do not participate in science courses in the same proportion as boys; consequently few women work as scientists in teaching, industry and the public sector in Canada. . . . Canada can no longer afford to shrug off the underrepresentation of girls in science classes in secondary schools. (pp.25-26)

This concern is followed up by the Science Council of Canada recommending that changes be made in curriculum, teaching methods, and in career counselling.

Summary

The review of the literature from a variety of perspectives suggests that the term "tinkering" needs further clarification. Although constructivism can provide a theoretical framework for the interpretation of tinkering as one method by which children acquire their scientific knowledge we still need to clarify the notion of tinkering. Given that there are no empirical studies on tinkering my study was the first exploration of tinkering. If tinkering can be viewed as a method by which children acquire some aspects of their science knowledge base, then the results have implications for science education.

CHAPTER III: METHODS

Introduction

The focus of my exploratory study was on description and interpretation of tinkering as a phenomenon or practice, rather than on the measurement of success with tinkering. Given the exploratory nature of the study the method of data collection and analysis evolved over a period of time and involved three research phases. Figure 3-1 provides an overview of these three phases.

Research Design

My study was conducted in a school district in one of the Altantic Provinces where I had worked previously. This was an advantage in a naturalistic study because I did not have to spend extra time to familiarize myself with the cultural context. Moreover since I had worked in a supervisory role within that district it also allowed me to quickly identify a research site. I not only wanted a school which would satisfy my research criteria but one that would also be open to having a researcher present for a complete semester. The formalities involved after obtaining permission from the district superintendent was to make contact with the school to obtain official permission from the principal, teacher and students. Since I had worked on prior occasions with both the principal and teacher I was able to quickly gain access to the research site.

My case study was of grade nine students from middle class backgrounds who were described as being average or above, in terms of academic success. Efforts were made to choose a class with students of average or above average

Figure 3-1: Research Plan

PHASE I **PRELIMINARY INVESTIGATION**

PHASE II **PILOT STUDY**

PHASE III **STUDY**

Stage A <u>Selection Process</u>

1. identification of target classes

   -observation

   -survey of prior electrical experiences

2. selection of target class

3. selection of target students

Stage B <u>Interview</u>

1. video-taping of target student doing:

   a) school type tasks

   b) non-school type tasks

2. reflective conversation focusing on:

   a) tasks

   b) survey

Stage C <u>Classroom Observation of Target Students</u>

1. fieldnotes of classroom observations

2. audio tapes of large and small group discussions

ability, and whose teacher utilized a "hands-on" approach to science. It was necessary to have a sample of students of average and above average ability since these students would have the potential of going on to study physics at the senior high level. This sample also allowed for the discussion of literature which centered around achievement in physical sciences. Given the fact that the subjects were at the grade nine level this also allowed for a longitudinal or follow-up study in subsequent years, if an opportunity arose. Moreover, I also wanted subjects who were similar in academic ability such that differences in tinkering could not be attributable to differences in academic ability. Beyond having that requirement results from my preliminary studies suggested it was necessary to select a class where the teacher utilized a "hands-on" approach if I wanted to observe tinkering.

The research design consisted of three phases. Phase I, Preliminary Investigation involved a review of the research literature plus early exploration of tinkering through classroom observations and interviews with subjects described as tinkerers. The focus of Phase I was to help define the parameters of my study. Phase II involved the piloting of classroom observation techniques and the specific tasks that were used in the study. Phase III, the actual study itself, involved three stages. Stage A of Phase III, or the selection process required a selection of target class. Based on my observations of two grade nine classes for six weeks one class which showed the greatest potential for the observation of tinkering was selected. What was obvious to me within a week observing was that one class (Class A) had far more students who engaged in tinkering activities than did the other (Class B). Class A consisted of 15 males and 12 females and Class B consisted of four males and 16 females. I attempted to confirm this observation by checking with their previous grade seven and eight science teachers. Nevertheless, I still continued my observations of both classes for another three weeks before deciding on a short list of ten students from Class A. My decision to select Class A was also supported by the fact that more students indicated on the Survey of Electrical Experiences they had engaged in electrical activities. It was also the class that contained the greatest number of students who were described by their former teachers as tinkerers. Moreover my observations over the six week period confirmed the teachers' judgement.

Ten target subjects (five female and five male) were then identified within that one class. My intention was to have an equal number of female and male subjects. These ten subjects were initially categorized either as tinkerers or non-tinkerers based my preliminary observations, the survey of prior electrical experiences and teacher descriptions. These subjects were chosen as a representative sample of students with varying amounts of tinkering, as defined by the following steps in the selection process:

1. Observations for a six week period.
2. A discussion of potential subjects with their former grade seven and eight science teachers.
3. A review of results on the Survey of Electrical Experiences for each potential subject.

While it was not difficult to identify male subjects who could be classified as tinkerers it was impossible within the target population at Phase III of my study to identify female subjects who could be labelled as tinkerers. The target subjects were then interviewed as outlined in Stage B. I then observed the same subjects for six weeks as outlined in Stage C.

Finally after data collection was completed six subjects (three female and three male) were selected from the larger data base of ten. The data on the remaining four was set aside for archival reasons, allowing for a cross check after data analysis was completed.

In conclusion the multiple case study approach is ideally suited to explore tinkering within the context of physical science. The case study approach is ideal in that it meets the criteria defined by Yin (1984):

1. It investigated a contemporary phenomenon (tinkering) within its real-life context (school science); where
2. the boundaries between phenomenon (tinkering) and context (school science) are not clearly evident; and in which
3. multiple sources of evidence were used for each case (survey, interview and classroom observation).

Overview of Instruments

Introduction

For the present study the following were used as data bases:

1. Survey of Electrical Experiences
2. Interview focusing on Electrical Tasks
3. Field notes from classroom observations

The score on the Survey of Electrical Experiences was used as one of the criteria to select the target students. After the target students were selected they were given a series of assigned electrical tasks, in an interview setting. Later they were followed up with observation in a classroom setting where they were being instructed in a unit on electricity. A brief overview of each data collection method is given below.

Survey of Electrical Experiences

The purpose of this instrument was to ascertain the depth and sources of tinkering experiences that students have been engaged in prior to the electricity unit. The survey consisted of a series of questions which focused on prior experiences with electricity. Based on responses to the survey an activity index was constructed for each student. This instrument assisted me in identifying students with different levels of experiences with electricity.

A copy of the Survey of Electrical Experiences is included as Appendix A.

Electrical Tasks

Overview of Tasks

Students were asked to perform three school-type and three non-school type electrical tasks. The school-type tasks were on the topic of electricity typically found in the grade nine level physical science curriculum. These school-type tasks consisted of the construction of an electric tester, an electromagnet, and the demonstration of magnetic induction. The three non-school type tasks consisted of activities which met the following criteria:

1. an opportunity for something to go wrong or for something which was broken to be repaired,
2. a situation where an ability to complete the task did not require special experience or concepts beyond the grade nine level, and
3. involved electrical objects from the students' everyday experiences rather than their school experience.

These tasks included the attachment of two and three prong plugs to electrical wires, the repairing of an electrical appliance, and the repairing of a flashlight.

For the completion of the school-type tasks students were given written directions, and verbal directions were given for the completion of the non-school type tasks. All tasks were piloted to determine if such tasks could be performed by ninth grade students and to see if the tasks provided an opportunity for tinkering to occur.

School-Type Tasks

The pilot study was conducted using six tasks from the *Searching for Structure Program*, a textbook series used with the target class. Three of these six tasks were selected for use in the study. The criteria for the selection of the three tasks are outlined below. Features considered in the final selection of the three tasks were:

1. an opportunity for students to engage in tinkering, and
2. tasks that could be performed by the average grade nine student.

Task 1 Construct an electric tester

Purpose: To test materials to see if electricity can pass through them.

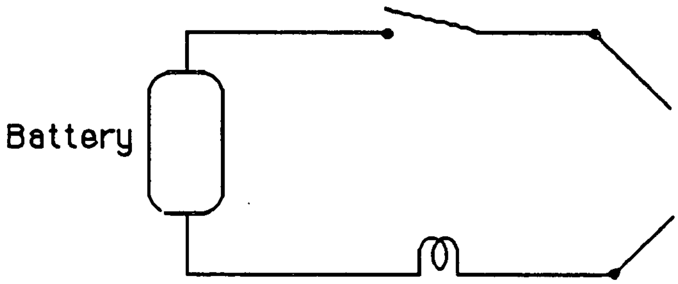
Apparatus:
3 V battery made from two D-cells
bulb in bulb-holder
wire
cardboard square
assorted test materials

Directions:
Make an electrical "tester" according to the plan (Figure 3-2).

Place various materials across the ends of the test wires. What should happen if the material permits electricity to pass through it?

Materials that permit electricity to pass through easily are called electrical conductors. Materials that do not permit the passage of electricity are called electrical insulators.

Figure 3-2 Plan for Electric Tester



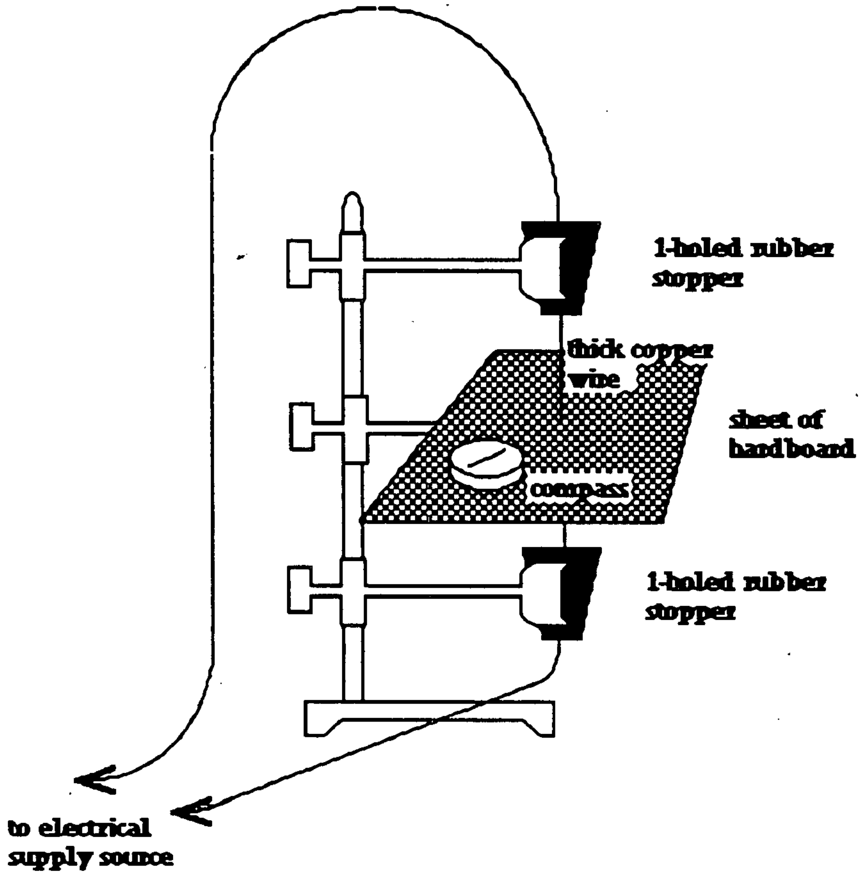
Task 2 To make an electromagnet

Purpose: To illustrate the magnetic force produced by an electric current

Materials:
6 V battery
wire
retort stand and support
clamps
4 small compasses
electric switch

Directions:
Set up the apparatus, as illustrated in the figure (Figure 3-3). Close the switch and observe the compasses. (Note: Do not leave the switch closed for more than a few seconds. The resistance of the circuit is very low, and the battery will therefore lose its energy quickly.)

Figure 3-3 The Set-up of Apparatus to Illustrate Magnetic Force Produced by an Electric Current



Sketch the directions in which the compasses point when the circuit was opened and closed.

Reverse the connections to the battery. What effect does this have on the current in the circuit?

Task 3 To demonstrate electromagnetic induction

Purpose: To use magnetism to produce an electric current.

Materials:
galvanometer
strong bar magnets
electric wire

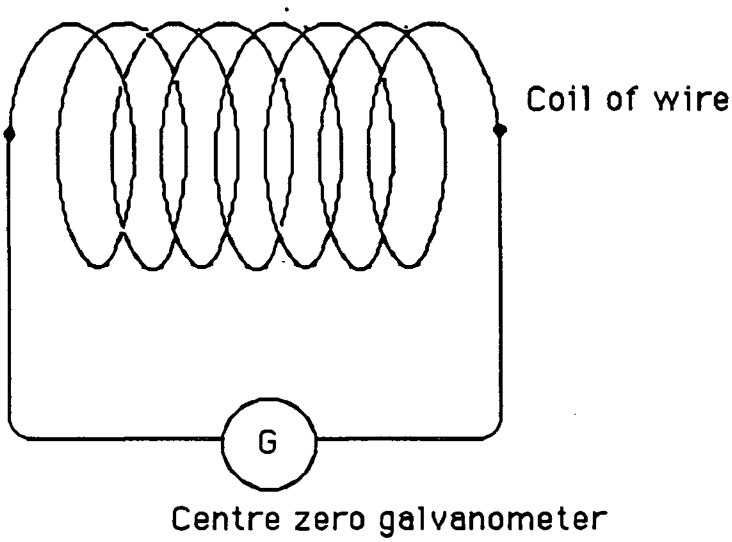
Directions
Set up the apparatus as illustrated in the figure (Figure 3-4).

Connect the ends of the wire to the terminals of the galvanometer. Adjust the galvanometer to read on its most sensitive scale. Your teacher will advise you how to do this.

Move the magnet(s) back and forth over the wire or in and out of the coil. Observe the meter.

Keep the magnet at rest and move the wire into the jaws of the bar magnets, or move the coil back and forth over the magnet. Again observe the meter.

Figure 3-4 The Set-up of Apparatus to Demonstrate Electromagnetic Induction



Non-School-Type Tasks

The following three non-school-type activities were selected from six tasks after piloting.

Task 1 To attach two and three prong plugs to electrical wires.

Materials:
2 and 3 prong plugs
variety of electrical wires

Directions:

I would like you to hook up these two plugs to some wires.

Task 2 Repair an electrical appliance

Materials:
facial sauna, variety of electrical tools and materials.

Directions:
This electrical appliance is not working. I would like to see if you can get it working.

Task 3 To get a flashlight to work.

Materials:
flashlight (not working), variety of batteries, variety of electrical materials and tools.

Directions:
Here is a flashlight which is not working. I would like you to make the bulb light.

The objective of task #1 was for the students to select the appropriate wiring and assemble the plugs. For task #2 a wire was disconnected from the switch and the students had to reconnect the wire for the sauna to work, whereas for task #3 the switch in the flashlight was broken and had to be repaired in order to work.

Interview Protocol

The students were interviewed while they were completing the school-type and non-school-type electrical tasks; the interview time and task time occurred simultaneously. An interview is a useful method of data collection in that it allowed for an indepth probing of the dimensions of tinkering displayed in the completion of tasks; as well an opportunity to explore the role of prior experiences.

The interview format was semi-structured. That is, it consisted of a number of specific questions based on the tasks and the students' prior experiences, as identified in the survey, that were relevant to the research questions, yet not so specific as to restrict the interview to an inflexible question-answer format. This allowed the subjects the freedom to expand their responses and it allowed me to pursue those responses.

After piloting the school-type and non-school-type tasks, an interview protocol (Appendix B contains a sample interview protocol) was developed using the following criteria:

1. questions relating to the dimensions of tinkering,
2. questions on the relationship of prior experiences with similar tasks.

Each subject in the study was interviewed alone in a quiet room during school hours. Before starting the interview the subjects were informed that the results of the interview were for research purposes only and as such would not be made available to teachers or peers. They were also asked for their permission to videotape the interview. The interview format consisted of my asking a series of questions based on observations made during the completion of the tasks. When it was appropriate, the students were asked about their experiences with mechanical and electrical objects. Each interview lasted approximately two to three hours, allowing for breaks at convenient times such as recess and lunch time. Such breaks were necessary to reduce fatigue.

The specific questions asked had to be open-ended enough to respond to each student's performance on various tasks and their descriptions of prior tinkering. No specific list of questions was therefore suitable for use with all students. However, after initial piloting a general outline was developed.

Field Notes on Classroom Observation

For purposes of collecting data based on the classroom discussions and activities, field notes were used. Field notes on classroom observations were a part of a logbook that was kept on all activities, beginning with the preliminary phase and up to and including the final phase of the study. Classroom observations involved the collection of data on the target students for all lectures and activities during the grade nine electricity unit presented by the teacher. Specifically, these anecdotal notes focused on the research questions posed earlier. That is, these notes described how the target students played out their tinkering through their words and actions in classroom discussion and laboratory activities.

The field notes collected the following data on the target students:

1. the personal interest displayed by subjects toward the assigned work throughout the unit,
2. a selection of the verbal statements made by subjects in carrying out tasks and participating in large group and small group discussions,
3. a description of the nonverbal actions of subjects in carrying out tasks, and
4. any evidence of prior experience with tasks.

The following selected observations from my logbook are illustrative of the type of field notes that were taken:

> Date: Oct 10 (Day 4): Pilot Study (Observation of Target Classes)
> Topic: Dissection of Flower
> Description of Activity:
>
> Observations:
> Sean asks for microscope. He gets a microscope from the side bench.

He played with electrical apparatus.

Students who played with microscope - Paul N., *Sean*, Jason F., *Gary*, *Paul*, Glenn, *Jason*, *Frankie*, Raymond, Terri, (Michael & Stacy)?

Jason and Frankie worked on electric motor on the side board. They noticed it sitting on the side and went and got it.

Interpretation: Target subjects engaged in volunteer hands-on activity.

Date: Oct. 29
Topic: Activities 4 & 8
Description of Activity:

Observations:
Act 4 - Haritha & Leann
- Haritha collects materials for group. She has difficulty with cutting wire.
- Came to ask for directions for setting up parallel circuit.
- Leann uses text to help in the setting up of a parallel circuit.

Act 8 - Sandra & Natasha
- After some time they get the cell to work but they are unable to read the galvanometer. They ask the teacher to explain it to them.

- Female groups didn't ask for KCrO2, or test bulbs.

- I ask them (Sandra & Natasha) if their cell would light a bulb. They didn't know. They later get a bulb to test. (*It appears to me that they rely on help or someone noticing that they need help.*)

Comments
- Other than Haritha the female target subjects do not take an active role in seeking out info, male target subjects appear to take an active role (esp. Sean, Gary, Paul, Jason & Frankie)

- I did not observe female target subjects engage in any hands-on activity beyond what was absolutely required to complete the task. They appeared to rely on the teacher or text for information. For example at the beginning of the period Sandra and Natasha asked me (after I checked on their progress) what the galvanometer was for.

- After class I discussed Sandra and Natasha with the teacher. He confirmed the above pattern. He also noted that Sandra got the second highest mark on (1st or 2nd) test. He said he did notice a pattern, she didn't get questions right that he didn't explain in detail in class. That is, questions that required some hands-on activity on the student's part.

In addition to writing anecdotal notes on each of the target students I relied on such techniques as memoing and the use of contact summary sheets. Throughout the study memoing was used to describe the overall patterns that were noted. Miles and Huberman (1984) describe memoing as:

> . . . . theorizing write-up of ideas about codes and their relationships as they strike the analyst while coding . . . it can be a sentence, a paragraph or a few pages . . . it exhausts the analyst's momentary ideation based on data with perhaps a little conceptual elaboration. (p. 69)

The above technique was mainly utilized during data collection and analysis.

After an intensive field contact of approximately one week, I would pause and consider what were the main themes, issues, problems and questions during the contact. This reflection was then documented in a Contact Summary Sheet. This Contact Summary Sheet was adapted from Miles and Huberman (1984).

Classroom lectures and activities were all audio taped and cross-referenced with the field notes. This provided support for any patterns that were apparent. A sample transcript from small group discussion is included in Appendix C.

Rationale for Techniques

Since the major objective of my study was to develop a model of tinkering in its naturalistic state I chose to use case study technique. Also, since no prior studies have been done my study had to be exploratory in nature, focusing on qualitative data collection methods. One of the best methods for such a focus is through a case study which allows for an in-depth collection of data.

The scores on Survey of Electrical Experiences were used as one of the criteria for selecting the target students. It allowed for the selection of students with varying tinkering experiences in electricity as defined by scores on the survey. In addition the survey provided information on each of the target students in terms of their prior experiences with electricity.

The interview procedure was designed to get subjects to reflect-in-action as elaborated upon by Schon (1983). The interview also focused on prior experiences with electrical devices. The objective was to see what role tinkering might play in the students' understanding of electricity when encountered in the specific tasks. Both school-type and non-school-type electrical tasks were used as stimuli.

The observation of students in the classroom setting provided a source of data to see if patterns observed in the clinical setting (tasks observation and reflective conversation) were replicated in the classroom setting: That is, it allowed a cross-check to see if the pattern of tinkering observed in a clinical setting was consistent with the classroom setting. In addition it provided for the possibility of viewing any new patterns which might have been visible in the interview setting.

Overview of Unit

Before presenting the framework for the analysis of the data it is necessary to provide a brief overview of the unit that the students were exposed to during their study of electricity. The electricity unit taught was from the *Searching for Structure* program edited by D. H. Pike, and published by Holt, Rinehart and Winston of Canada, Limited in 1978. This program promotes an hands-on approach to junior high science teaching. Based on the results of the pilot studies, it was noted that for tinkering to be visible to an observer an hands-on approach to science teaching was necessary. The teacher who cooperated with me in the study agreed to take mainly a hands-on approach for the electricity unit, as such an approach was necessary to view tinkering within a classroom context. Table 3-1 lists the order of the lectures and activities presented to students during the unit. The lab activities numbers are presented as they appeared in the above science curriculum used by the school, while the day denotes the actual order in which the presentation of the activities occurred.

The Analysis of Data

Introduction

My study utilized mainly qualitative measures in the analysis of all data collected on the six target students. However, in analyzing the data obtained from each student multiple sources of evidence (tasks, interviews and classroom observations) were used. I will now present a brief overview of the analytical methods used for all data collected in the study. This will be followed by an outlining of the categories that were developed to make sense of these data.

Data from the Survey of Electrical Experiences

The Survey of Electrical Experiences was used as a screening instrument to help select students with various amounts of tinkering experiences. It was analyzed by computing an activity index for each subject and this activity index was used as one of the criteria in the final selection of target students. Such activity indices could be done on the population at large if one were interested in obtaining this type of information. This, however, was not the intent of the present study.

Data from Interview

The interview data were analyzed considering the questions proposed in the research questions. Specifically, the videotapes were transcribed, coded and analyzed for:

1. the dimensions of tinkering displayed by the target subjects in the completion of the school-type and non-school type tasks,
2. the contextual factors associated with tinkering that were revealed during the interviews.

In addition gender patterns were noted in the interview data.

Data from Classroom Observations

Two methods of data collection were used in the classroom observation of target students field notes and audio tapes. Field notes were made on each target student. The field notes made every attempt to describe student behavior in terms of the total context of the classroom. An additional source of data was obtained from the audio recording of all lectures, large group discussions, and selected small group discussions in which the target students were engaged. The tape recorded data were then transcribed, and together with the fieldnotes were coded and analyzed.

Table 3-1 Overview of Class Activities During Electricity Unit

DAY	TYPE OF CLASS	DESCRIPTION
Day 1	Activity 1:	To make a simple electric circuit
Day 2	Lecture 1:	Review activity one and discussion of activity two
Day 3	Activity 2:	To invent some other electric circuits
	Discussion:	Electrical terms related to an electric circuit
Day 4	Activity 4:	To examine series and parallel circuits
Day 5	Activity 8:	To make an electric cell
Day 6	Review of Activity 2	
Day 7	Activity 5:	To test materials to see if electricity can pass through them
	Activity 6:	To observe the effect of passing electricity through a liquid
Day 8	Lecture 2:	Discussion of activity two
	Activity 3*:	To light a regular household bulb
	Activity 8*:	Extension to activity 8
Day 9	Activity 11:	To observe some of the properties of electric charges and forces
Homework assigned:		
	Activity 7:	To decide what you think electricity is like
	Activity 9:	To locate the electric circuits in a house
Day 10	Discussion:	Introduction to electrostatics
	Activity 12:	To make a metal-leaf electroscope
Day 11	Lecture 3:	Electrostatics
Day 12	Review:	Teacher demo on series and parallel circuits and series and parallel batteries
Day 13	Activity 13:	To illustrate the magnetic force produced by an electric current
Day 14	Activity 16:	To use magnetism to produce an electric current
Day 15	Exam	

*done as class demos
- Activities 14 & 15 were given as optional activities that students could do if they were interested on days 13 & 14

Activity 14: To illustrate the magnetic force produced by an electric current
Activity 15: To make an electric motor

Categorization of Data

Overview of Categorization

This study covered two broad areas which formed the nucleus or primary focus for the categorization of data. These are:

1. the characteristics of tinkering, and
2. the contextual factors of tinkering.

There was however a secondary focus on the discussion of the interaction of gender with tinkering. Since a detailed discussion of the categorization will follow in chapters four and five, with a discussion of gender in chapter six, a brief overview will only be provided here.

Categorization for the Characteristics of Tinkering

From the preliminary phase of my study a typology of tinkering was constructed as consisting of two characteristics -- different purposes and different levels of proficiency. The different purposes for tinkering were initially labelled as utilitarian, technological and scientific. These three purposes held throughout the first two phases of the study, with a pragmatic category being added during the final phase of the study. The data were also analyzed for proficiency of tinkering. The scale constructed for data coding was master, professional, amateur and novice.

Tinkering was also describable by a process dimension. By analyzing patterns in the interview and classroom settings I was able to describe three phases in the tinkering process: framing the problem, solving the problem and testing the solution.

Finally, another dimension, the knowledge displayed by the subjects when tinkering was coded as verbal and actional knowledge. Both verbal and actional knowledge levels were identified within the data base.

Categorization for the Factors Influencing Tinkering

The second question explored the contexts of tinkering. The specific sub-questions asked were:

1. What role do prior experiences play?
2. What are the social influences on tinkering?
3. What role do personal interests play?

The above questions provided three broad categorizes (experiential, social, and personal) for the coding of data that were collected by the three data bases used in this study. These categories form what will be described in chapter six as "the apprenticeship".

A Discussion of Gender Differences in Tinkering

After the above categorization for the dimensions and contexts of tinkering was complete it was then possible to examine such data for gender differences. A discussion of these gender differences will be undertaken in chapter six.

Trustworthiness of Data

A naturalistic study has to convince the readers that its data are trustworthy. My study, in attempting to establish the trustworthiness of the data analysis, followed the Lincoln and Guba (1985) criteria of "credibility," "transferability," "dependability," and "confirmability" which are the naturalist's equivalent to the conventional terms "internal validity," "external validity," "reliability," and "objectivity." Based on the above criteria the following review will outline how I attempted to establish the trustworthiness of its data analysis:

1. Credibility

I utilized such techniques as prolonged engagement, persistent observation and triangulation to enhance the credibility of findings and interpretations. First of all, I undertook a prolonged stay at the actual site of data collection. The study itself was conducted over a three month period. Moreover, I had already spent five years in a science education consulting role at the actual site prior to the study. During data collection my observations were persistent in that I constantly checked my observations with the target subjects and their teacher. Finally I utilized triangulation by using multiple and different sources (survey, interview, and classroom observations) to collect and analyze the data .

Beginning at the preliminary phase of the study and continuing to the end, I constantly sought out my peers to test patterns that developed during analysis. I did this by presenting preliminary categories to describe data patterns. This process also continued throughout the writing of the thesis.

A further attempt to establish credibility was the utilization of negative instances. Specifically negative instances were helpful in the checking of the emerging patterns that developed during the data analysis. Through the utilization of negative instances I was able to look for any evidence that did not fit the pattern.

I utilized audio and video tapes to collect a large portion of the data that was used. A fair proportion of such data was set aside for referential adequacy (Lincoln & Guba, 1985). That is, these data were set aside so that after data analysis was complete the categories that were developed could be further examined. This was possible because I had set aside as archival material all the data that were collected on four students. The data base which was archived constituted two fifths of the data collected. This allowed for an adequate data base for such a process.

Member checks were undertaken during the study. I kept checking any patterns noted with the subjects while I was in the field. The students were consulted during the data collection period. One instance of this was, after the interviews were completed, I played videotapes back to students to get their reactions and to check their reactions. I also utilized the students' science teacher and former science teachers to test emerging patterns that appeared to explain the data.

2. Transferability

My study attempts to provide the reader with the thick description (Miles & Huberman, 1984) of the setting in terms of time and context. Since this is a naturalistic study I cannot specify the external validity of the study but only provide sufficient description that might allow interested readers to reach conclusions about transfer to another context.

3. Dependability

I attempted to establish that the process used was dependable, by asking for critical feedback from science educators and the dissertation supervisory committee on the instruments used (Survey of Electrical Experiences, Field

Notebook, Transcripts of audio and videotapes). Moreover I tried to establish through my extensive piloting a dependable process. I was not however successful, given financial and time restrictions, at arranging for a formal inquiry audit.

4. Confirmability

As part of the informal audit the final products produced during the data analysis were also examined by a science educator familiar with both qualitative data analysis and junior high school science. While this does not substitute for a formal audit all comments and criticisms given by the informal auditor were considered in the production of the final draft of my dissertation. Necessary revisions in data analysis were also made as a result of this informal audit.

Summary

Data collection and analysis consisted of three phases. Phase I was the stage of preliminary investigation where I developed instruments to be used in the study, as well as a preliminary model of tinkering. Phase II involved a number of pilot studies to field test data collecting techniques and the development of criteria for the selection of target subjects. Phase III, or the final phase of the study, resulted in the collection of data used in this study.

This chapter concluded with the measures that were taken to increase the trustworthiness of the study, at various places throughout the study and particularly at the end with the audit. Chapters four through six will present and discuss the findings based on multiple data sources. Chapter four will outline the dimensions of tinkering. Chapter five will outline the experiential, social, and personal factors influencing tinkering. The final chapter, Chapter six will discuss the gender differences as presented in Chapters four and five.

CHAPTER IV: THE CHARACTERISTICS OF TINKERING

Introduction

I began the study with a tentative framework for a model of tinkering. This tentative framework was based on a review of the literature, plus an analysis of data collected during the preliminary research and pilot phases of the study. The early analysis of data resulted in the construction of a model of tinkering which had three components: affective, psychomotor and cognitive. It was recognized at the time that it was only a working model. However further analysis of the data, after the study was completed, made me think that the cognitive and psychomotor components could be more appropriately labelled verbal and actional knowledge. By verbal knowledge I mean any statements made by the subjects which indicated something about their understanding of electricity; by actional knowledge I mean the actions displayed by the subjects during their activities with electrical apparatus or objects. Therefore, tinkering can be viewed as a process which has both cognitive and psychomotor components. That is to say that both verbal and actional knowledge were displayed by the target students when they tinkered. This chapter, by examining the statements and actions of the target subjects during the interviews and in the classroom setting, will construct for the reader the various characteristics of tinkering. The analysis of the actional and verbal knowledge patterns displayed by the target subjects in the interview and classroom settings allowed me to construct:

1. a typology of tinkering, namely,

    (a) purposes for tinkering, and

(b) a proficiency of tinkering,

2. the process of tinkering, and
3. the levels of verbal and actional knowledge associated with tinkering.

The Typology of Tinkering

Introduction

At a societal level we are aware of adults who through educational choices have formally shown an interest in the study of physical objects, such as electrical devices. The focus of their interest however varies. For instance, there are electricians, electronics technicians, computer technicians, engineers and physicists, and so on. There are also adults who have informally taken up these areas of interest for hobbies, or for other reasons. Some children, too, informally become interested in such areas and through schooling they are formally introduced to the study of electricity and related fields.

It is clear that not everyone will bring the same level of interest or focus to the study of electricity. The specific focus that some students brought to the study of electricity is what I initially referred to as tinkering. By tinkering, I initially meant the informal study of electricity through the actional process of manipulating electrical and electronic objects. As early as grade nine it is not surprising that we find students who have a specific interest in the study of electricity, expressed in both their informal and formal activities. In the early stages of my study it became evident after observing children interact with electrical devices that their interactions varied. After probing as to their interest in the study of electricity I received a variety of responses. On the basis of how they interacted with electrical objects and their reasons as to why they were or were not interested in electricity, a typology was proposed. This typology was then subsequently used in the pilot studies, and again in the main study to interpret the data. After the pilot studies three purposes for tinkering were identified, with a fourth type identified in the final stage of data analysis. In addition to the identification of a fourth type of tinkering, at the final phase of data analysis, a proficiency of tinkering was also constructed. The following two sections will present those two aspects (purpose and proficiency) of the typology. The reader should note that these categories should be viewed as the target subjects dominant performance patterns within the context of the study of school science.

Purposes for Tinkering

My study has identified the following four purposes for tinkering that can be illustrated through the way different students approached the tasks:

1. Utilitarian tinkering (use)

   - is interested in fixing things and someone who engages in this type of tinkering is regarded as the fix-it type
   - is interested in fixing mechanical and electrical devices because it is perceived as useful for everyday living
   - looks at tinkering as a means of saving or earning money

2. Technological tinkering (application)

- is interested in the electrical and electronic hardware (the application of knowledge of electricity to electrical and electronic hardware) and is fascinated by any electrical or electronic device
- is very adaptable to new technological devices
- is interested in being in control

3. Scientific tinkering (theory)

- is interested in the how and why of electrical and electronic devices or the theory behind how an electrical or electronic device works
- is more interested in understanding than doing and will engage in activities for the sole purpose of understanding

4. Pragmatic Tinkering (performance)

- is interested in performing for grades or doing what the teacher wanted
- only tinkers when absolutely required for a well defined task such as school work or to meet some very limited specific need.

I will now select interview and classroom data for representative target students[1] to illustrate the types of tinkering proposed above.

[1] all the names used in this study are psedonyms

Jason (A Utilitarian Tinkerer)

Interview data .

Jason's behavior was the best illustration of utilitarian tinkering in the target class. Jason was classified as a utilitarian tinkerer because the prime focus of his behavior was on fixing things. He perceived such an activity as being useful or a means of earning or saving money. The analysis will outline illustrative examples from the interview data that were used to develop the criteria for defining Jason's behavior as utilitarian tinkering.

Criterion 1: **Is interested in fixing things**

Jason's behavior can be best described as utilitarian tinkering in that his prime focus was on fixing things. The first reference that he made to fixing things was at the beginning of the interview.

> I: Mmh, mmh. So, are you used to sort of, something not always working the first time.
> J: Ah, oh yes. Well I got a ah, dad had an old stereo home right.
> I: Right.
> J: He a brought it up to a place to be **fixed** in town and like they couldn't **fix** it and I picked it apart and looked at it and had it working after awhile.

The above dialogue seems to indicate that Jason thinks of himself as having a superior expertise in fixing things. In addition, he also appeared to be delighted to tell me that he could fix the stereo whereas the technicians at Radio Shack could not. Not only does he think of himself as having expertise but he also indicated an interest in fixing things. Throughout the interview he made many references to fixing things. The following excerpt illustrates such a reference:

Task # 4 - To attach plugs to electrical wires

J: Cause I got. Now this one here is going to be a bit shabby. You want me ah cut it off?
I: Oh, do it.
J: **Fix** it?
I: Do that if you like.

While Jason is still working on task # 4 he makes further references to repairing things so the interviewer raises the following question:

I: So it seems like you are into lots of repairs and that kind of stuff?
J: Oh yes. Whatever, there is usually broke I **fix** it right.

Here Jason seems to indicate that he would be willing to fix anything that is broken. Jason does however throughout the interview make specific reference to activities where he has been involved in fixing things. The following is an illustration of such activities:

J: **Fixed** couple of toys I think for my sister.
I: For your sister like what? What would she have broken?
J: Probably like a motor in something or I used to **fix** remote control cars when I was younger. Take the motors out and that, something in the motor like a fan.

A further illustration of Jason's preoccupation with fixing things occured when Jason was working on the flashlight activity, Task # 6. At one point he makes reference to the fact that he had summer jobs, such as assembling bikes. The interviewer then probes him further and the following conversation takes place:

I: Have you worked with motor bikes as well?
J: Yeah. I got one myself. I am usually doing something with that all the time. **Fixing** something or changing.

Such dialogue is a further indication that Jason is constantly involved in fixing things and that his focus appears to be wide in scope. One could describe Jason as a "Jack of all trades".

Criterion 2: **Perceives of such an activity as being useful**

I will now select excerpts from the interview which provide some indication that Jason viewed tinkering as being a useful activity. That is, he focused on engaging in activities where he could produce a product, or where he could acquire more information about a specific object. The following excerpt informs the reader how Jason responded to a question on how he likes to spend his free time:

> I: No, what would you really prefer to do?
> J: Well, listen to music first. To me there's, nothing better than that right, it is like, for having, yeah like you got nothing to do right unless you wants to make something right. I made stuff like that, wood like.
> I: Do you?
> J: Yeah I made couple gun racks and I sold one and I made a dart board cabinet to put a dart board in. And I made, made this box as long as this table. And I put, six beer cans in it. And Christmas lights in the cans. And you plug it in and lights shine out.
> I: Oh I see.
> J: And I put carpet around it.

Given the option of what to do in his free time Jason chose as his second choice to be involved in tasks where he would produce something. He perceived of such tasks as being useful.

Another illustration of how Jason engaged in activities which he perceived as being useful is when he informs me that he put a light in his bedroom closet at home:

I: So you needed a light in your closet, like you did put one in?
J: Yeah.
I: How long have you been doing that kind of stuff?
J: Like I couldn't really tell you, I don't know when I started that kind of stuff.
I: Been doing it for awhile?
J: Yeah.

The following two excerpts indicate that Jason was caught up in actual objects or things (Jason's word):

Excerpt # 1
I: Mmh, mmh. Why do you think you enjoy doing that sort of stuff.
J: I don't know. Ah, I don't know just like **things** I suppose.

Excerpt # 2
J: But seriously science, ah I rather do science than anything. But I don't like dissecting that much right.
I: Why?
J: I don't mind doing it but.
I: Why?
J: I don't find it as interesting as, **things**.

Jason is clearly caught up in the actual objects especially if these objects are mechanical and electrical devices. Science appears to have the most meaning for Jason if it has a utilitarian focus.

Criterion 3: **Is a means of saving or earning money**

The following two excerpts indicate that Jason viewed tinkering as a means of saving or earning money:

Excerpt # 1
I: So are you into much of this kind of stuff at home?

J: Yeah I loves stereos. This summer I was working with my father* right and. The money that I made, I went and bought parts for a stereo.

Excerpt # 2
I: Do you repair bikes and stuff like that?
J: Yeah. Bikes or . . . . This guy I knows down, Good Avenue, not Good Avenue. No down around somewhere. He fixes bikes. You know Jones, Cliff Jones.
I: No.
J: He fixes bikes for everybody in town just about right. And I use to work for him, use' to fix them, I use to put them together for Woolworths and stuff like that.

Both of these excerpts indicate that Jason has had summer or part time work where he had utilized and further developed his tinkering. Also, his ability to earn money while still in elementary school at such jobs may have encouraged him to view tinkering from a utilitarian perspective.

The following dialogue gives a strong indication that Jason is mainly interested in tinkering for utilitarian reasons:

I: Do you find that your skills you know in terms of being able to put things together and build or repair useful?
J: Yeah. I finds it alright, as long as you can make something or something else or don't have to go buy it or anything.
I: Do you see any other use for, you know being involved in stuff like that?
J: Any other use, I suppose . . I don't know. I suppose there could be other.

Jason obviously viewed tinkering as a means of earning or saving money. He appeared to have brought a strong utilitarian focus to the type of activities that he engaged in.

---

* his father owns a printing company

Classroom data.

I will now review the classroom data which helps to illustrate how that Jason's behavior during the electricity unit was utilitarian. His focus while doing the activities and participating in discussions was on getting things to work, or fixing or repairing electrical apparatus. I have selected the following classroom events as some indication of his orientation:

1. Pilot study	While Jason was studying a biology unit he noticed an electric motor stored in the lab. He then removed it and attempted to get it to work. When I later asked him about his interest in electric motors he informed me that he had made electric motors before and that he knew how to get them to work.
2. Activity 1: To make a simple electric circuit	When asked to set up simple electric circuits Jason and his lab partner are the first to get it working four different ways.
3. Activity 4: To examine series and parallel circuits	He was successful in getting circuits to work without any assistance. At one point during the activity he checked on Paul and Gary at a near by lab station. His comments were "Boys how come your batteries are so squish . . . . look at the bulb." Such comments are obviously directed toward the way to do the activity to get it to work. Later when Sean is testing the maximum limits of a simple circuit Jason becomes part of the activity.
4. Activity 5: To test materials to see if electricity can pass through them	Prior to activity Jason tested batteries with a galvanometer to see if they worked. This was not suggested by the teacher.
5. Activity 11: To observe some properties of electric charges	Jason became actively involved in this activity by testing out materials to see which ones worked. In fact he and his lab partner begin to test out some of the suggested materials even

when the teacher is introducing the activity at the beginning of the class.

6. Activity 12: To make a metal-leaf electroscope

Jason selects a beaker to make his electroscope instead of a flask. He questions the teacher if it will work and the teacher suggests that he try it. Later he also questions the teacher as to whether a glass rod will work instead of a pencil. Again when it is suggested to him to try it his response is "It is an insulator isn't it?" He does however get the electroscope to work with the substituted materials and he then tests out a variety of materials with it.

The above data suggest that Jason's focus was on getting the activity to work. He did not concentrate on making elaborate notes, or listening to the teacher's directions, but rather on getting the activity to work. Any spare time that he had he spent playing around with the materials, rather than completing the specific work outlined by the teacher.

Other classroom data.

Instead of using a tape recorder I used a ghetto blaster to tape record some of the small group discussions. On a number of occasions Jason expressed an interest in it. One specific instance was when he brought in some tapes of a rock group named AC/DC hoping that he could play them. Another instance when the tape recorder would not record, he was the first to notice that there was a problem. He then proceeded to check out the source of the problem. On yet another occasion he pointed out to me at the beginning of the class that the power was on but the tape recorder control was not on. The above instances are some indication of what appeared to be a pattern for Jason. That is, he was always on the alert for something to get his hands on, to see if he could get it to work.

Jason was prone to a lot of off-task behavior during activities. His off-task behavior was spent on mainly playing around and testing out the equipment and, in some instances, just fooling around. He was satisfied if it was all hands on for he was not interested in reading and writing anything about the activities. He did not voluntarily make notes during the activities even when it was suggested that he do so. Only occasionally did he lend some assistance to other students. His focus was on getting the device to work and if he got it to work he was quite satisfied.

Jason was very anxious to see the videotape of his interview. He came with his friends on three occasions to request to see it. When he did view the tape his discussion focused on getting things fixed. Specifically, he talked with Sean about fixing the facial sauna and the flashlight.

Sean (A Technological Tinkerer)

Interview data.

Based on the data collected I would describe Sean's behavior as technological tinkering. Criteria for so defining Sean's behavior as technological tinkering are outlined below.

Criterion 1: **Is interested in electrical and electronic hardware or the application of knowledge of electricity**

The following dialogue is illustrative of Sean's interest in electrical and electronic hardware:

I: Sean have you worked much with this kind of stuff?
S: Yeah I have worked a nice bit.
I: Where in school or out of school?
S: Mainly out of school like I use to take apart my electrical toys.
I: Mmh, mmh. Why do you do that?
S: I don't know I just like. I like fooling around with electrical things and that.
I: Mmh, mmh. Why are you particularly interested in electrical?
S: I don't know it the way it makes things run and that. Same thing with motors and engines and things like that.

The above illustration is typical of Sean's fascination with electrical and electronic hardware. This fascination is so strong that his specific interests are evident even when he discusses his favorite subject:

I: What is your favorite subject?
S: Science.
I: Why do you think science is your favorite subject?
S: I just like the things that we do and the labs and that. I just like knowing things more about science.

Here Sean is alluding to the fact that he is caught up in the scientific hardware. Sean's fascination for science is especially focused on the scientific hardware or the technology. Science provided an opportunity for Sean to be a "technological buff".

Criterion 2: **Is extremely adaptable to technological devices**

Sean's knowledge of and interest in technology is obvious from the kinds of activities that he described himself as engaging in. Sean is very involved with computers and he mentions this at a number of points during the interview.

Sean has also been involved in video taping and one instance which illustrated this was his knowledge of the video camera. When I initially set up the video equipment for interviewing I pretended not to have a good working knowledge of the equipment and went in search of a student in the target class who might help me. Sean was identified by a number of students as the person who would be able to help. Sean was then asked to help set up the equipment. Sean came to the interview room, arriving about 5-10 minutes before his next physical education class. He quickly set up camera (fine adjustments, tripod, did focusing, attached some wires, etc.). The camera had only been partially set up prior to his arrival. While setting up the equipment he made comments on the quality of the equipment being better than that which he had used in elementary school. Apparently while he was a student in elementary school he took advantage of the opportunity to use video equipment to do filming in drama classes and elsewhere.

Another instance which illustrates Sean's technical knowledge occurred when his interview was being videotaped. At one point in the interview I was concerned about the quality of the lighting for videotaping. Sean made some suggestions and moved the equipment to another location to improve the quality of the picture being recorded.

A number of illustrations of his adaptability to technological devices occurred during the completion of tasks. One such illustration of this occurred when he was working with two and three prong plugs:

S: Was I right?
I: Do you think you are right?
S: I don't know. What I would is I, like put if I'd put it on and take a battery wrap it on each side of the plug end, and then I would. I'd

> test it with the voltmeter and if the right amount of volts come out. Then I am right if not I have to look at it and go through it again.

Here Sean decides to test out the plugs that he has fixed to see if they work. Sean's decision to use a voltmeter in such a novel way is a clear illustration of his adaptability to electrical devices. Later during the interview when given a facial sauna, which he had never seen before, to fix, he quickly located the problem and proceeded to fix it.

Criterion 3: **Wants to be in control through utilizing technology**

During the interview one got the feeling that Sean sees technology as a means of being successful by being in control. One example of his viewing of technology as a means of control comes at a point during the interview where we are discussing his personal interests:

> I: Eh, your computer what do you like about the computer?
> S: It is something that I can control right. And it is something that like I can make it do a lot of things and that, like play games and things like that with it.

Later in the interview when the topic of computers came up again the following dialogue takes place:

> I: So what is an interesting thing to you about the computer?
> S: The most interesting thing, is the way you can make it do things, like make it program things like if you had enough things you could make it walk or talk or do anything.
> I: Do you like the idea of things doing things?
> S: Mmh.

The above illustrations suggest that Sean views knowledge of technology as a means of being successful. Technological knowledge does not frighten him but rather gives him a sense of success, by being in control. He appears to want to use powerful technological devices such as the computer. Sean's fascination for the computer and the idea of being in control is also evident in his future career interests:

> I: What do you think you would be interested in for a career when you finish school?
> S: Going into the air force.
> I: Aah, aah. What would you do there?
> S: Fly, jets.
> I: Flying jets.
> S: Mmh.
> I: Aah, aah.
> S: Or may be I just like, be a co-pilot.
> I: Mmh, mmh, mmh. Why do you think you would be interested in flying jets?
> S: I don't know I just like, like I when I fly in planes I really, really enjoy it.
> I: Mmh, mmh, mmh. Anything else about it?
> S: Well it has got a lot to do with computers and that and I like to work with computers when I get older.

Sean's obvious fascination for technology, and the use of technology as a means of control appears to have a very strong appeal to him. This appeal appears to be strong enough to be influencing his future career choice.

Classroom data.

The technological orientation displayed by Sean during the interview was supported by the data collected during classroom observations and from transcripts of small group activity. Sean's prime focus was on doing the activities and getting the activity to work from a technical viewpoint. He paid little attention to textbook procedures. Although he was interested in completing the task, he paid little attention to reading and writing but rather focused on technically perfecting the task.

During class activities Sean was often engaged in off-task behaviors. The majority of his off-task behavior was spent on providing technical assistance to his classmates. The next most frequent category of off-task behavior was when he was exploring various lab apparatus. For example, on one occasion he spent considerable time during one class weighing a screwdriver. I not only observed such behaviors during the electricity unit but I was also able to observe similar behavior during a biology unit on reproduction. Specifically, on one occasion, I observed him collect a microscope from the side and begin experimenting with the electrical light apparatus.

I will now take some specific activities which will describe Sean's behavior as displaying a technical orientation to the study of electricity:

Activity 1: To make a simple electric circuit	For this activity Sean choose to use a 1.5 volt lantern instead of a D-cell (1.5 volts). He was the only student to do this. At a later point in the activity he drew a diagram of a simple circuit on the board for the other students.
Activity 3: To light a regular household bulb	This activity was done in class as a large group activity. The teacher asked the class to divide into two groups and to use all their batteries to make a 25 watt household bulb light. The group that Sean was in got their bulb to light dimly first. Sean and his partner were in charge of the group. The second group had difficulty getting theirs to light so Sean and his partner helped them. Later in class discussion Sean suggested that a voltmeter be used when there was difficulty in pin-pointing such problems.
Activity 4: To examine series and parallel circuits	This was an activity which many grade nine students in this class had problems. However, Sean did not

experience any such difficulties and was able to set up both circuits without any problems. At one point he noticed a group have problems getting their bulbs to light. He then proceeded to assist the group by testing out the bulbs.
At another point during the class Sean decided to test the limits of the light bulb in the circuit by adding batteries. When questioned by the teacher on the fact that he might blow the light bulb Sean was quick to point out that he knew what the limits of the circuit were.

Activity 6: To observe the effect of passing electricity through a liquid

Again Sean's group was the first one to get this activity working. After he got it working initially he then began experimenting with the effect of KCrO2 on the system. Finally he helped others to set the activity and at one particular point he distributed KCrO2 to some of his class members.

Activity 12: To make a metal-leaf electroscope

There were some commercial electroscopes available for students as well as the students were asked to make them. When Sean saw the commercial type he inquired if it was similar to a Van de Graf generator. Sean had no problem making an electroscope. His technical expertise was obvious from a number of instances which occurred while he was making it. One specific instance was the substitution of cigarette foil in the making of electroscope leaves. Another was the discussion with his classmates the importance of using copper wire. Still another instance was his discussion of grounding out the electroscope. Again he offerred assistance to his classmates.

Activity 14: To illustrate the magnetic force produced by an electric current

Some isolated conversation recorded during this activity shows how Sean was constantly bringing in his technical knowledge of electricity. When some students got their circuit set up and it produced no magnetic effect and made a comment that it didn't work, Sean was quick to point out that their wire was too skinny.

Optional Activities

On the last day of class before the exam students were asked to finish activities and proceed to do optional activities 15 and 16 to make an electric motor and to use magnetism to produce an electric current. Sean had been absent the last day but he proceeded to do activity 15 on the electric motor. His lab partner assisted him in the activity as did Jason and Paul who became involved after Sean started. Students had been told at the end of the last class that they could work on optional activities in the last class. Sean and his partner declared upon entering the class that they were going to make an electric motor. When it was suggested that he might consider working on activities 13 and 14 because he was absent the last day he was quick to point out that he had done these activities when he was interviewed. However since he had done other activities in class that were also part of the interview without commenting on them then it was clear that he was keenly interested in making an electric motor. Sean was the class leader in this activity. He provided directions and technical expertise to the other students who attempted the activity. At one point where they had problems with the activity Sean made a number of comments on the fact that the wire should have been finer.

Other classroom data .

On one occasion a problem developed with my tape recorder, the tape would not record. Jason was the first one to note this problem. Sean, however, was the one who analyzed the problem. He pointed out that the tape heads were dirty and needed to be cleaned. He suggested that I purchase some cleaning fluid and a cleaning tape. Later, after following up his suggestion, the problem was eliminated.

When Sean and Jason viewed the videotape of the interview Jason had focused the discussion on fixing things. Sean however took the conversation in a slightly different direction by pointing out the technicalities involved in fixing the sauna and the flashlight. He clarified for Jason just what was involved, pointing out to Jason what he should have done and also commenting on his own mistakes in fixing the sauna. Sean also got caught up in a discussion with Jason about the various types of timing mechanisms on the VCR.

On one occasion I visited the target class during a religion period. They were given an assignment which required research work in the library. After they were given directions Sean became quite busy examining the contents of a computer magazine *Compute Today*. It was the first book he picked up after they were given a brief introduction to their religion assignment. I asked him if the magazine was any good. His response was "O.K. It's one of the few magazines the library has." Such incidents illustrated to me that Sean's technological focus may have extended outside his science class.

Another indication that Sean was interested in technical complexity was in how he described the unit. During my interview with him prior to the classroom observations he had referred to the unit as basic. In addition, during our classroom conversations he made frequent reference to the fact that the activities provided little opportunity for him to advance his knowledge of electricity. Sean saw the classroom activities as things he knew how to do. I recorded a number of incidents where Sean made statements which indicate that he was interested in doing an electricity unit which involved more technical complexity. Whenever Sean was asked how he was finding the unit his response was always "It is basic." After he wrote his test at the end of the unit the following conservation took place:

I: How did you find the test?
S: Basic.
I: What do you mean by basic?
S: It was simple but I am not going to get 100%.

One interpretation might be that he is referring to the fact that he thought it was an easy test. An alternate interpretation, consistent with his reference to the unit as being basic, would be it provided him with very little opportunity to advance his technological knowledge of electricity. He also made reference to the topics covered in the unit as being basic when he viewed the videotape of his interview.

Paul (A Scientific Tinkerer)

Interview data.

Paul's tinkering was classified as being scientific in type. The criteria for defining Paul's behavior as scientific tinkering will now be examined.

Criterion 1: **Is interested in the how and why, or the theory behind**

The following excerpt indicates that Paul is interested in the how and why of electric and electronic devices:

P: Yeah like microchips I like taking apart calculators and stuff like that and see what's inside of it.
I: Do you?
I: When did you first start taking things apart?
P: Probably this last year, not last school year.

P: I did after I got my computer to see what the microchip looked like. I didn't get them back together all the time though. I usually use old ones.

When Paul was first introduced to his computer it is obvious that it was important for him to understand how it worked. This interest in wanting to know how something worked did not only apply to the computer but he also took old calculators apart to find out how they worked. Later in the interview he went further than that, by noting he not only wanted to understand how something worked but he wanted to know why.

I: Is it important to you to understand how something, works?
P: Yeah but I want to understand I usually ask why it works.

Later still he reiterates this point:

P: Like eh, if I saw something being, fixed, and I didn't know what was the trouble with it first how they fixed it I would ask, why and how it was fixed.

Paul was clearly not interested in the actual fixing of something, nor was he captivated by technical complexity but rather he wanted to know the how and why of electrical and electronic devices. This appeared to be his prime focus for becoming involved.

Criterion 2: **Is more interested in understanding than doing**

Paul did not get caught up in the fixing of things, nor the technology of an electrical device. His focus rather was on the actual understanding. The following excerpt illustrates that Paul's focus during the electricity unit was on understanding:

I: Is it useful to be involved in eh, this kind of stuff?

P: Yeah it will help you, later on to understand things. You will have that much more knowledge of it.

Throughout the interview it is obvious that Paul had difficulty in completing the assigned tasks, yet he insisted he was interested in electricity. The following conversation further confirms that his interest lies more in the how and why, or the actual understanding than the actual doing of an activity:

I: Despite all that you said you are interested in electricity.
P: Yeah.
I: Why?
P: I don't know just, I am interested in the electricity like, makes things, how it goes into something and makes it work right like electric power, how the power from a battery goes, say a calculator or something, make it, makes the microchip, figure out problems and things like that.
I: Mmh, mmh. Are you more interested in that than say fixing it? Or are you more interested in fixing it.
P: I say that more than fixing it.

Paul clearly puts a large emphasis on understanding (how and why) rather than the actual hands-on experience. This emphasis, although revealed by the analysis of Paul's interview transcript, is even more evident in the analysis of his classroom behavior which I shall present in the next section.

Classroom data.

Paul's prime interest in electricity appeared to be limited to the understanding of the school science presented; not in developing a technical expertise, or in fixing or repairing electrical apparati. The following highlights from classroom activities are illustrative of his scientific focus to the study of electricity:

1. Activity 1: To make a simple electric circuit

When working on the simple circuit Paul did test out the number of ways to light a bulb. The directions had suggested that there might be only

	four ways so he was interested in finding out if there were more. It was suggested by the teacher that the students should look for more than four ways but Paul was the only target student who was concerned about this.
3. Activity 4: To examine series and parallel circuits	At the beginning of the activity Paul insists that the lab group set up and do the chart as suggested for the series and parallel circuits. While working on a series circuit with his lab partner, Gary, he insists that they concentrate on discovering the characteristics of the two types of circuits.
4. Activity 5: To test materials to see if electricity can pass through them	Paul takes a responsible leadership role for the group that forms at his lab station. He makes sure all the suggested materials are tested for electrical conductivity and he makes a careful record of all the results. Prior to setting up the circuit tester he tests the batteries to make sure they are working.
5. Activity 7: To decide what you think electricity is like	For this activity which was assigned for homework, students were asked to describe what electricity was like and their homework was discussed in class later. Paul choose an interesting analogy to describe electricity. Paul was one of the few students in the class to use analogy. Many of the students took a descriptive or textbook approach to describing electricity.
6. Activity 8: To make an electric cell	At the end of the activity during the clean-up, he asked the teacher about KCrO2. He wanted to know how it worked in the salt solution. Once Paul had initiated the question then Sean and Jason also became interested. In addition when an extension to the activity was done in class at a later date he was very interested in observing the outcome of the activity.
7. Activity 11: To observe some of the properties of electric charges and forces	After being assigned the activity on electrostatics Paul stayed on task testing a variety of materials for static electricity. He made notes of the results. At one point he was working with acetate strips and a charged

balloon and when I checked on him he made the following comment:

Paul:This one contracts. No, I mean comes to it . . . attracts. This one goes away . . . repels. It's just like magnets.

He attempted to get the researcher to comment on why the acetate strips moved toward or away from the balloon. He reveals that he is interested in understanding the scientific reason for their movement by comparing the electrostatic movement of the acetate strips to the attraction and repulsion of magnets. This is an example of the many attempts that Paul would make to better understand the scientific reason(s) for his results.

8. Activity 12: To make a metal-leaf electroscope

Again Paul is on task throughout activity. He is always at his lab station except to collect materials. He follows directions in the text to make his electroscope and then he tests it out. He is concerned about getting the leaves to attract and repel. After making the leaves repel he rubs the wire and the leaves attract and when I check on him he repeats the same procedure to show me how it works. The leaves repel when a charged balloon is brought near. He rubs the copper wire with his finger and the leaves move a little closer together. He notes that it is not working as well as it did when he tried it before. This incident is an indication that Paul is very concerned about getting an activity to work as the text suggests or he thinks it should. There were a number of factors which influenced the function of the electroscope namely it was a very dry day and the materials that he selected to make the electroscope may have influenced the results, for example he used the thinner variety of household aluminium foil to make his leaves. There were two other materials

	available to make the leaves cigarette foil and proper electroscope foil.
	On another occasion when we discussed the making of an electroscope I suggested that he might also use Christmas tree tinsel. He informed me that he had experimented with it in elementary school.
9. Optional Activity 15: To make an electric motor	Paul completed activities assigned previously and then became involved in assisting Sean with the building of an electric motor. It was important for Paul to get an overview of everything. He did not want to miss out on anything done in class.

Other classroom data.

While Paul was in class he worked very intently on the assigned activities. It was very rarely that he ever engaged in any off-task hands-on activities. He concentrated his efforts on understanding the science concepts. He did all the activities as suggested by the teacher without resorting to shortcuts, as did many of the students in the class. Although he relied on the text for directions, he was not satisfied with mere textbook type descriptions but rather wanted to understand things.

During a lecture on electrostatics, he took down all the details, paying close attention. This is typical of how he acted in all his classes. While during another lecture on series and parallel circuits and batteries he tried to get into discussing the correct model of an electric circuit. Earlier students were asked to select what they thought was the correct model to explain current flow in a simple electric circuit (Osborne & Freyberg, 1985). It was stressed by the teacher that he was interested in what they thought but not the so called right answer. So Paul took an advantage of an opportunity to find out the right answer. In fact he tried to trick the teacher into revealing the answer. He raised the following question: "Is there the same amount of electricity coming out at the negative end of the circuit as going in the positive end?" The teacher recognized what he was up to and redirected the question back to Paul. Paul then said he had chosen model D and he wanted to know if it was right. Later at the end of the class Paul still tried to pressure his teacher into telling him the right answer. The teacher's comment after class was "I won't be surprised if he goes home and asks his father about this." It is not that Paul wanted to be given the right answer and that alone would satisfy him but what he really wanted was to understand the how and why of electric circuits. This is just one illustration of how he went to great lengths to try to understand something. This interpretation is consistent with Paul's former teachers' descriptions of him as "more of a thinker than a tinkerer".

When students were assigned activity nine for homework, the investigation of electric circuits at home, Paul did the assignment as suggested. Sean and Jason however did not do it because they said they already knew. Others, such as Sandra did not do it because they did not know how. It was important to Paul to understand the electrical concepts that were presented in class. He went to great lengths both in and outside school to understand the concepts.

Sandra (A Pragmatic Tinkerer)

Interview data.

The type of tinkering displayed by Sandra can be described as pragmatic. I will now discuss the criteria that was used to define pragmatic tinkering based on Sandra's behavior.

Criterion 1: **Performance for grades**

The interview data suggest that Sandra's focus was on performance for grades, or completing the activities exactly as outlined in the textbook, or doing as the teacher instructed. One such indication is that while Sandra was working on Task # 1 she raised the following question:

S: Are you supposed to get it like the diagram?

The above question is typical of the type of questions she asked frequently throughout the interview. Her questions focused on the textbook requirements for successfully completing the task.

The following excerpts are further illustrations that Sandra's focus during the study of electricity was primarily to satisfy school grade requirements.

Task # 2

S: What do you mean have someone teach them how to do it or?
I: Well what would you think would be the best thing?
S: Get someone to teach them or show them.
I: You mean out of school, or in school or what?
S: I don't know someone who knows.

Task # 3

I: Do you usually do fairly well in science?
S: Well, in grade, last year, in grade, what do you mean?
I: Yes. How do you usually do in science?
S: I can do good in any subject if I study. But one with any maths in it I really finds it hard to study cause like, I never used to really think that it was important and that, the teachers was rattling on with it so. And so I start studying it and the one we did on the frog I got nine out of ten on that, test. And the next ones I had a hundred, and eighty and I finds it easy to study if it is up to you.

The satisfying of school requirements appeared to be Sandra's prime focus in completing the activities. This focus was quite logical given she saw no other reason for tinkering other than to do well on tests.

Criteria 2: **Tinkers when required**

The following excerpt is an indication of Sandra's interest in tinkering:

Task # 1
I: Have you done much with screwdrivers and stuff like that?
S: Mmh, mmh. I use them around the house.
I: Do you?
S: Mmh, mmh.
I: For what like?
S: Curling iron (laughs)
I: Ah, for your curling iron. What, does it come apart?
S: It comes apart.
I: Do you use it for anything else?
S: Well when we built our house I put all the plates on the plug-ins.

Such an illustration indicates that Sandra's interest does not lie in tinkering unless it is required. Other than putting plates on electrical plug-ins, she only got involved in tinkering when her curling iron broke. Her curling iron appeared to be so important to her that she became involved in a task which she normally would have had little interest.

Sandra would undertake tasks outside school if she saw it as having a school related function, such as a science fair project. She had been quite successful with science fair projects. She was selected on at least one occasion to represent her school at a regional science fair. The following conversation focuses on any experiences that Sandra might have had other than science fair projects:

Task #3
I: Do you build anything?
S: Like what?
I: Anything.
S: No not really.

I: So the thing for your science fair project was about the only thing you ever.
S: Built you mean like?
I: Made.
S: I guess, besides that meccano set I used to make cars.

The meccano set she refers to was not part of her everyday experiences but was rather a part of her childhood experiences. It was in fact her brother's toy which she was interested in when she was a small child. Sandra engaged in science fair projects which sometimes called for a little more tinkering than she normally engaged in. It can be interpreted that she saw such activities as a way of being perceived as performing well in science. There was, after all, rewards for doing well at the school science fair. Science fairs were also viewed as part of the academic game.

Although Sandra did attempt tasks outside of school, such as fixing her curling iron, she did not extend this need to repairing other things, as indicated by the following excerpts:

I: Are you into repairing bikes?
S: Like the brakes. Well, not really like brakes on a bike this summer did not work but I did not bother to fix it because it needed a new part. I don't understand how that works.

I: Have you worked with that kind of stuff before?
S: Mmh.
I: Mmh. Where?
S: Home.
I: So you have done, plugs and wires before, have you?
S: Not a lot. Dad always does it and Neil, my curling iron has always got a loose connection.

I: Did you ever repair any appliances besides your curling iron?
S: Fixed it like.
I: Yes.
S: I never fixed it just tighten up the.
I: Yes.
S: I don't know.
S: My hair dryer was broken but dad took it apart.

Such illustrations suggest Sandra's limited tinkering had a very narrow focus in that she did it only when it was absolutely required.

During the interview, when Sandra was engaged in the tasks she did a number of things which led the researcher to suspect that her prime focus was on performance for grades. She constantly asked for directions, was intent on doing the tasks, and attempted to read the interviewer's facial expressions and gestures. Such actions appeared to be part of her unconscious level repertoire of strategies for academic success.

Classroom data.

Sandra brought a pragmatic orientation to the study of electricity. She appeared to have no great desire to really understand the science concepts presented but rather her focus was on discovering what the teacher wanted the students to know for the test. The approach that she took to the study of electricity was one of totally relying on the teacher and the textbook for all the information she needed. She appeared to express, through her lack of involvement in hands-on activities, only a desire to know what the outcome of the activities were. The following selected activities provide some indication of her orientation:

1. Activity 1: To make a simple electric circuit	Sandra followed the directions in the text for setting up a simple circuit. When the researcher asked her what a circuit was she had no concept of a circuit. She defined a circuit as it was defined in the text but she had no understanding of what the definition really meant. She had no interest in discovering what a circuit was but rather she wanted to be told what it was. Later during the activity I observed Paul demonstrating the various ways to place the bulb in a simple circuit to Sandra and her

	partner. After examining her notebook near the end of the activity I noted that she drew four diagrams showing how to arrange the bulb to complete the circuit.
2. Activity 2: To invent some other electric circuits	She did not seek out materials or help when doing this activity but rather relied on being helped by the teacher. When I rechecked on her concept of a circuit she still gave me a textbook response and when I asked her to explain what she meant she was not able.
3. Activity 4: To examine the series and parallel circuits	Sandra relied on the textbook for directions and the result was she not able to set up her models of series and parallel circuits but later with the teacher's assistance she got it to work.
4. Activity 8: To make an electric cell	She followed the text and relied on getting assistance, by being noticed by the teacher. Eventually she got the electrical cell to work. She had difficulty substituting a galvanometer for a bulb which was suggested by the teacher at the beginning of the activity. Some of her difficulties were due to the fact that the text did not provide her with directions for such a substitution.
5. Activity 5: To test materials to see if electricity can pass through them	After some difficulty with getting the circuit tester initially set up she tested various materials for the conductivity of electricity. Again she relied on the text and the teacher. She did not however take initiative. Unless noticed by the teacher she appeared to make modest efforts.
6. Activity 12: To make a metal-leaf electroscope	Sandra followed the text in detail when making an electroscope and did not adapt materials to fit equipment available. Even when materials did not fit she was still preoccupied with following the textbook directions.
7. Activity 13: To illustrate the magnetic force produced by an electric current	Sandra struggled with the text directions for getting this activity to work. Even though she had attempted this activity during the interview prior to doing the unit she was still

	unable to carry out the activity successfully without assistance.
8. Activity 16: To use magnetism to produce an electric current	Although she had difficulty in getting this to work by following the textbook directions she did not trouble-shoot. She did the minimum experimenting.

<u>Other classroom data</u>.

At the beginning of the unit students were asked to bring some D-cell batteries to use in the investigation of electric circuits. Sandra and her lab partner were the only target students who failed to comply. They relied instead on the materials that were available in the school. Generally, Sandra avoided getting her hands on electrical materials and did only the minimum. She appeared more interested in what the text and the teacher said rather than discovering for herself. She did however utilize the teacher's attention to the maximum. That is, Sandra and her partner received the maximum help and advice from the teacher during the activities. Her strategy for receiving that attention appeared to be one of applying "learned helplessness". It seems that her focus was on getting the surface description which was all that she perceived to be required for success in school science.

When activity 3 was demonstrated in class Sandra did not become involved in the activity but rather observed from the distance. She wanted to know the outcome of the activity but did not get involved in the hands-on part.

Sandra displayed an interesting reaction during a class lecture when the teacher suggested that they experiment with removing the fuses from the fuse box to discover the various circuits. She smiled at her lab partner as if to say, "You don't expect me to do that do you?"

Sandra and her lab partner viewed the videotape of their interview that was conducted prior to the electricity unit. Sandra noted that she had asked her father what the function of the third wire was in the three prong wiring. She said it was used for a ground. Then her lab partner asked her what the other two wires were for. Her response was "It is like a circuit, like we are learning in class."

Generally the classroom data and interview data suggest that Sandra was a pragmatic tinkerer. However, when comparing the classroom data to her interview data, there is one striking difference. In the interview context she was intent on actually carrying out the task whereas, in the classroom she relied on the teacher and others for assistance. One possible explanation for this is that she might have perceived the interview as a testing situation and wanted to perform well.

<u>Purposes for Tinkering of Other Target Subjects</u>

An analysis of both interview and classroom data was also completed for the other target students Leann and Haritha. No new purposes for tinkering were constructed for these two subjects. The analysis categorized Leann's behavior as pragmatic tinkering whereas Haritha's behavior was categorized as exhibiting both scientific and pragmatic tinkering. Based on the data analysis of other target subjects no new purposes for tinkering were therefore proposed. The list proposed however is not meant to be exhaustive and could obviously be expanded and/or revised in future studies.

Proficiency of Tinkering

The Defining of a Level of Proficiency in Tinkering

It occurred to me during the data collection phase that there must be a depth to tinkering. Tinkering appears to be an activity which we all engage in with varying degrees of success. The degrees of success I shall refer to as proficiency of tinkering. Initially during the selection of the target subjects I conjectured about two depths of tinkering, tinkerers or non-tinkerers. I described Sean and Jason as tinkerers and Paul, Haritha, Leann and Sandra as non-tinkerers. As I moved further into collecting classroom data this categorization bothered me. Two of my subjects, Paul and Haritha started to exhibit patterns that would place them into the category of tinkerer. Yet their proficiency at tinkering was quite different from Jason and Sean. A further analysis of the data allowed me to develop a tinkering continuum of master, professional, amateur, and novice. I found that this continuum was appropriate in describing the proficiency of tinkering for the target subjects. Table 4-1 displays the proficiency of tinkering that I was able to construct from the data.

Overview of Proficiency of Tinkering for Target Students

1. Sean (Master Tinkerer)

- He was sought out by the other students in the class for technical advice. The professionals especially consulted with him frequently.
- He did not need any technical advice and was often superior to the non-

physical science trained teacher.

- He was generally the first to get things working.
- He rarely consulted the textbook but concentrated on doing the activities.
- He did not need to follow directions and often improvised.
- He had excellent visual perception.
- He was familiar with a wide variety of electrical apparatus.
- He was skillful in his utilization to tools to complete electrical tasks.
- He did not need teacher assistance to successfully complete the assigned tasks.
- He had a very high level of interest in electricity.

2. Jason (Professional Tinkerer)

- He was technically competent in completing the tasks but occasionally, needed some help.
- He was sometimes helpful to the amateur and novice tinkerers.
- He consulted with the text only when in trouble.
- He had good visual perception.
- He was very adaptable to new apparatus.
- He followed directions and on some occasions did improvise.
- He showed some creativity with new apparatus.
- He was skillful in his utilization of tools to complete the tasks.
- He had a high level of interest in electricity.
- He rarely consulted with the teacher.

3. Paul and Haritha (Amateur Tinkerers)

- They had some problems technically but were generally able to complete the tasks with some assistance.
- They were interested in hands-on type learning.
- They saw the textbook as very useful but wanted to do the activity to be convinced.
- Their visual perception was weak.
- They had some difficulties with apparatus they had not used before.
- They showed limited skill in the utilization of tools.

- They followed directions and did not improvise generally.
- They lacked the experience to be creative with electrical apparatus.
- They were interested in electricity.
- They consulted with the teacher and other students but still wanted to do it on their own.

4. Leann and Sandra (Novice Tinkerers)

- They were technically incompetent to carry out assigned tasks without assistance.
- Their prime interest in completing the tasks was to find out the objective of the activity.

Table 4-1. The Proficiency of Tinkering

Proficiency of Tinkering	Description of Defining Characteristics
Master	goes beyond the given, extends, improvises, test out solutions
	acts as consultant to peers and is regarded as an expert by his/her peers
	very skillful at doing assigned tasks, does not follow directions
Professional	pursues an activity in an intense, calculating manner and is generally successful with tasks
	works on tasks skillfully
	generally does not need to follow directions
Amateur	attempts tasks on own but often needs assistance to complete
	works on activity more or less unskillfully
	follows directions given
Novice	needs constant assistance to complete tasks
	relies on text and teacher for guidance
	has difficulty in following directions

- They were generally not very interested in hands-on type learning with electrical objects.
- They were more interested in textbook type learning.
- They had difficulty following diagrams in doing activities.
- They were often intimidated by new apparatus.
- They showed limited skill in the utilization of tools.
- They followed directions without any consideration of improvising.
- They were not creative with electrical apparatus.
- Their interest in electricity was not high.
- They consulted often with the teacher, text or other students to explain how to do tasks.
- They preferred being told what happened as opposed to working it out on their own.

Based on the interview and classroom data the target students brought a variety of typologies to the study of electricity. On the basis of this data I have described four purposes for tinkering (scientific, technological, utilitarian, and pragmatic) that students displayed when asked to engage in hands-on electrical activities both in the interview and classroom settings. In addition to different purposes for tinkering, I observed differences in proficiency of tinkering. The proficiency of tinkering can be best illustrated on the continuum novice, amateur, professional, and master. The construction of such a continuum suggests that tinkering may be viewed as developmental.

The Tinkering Process

A Description

After transcribing the interview and classroom data a pattern which described tinkering as a process was constructed. This process was defined as consisting of four phases:

1. searching for the problem,
2. framing of the problem,
3. solving the problem, and
4. evaluating the solution.

Once the phases outlined above were developed as an analytical framework I described tinkering as a problem solving process. This then led me to view tinkering, within the context of this study, as a process of solving problems with physical objects such as electrical devices.

An examination of how the target students went through this process provides further support for the proficiency of tinkering proposed, and the subsequent classification of the target students as master, professional, amateur and novice. This classification was based mainly on classroom observation. However, by identifying the phases of tinkering the interview data could then be used to enrich the basis for the original classification system and provide further support for the proficiency of tinkering. In the next section, by examining representative tasks from the interview and classroom data, I will present a brief overview of the phases in the tinkering process that were exhibited by the target students.

Interview Data

Table 4-3 summarizes patterns in the tinkering process for the master, professional, amateur and novice as revealed by the interview data. Before proceeding however I would like to give the reader some idea of how this classification was developed. First Table 4-2 displays two representative tasks for one of the target students, Sean, as an illustration of how I identified phases in the tinkering process. This is followed by Table 4-3 which highlights the patterns displayed by four of the target students in the interview setting. Sean (master tinkerer) consistently not only went through the process of **searching** (identifying the problem), **framing** (deciding on how to solve the problem) and **solving** the problem, but he also became involved in **testing** out his solutions. Jason (professional tinkerer) was able to search, frame and solve most problems but he did not test out the solutions as Sean did. Paul (amateur tinkerer) was also able to search and frame his problems but he did not have the same level of success as did Jason. Sandra (novice tinkerer) did not get beyond the phases of searching and framing for most of her tasks. Haritha (amateur tinkerer) and Leann (novice tinkerer) also showed similar patterns to Paul and Sandra although there were individual variations from the above patterns. The pattern outlined above not only supports the proposed phases but also provides further data to describe the proficiency of tinkering proposed earlier for the target students.

Given the above table shows distinctive patterns for the master, professional, amateur and novice tinkerers, there is at least one important point to consider. Specifically an important consideration is the length of time it took the subjects to complete the various steps in the problem solving process. Sean, for example completed the searching and framing of the

TABLE 4-2 Sean's Phases of Tinkering - Two Representative Tasks

Stage	Description
	In-school Type Task - Task #3 Electromagnetism
Searching & Framing	Reads text briefly just prior to activity to clarify what he has to do.
Solving	**Set-up # 1** He attaches wire to two terminals of galvanometer then selects two bar magnets and rubs wire between magnets. An adjustment of the galvanometer needle is then made followed by a rubbing of the wire with the two bar magnets. The two bar magnets are exchanged for one horseshoe magnet. The wire is then moved back and forth inside the horseshoe magnet. He attempts to adjust the needle again on the galvanometer, exchanges galvanometer for voltmeter with variable adjustment, tries out a variety of terminal arrangements, selects another piece of wire and then tests new wire which shows a reading. Finally he disconnects the voltmeter. **Set-up #2** He selects voltmeter and wire and coils wire around battery. Next, he moves bar magnet back and forth in coil getting a reading on the voltmeter and then he disconnects apparatus.
Testing solution	He did not test the solution in this activity. However set-up # 2 described above may be interpreted as a test.
	Out-of-school Type Task - Task # 4 Two and Three Prong Plugs
Searching & Framing	Interviewer passes bag of plugs and wires to Sean. He examines contents and discovers that a two prong plug and a three prong plug need to be attached.
Solving	**Plug # 1 - three prong plug** He selects the three prong wire, separates wires and begins to attach to screws in the bottom of the three prong plug, tapes bare wires with electrical tape. He discovers top of three prong plug which he then puts over the bottom of the plug. Clamp is then put in place and tightened. **Plug # 2 - two prong plug** He examines bottom part of two prong plug and attempts to insert in the center two prong wire (with an attachment) which have been previously stripped. He then attempts to adjust wires which he later removes and attempts to insert through the side hole in top of the plug. More coating is

TABLE 4-2 Cont'd

	then removed from the end of the wire which is later inserted through the top of the plug. He then inserts wire in the bottom part of the plug and puts the top on the plug.
Testing Solution	He makes up a circuit tester to test the plugs he has assembled. His conclusion after testing is that the three prong plug is assembled properly but his two prong plug is not.

problem almost instantaneously with the school-type tasks (1-3) but he took a little more time with the non-school-type tasks (4-6). He generally spent a longer time on the non-school type than in solving the school type tasks. In Sean's case there was relatively no distinction between the searching and framing phases of the problem.

Jason took just slightly more time than Sean in framing the problem. There was a further contrast between Jason and Sean, Jason generally took a longer time to solve the problems (flashlight) and in one instance was not successful (sauna). Again, there was relatively no distinction between the searching and framing phases of the problem for Jason.

Paul, in contrast to Sean and Jason, spent more time on framing the problem. For most of the tasks he was still framing the problem while he was attempting to solve it. He spent considerable time on reframing the problem while working through the tasks. He took more time on most tasks than did Sean or Jason. He attempted all of the tasks but was not successful in completing most of them.

TABLE 4-3 Overview of Phases of Tinkering for Representative Target Subjects Based on Interview Data

TASK DESCRIPTION	PHASES 1	2	3	4
Target Subject: Sean (Master Tinkerer)				
1 Electric Circuit	x	x	x(b)	x
2 Magnetic Force	x	x	x(b)	x
3 Electric Current	x	x	x(b)	x
4 Plugs	x	x	x(b)	x
5 Facial Sauna	x	x	x(b)	x
6 Flashlight	x	x	x(b)	x
Target Subject: Jason (Professional Tinkerer)	1	2	3	4
1 Electric Circuit	x	x	x(b)	0
2 Magnetic Force	x	x(b)	0	0
3 Electric Current	x	x	x(b)	0
4 Plugs	x	x	x(b)	0
5 Facial Sauna	x	x	x(a)	0
6 Flashlight	x	x	x(b)	0
Target Subject: Paul (Amateur Tinkerer)	1	2	3	4
1 Electric Circuit	x	x	x(b)	0
2 Magnetic Force	x	x	x(a)	0
3 Electric Current				
set-up #1	x	x	x(a)	0
set-up #2	x	x	x(a)	0
4 Plugs #1	x	x	0	0
Plugs #2	x	x	0	0
5 Facial Sauna	x	x	x(a)	0
6 Flashlight	x	x	x(b)	0
Target Subject: Sandra (Novice Tinkerer)	1	2	3	4
1 Electric Circuit	x	x	x(b)	0
2 Magnetic Force	x	x	0	0
3 Electric Current				
- set-up #1	x	x	0	0
- set-up #2	x	x	0	0
4 Plugs #1	x	x	0	0
Plugs #2	x	x	0	0
5 Facial Sauna	x	x	x(a)	0
6 Flashlight	x	x	x(a)	0

legend
x - stage identified
a- attempted to solve
b - successfully completed the task
0- did not reach this stage

Sandra spent most of her time on trying to search and frame the problem. That is, while she was solving the problem she was frequently struggling with what the problem was. When she did identify the problem, a large portion of her time was spent in reframing the problem which she was often not successful at solving except for task #1. Task #1 was on the electric circuit which was similar to an activity that these students had done in elementary school.

In conclusion, an analysis of the length of time that the target subjects spent at various stages as highlighted in Table 4-6 shows that Sean (master tinkerer) and Jason (professional tinkerer) spent the greatest proportion of their time on actually completing the task. Sandra and Leann (novice tinkerers), on the other hand, spent most of their time searching and framing the problem. Paul and Haritha (amateur tinkerers) were somewhat intermediate in that their time appears to be divided between framing and solving the problem. While Paul and Haritha did often spend some time on searching for the problem, they quickly moved into framing the problem.

Classroom Data

There was consistency between the students' behavior in the interview setting and their behavior during classroom instruction. Table 4-4 presents a short synopsis of the phases of tinkering displayed by subjects categorized as master, professional, amateur, and novice. To do this I will focus on classroom data for three selected activities to provide an overview for representative target subjects. This will be followed by a short review for each of the subjects.

Sean (master tinkerer) exhibited a similar pattern during the classroom activities as he did during the interview. His pattern was to successfully complete the task and test out his solution to the problem. One instance which illustrates this was when Sean was asked to make an electrochemical cell (activity #8). Sean made his electrochemical cell as suggested and then began to experiment with the effect of $KCrO_2$ on the system. After completing the activity he proceeded to help other students in the class. That is, he took on the lab assistant role which could be considered as an extension of his own activity, or the testing out of patterns he had already noted. So in the classroom setting, he would often check out and further confirm his findings through helping others. There are numerous incidents throughout my observations where he played lab assistant but it was generally always after he had completed the hands-on component of the assigned activity. He usually did successfully complete the activity long before many of the other students in the class.

Not only did Sean assume the role of lab assistant but other students in the class expected him to play this role. They would often call upon him for technical assistance. His lab partner, Gary, who I would describe as a professional tinkerer did this on numerous occasions. Another illustration was when students just came to watch Sean work.

Jason (professional tinkerer), on the other hand, exhibited a slightly different pattern. Throughout my observations of his classroom behavior he was generally successful in carrying out all the tasks assigned by the teacher. While he was quite successful in completing the tasks, he did not become the class expert as did Sean. Jason did however on a few occasions lend some assistance to other students if they happened to be part of his group.

TABLE 4-4 Phases of Tinkering for Representative Target Subjects Based on Selected Classroom Data

Act. #	Description	Phases Identified
Target Subject: Sandra (Novice Tinkerer)		
1	Sandra had difficulty constructing an electric circuit. She did not have the concept of how an electric circuit works. She asked for help.	phases 1 & 2
8	She had serious difficulties in getting the chemical cell to work. Even with teacher assistance she did not understand how it worked. She did not seek assistance but relied on being noticed by the teacher.	phases 1 & 2
12	She had difficulty getting electroscope to work. She needed very close attention from the teacher to complete task. Again she relied on being noticed rather than seek assistance.	phases 1 & 2
Target Subject: Paul (Amateur Tinkerer)		
1	Carried out task successfully Demonstrated task to Sandra and Natasha.	phases 1 & 2 & 3(b)
8	Paul successfully completed activity.	phases 1 & 2 & 3(b)
12	He was successful with activity.	phases 1 & 2 & 3(b)
Target Subject: Jason (Professional Tinkerer)		
1	Successfully completed task.	phases 1 & 2 & 3
8	Successfully completed task.	phases 1 & 2 & 3
12	Successfully completed task	phases 1 & 2 & 3

TABLE 4-4 Cont'd

Target Subject: Sean (Master Tinkerer)

1	He successfully completed task using alternate materials. He selected a 1.5 volt lantern instead of a 1.5 volt D cell.	phases 1 & 2 & 3 & 4
8	He successfully completed task. He then experimented with the effect of KCrO2 on the chemical system. He played the lab assistant role.	phases 1 & 2 &3 & 4
12	He successfully completed task. He suggested that the class use alternate materials to construct the electroscope and the teacher followed his recommendation.	phases 1 & 2 & 3 & 4

legend:
phase 1 - searching
phase 2 - framing
phase 3(a) - attempting to solve   phase 3(b) - successfully solving
phase 4 - testing solution

Generally he concentrated on working with his lab partner and best friend, Frankie.

Paul (amateur tinkerer) did not have the technical expertise to complete most of the assigned tasks on his own. He often utilized the assistance of the teacher, Sean, and sometimes Jason. They worked at lab stations near him. He was however always on task and was able to complete most tasks with some assistance from his friends, Sean and Jason.

Sandra (novice tinkerer) was not successful on her own with most of the tasks assigned. She spent considerable time on the searching and framing of the problem. She could not rely on her lab partner, Natasha who was also very technically weak. She constantly required assistance from the teacher for even the simplest things and even with assistance she generally did not complete the tasks as assigned. Both Sandra and Natasha relied strongly on the text and the teacher.

The two other target subjects, Haritha (amateur tinkerer) and Leann (novice tinkerer) exhibited similar pattern, as Paul (amateur tinkerer) and Sandra (novice tinkerer). The overall conclusion is that the pattern displayed by each of the target students in the classroom further confirms the pattern found in the interview data. Both data patterns for phases of tinkering lend support for the proficiency of tinkering as noted earlier. This support comes from the fact that the greater a subject's proficiency at tinkering the more advanced are the subject's phases of tinkering.

The Knowledge Bases of Tinkering

Overview

Based upon my analysis of the data, tinkering draws upon two knowledge bases which I have described as actional and verbal. Verbal knowledge describes any statements made by the target subjects during the interview or in the classroom which would indicate something about their knowledge of electricity. Actional knowledge, on the other hand, would be displayed by the actions taken by target subjects in completing the tasks assigned during the interview, or in the classroom. The categorization of tinkering as having two knowledge bases was useful in that it provided a format to describe the characteristics of tinkering displayed by the target subjects. Such a description was also helpful for it allowed for further examination of these two knowledge bases. In this section I will examine the level of verbal and actional knowledge displayed by the target subjects during their study of electricity.

Verbal Knowledge

Levels of Verbal Knowledge Identified

The level of verbal knowledge displayed by the target subjects when tinkering was quite varied. I will now review the interview data for the level of verbal knowledge displayed by the target students. After analyzing the interview transcripts for statements made by the subjects during the interview, relating to knowledge of the assigned tasks, I noted that their verbal knowledge appeared to follow a sequence. The first level of this sequence included statements which showed a lack of knowledge of how to do the task. This was verbalized through the questioning of the description of the activity, or asking directions which I shall refer to as the **Questioning Level**. The next level was the making of statements about some electrical aspect involved in the task which I shall refer to as the **Stating Level**. The third level was identified by statements which indicated the creation of new knowledge by the subject which I shall refer to as the **Invention Level**. I have selected Sandra (novice tinkerer) and Sean (master tinkerer) to illustrate these levels.

Sandra (Novice Tinkerer).

Sandra was classified as a novice tinkerer. An examination of her interview data revealed an interesting pattern. She was constantly saying throughout the interview "I don't know" or "I don't understand". She was also constantly asking for directions, both verbally and non-verbally or seeking directions from her textbook. Her non-verbal searching for directions took the form of her frequently looking at the interviewer. She appeared to focus on any non-verbal clues, such as facial expressions or body gestures. That is, throughout the interview she was predominantly at what I have labelled as the questioning level. She did however at times make some statements, or complete some actions that showed she had some limited knowledge of electricity. The following excerpts from the interview task #1 are illustrative of Sandra's dominant level of verbal knowledge, the questioning level:

TRANSCRIPT	VERBAL LEVEL
Task # 1 - Electric Circuit	
Excerpt 1	
I: Do you do stuff like this?	
S: **I don't know** how you does it.	**Level 1: Questioning**
Excerpt 2	
S: **What do I do** make a circuit?	
I: Yes, just call it a circuit tester, o.k. I was wondering if you could collect some materials and get started.	
S: **Is it all there?**	
I: Yes.	
S: **Don't know** how what a three volt battery is.	
I: O.K. what do you think? (pause) You can look at them and see what is on them if you want.	
S: **That one?**	
I: Well check that one and see what is on it.	
S: That one is one and a half.	
I: Yes.	
S: That one is six.	
I: Yes, so what could you do?	
S: **Use two of these.**	**Level 1: Questioning**
Excerpt 3	
S: **This is a bulb holder isn't it?**	
I: Yes. Mmh, mmh. Have you seen these before?	
S: Them (shakes her head for no).	
I: Yeah.	
S: No.	**Level 1: Questioning**

Excerpt 4
S: **Is that all one wire going right there?**
I: Yeah it looks basically like that. **Level 1: Questioning**
Excerpt 5
S: It says six volts that **is what you connects it to.**
I: Yes, mmh. **Level 1: Questioning**
Excerpt 6
S: **Just one of them?**
I: What do you think?
S: **Two of them?** **Level 1: Questioning**
Excerpt 7
S: **There is a, switch?**
I: Yes there is one there. **Level 1: Questioning**

Although Sandra's dominant verbal mode was that of asking questions or seeking directions, she did sometimes make statements which showed she had some limited knowledge of electricity. Let's examine some of these statements from a conversation which took place while she was working on assembling the plugs and wires, Task #4:

Task #4	Transcript	Verbal Level

Excerpt 1
I: Why are you twisting the wire?
S: **So that they can join.**
I: Mmh, mmh have you seen anyone do it like that before?
S: My dad. **Level 2: Stating**
Excerpt 2
I: So how do you know which one to hook up to which there?
S: **Well there is (pause) two I am using one short one.**
I: Ah, ah.
S: **On the middle and the sides.**
Excerpt 3
I: Any idea what these wires do?
S: **Make a circuit.** **Level 2: Stating**
Excerpt 4
I: You put it in the center.
S: **Yeah I have two of them in there.**
I: Why?
S: **Only place to put them.** **Level 2: Stating**
Excerpt 5
(after examining two prong wire with attachment a number of times)
S: **So this one wouldn't work.**
I: Probably it would but it depends on how you get it set up,

right.
S: **Can't see how it would work.** **Level 2: Stating**

Excerpt 6

I: Why do you think some plugs have three on them and some have two?
S: **You get more current or electricity.**
I: Mmh.
S: **Connects there.**
I: Is there any other reason?
(struggles with trying to get rubber top on three prong plug together)
S: **If you have it all on two wires it would blow up.**
Level 2: Stating

Another illustration that Sandra sometimes functions at the stating level occurred at the end of the session when she was trying to fix the facial sauna. The following excerpt is typical of her statements:

I: Is there anything that you would recommend before I try it?
S: **Check it.**
I: How?
S: (laughs) I don't know.
I: What would you do?
S: Before plugging it in? (looks at sauna)
I: Yeah.
S: I don't know.
I: As it is there now would you plug it in?
S: No.
S: **Well, I could get a shock if it is not done right.**
I: Mmh.
S: **You'd check it.**

Such transcripts seem to indicate that Sandra has some limited knowledge of electricity. In addition, while Sandra was working on trying to get the broken flashlight to light, the following conversation took place:

I: You know how a flashlight works?
S: **The batteries** (laughs).
I: Yes but how?
S: Is that it? (looks inside the flashlight) **It is just all connected.**
(picks up top part of flashlight)
I: All connected in what sort of way?
(Sandra looks inside the flashlight)
S: **Well the metal thing there goes down and touches the wire**

and touches the battery and touches that so when you flicks it and turns it on it works (examines top of flashlight, examines metal parts of broken switch)
I: So what does the switch do?
S: **Makes the current and you turn it on it touches the, you know makes it all connected so works when it is off it is not touching I suppose.**

Although Sandra sometimes functioned at the stating level, as indicated by the above illustrations, her dominant mode of verbal knowledge was at the questioning level. In fact, even when she made comments which could be classified as stating level she was also asking questions to help her in the searching and framing of the problem.

Sean (Master Tinkerer).

Throughout the interview Sean rarely functioned at the level of the question phase but rather operated predominantly at the level of stating of facts. However he did ask questions in a few instances. When he is presented with the first task he asked:

S: Does this battery work? (attaches wire to terminal)
I: Eh, it probably does. . . . .

This is an excellent question in that it shows he has experiences with working with batteries. Based on my observations, it was those subjects with prior electrical experiences, who asked questions about the quality of the materials or checked out the suitability of materials before beginning a task.

Later, Sean substituted a horseshoe magnet for a bar magnet in the activity. He did this when he was asked to produce evidence of an electrical current by magnetic induction. The following conversation then took place:

> S: You should be able to just rub it up and down like this shouldn't we?
> I: Mmh, mmh.
> S: I get it going but I don't see any. Anything coming out.

From there he proceeded to check out the possible source of the problem, by getting a voltmeter with variable settings and experimenting with the settings. His questioning in this case led to an exploration of possible solutions to the problem.

Another illustration of Sean's questioning occurred after he finished assembling the plug and wire. He raised the following question:

> S: Was I right?
> I: Oh yes that is fine.
> (starts to put top on plug)
> I: Do you think you are right?
> S: I don't know . . . .

This was a rare instance during the interview when he admitted that he did not know if he had assembled the plug properly. However, what is noteworthy about Sean's approach was that he immediately decided to check out the plug to see if it did work.

Another example of the context in which Sean asks a question is when he is presented with the facial sauna and asked to fix it. The following dialogue takes place:

> I: What I would like to do with you now, is I have got an appliance here that I would like for you to take a look at and see what you think of it. It is not working definitely, not

working.
S: What is it? (looks at appliance)
I: Well won't you take a look at it first and see.
(examines appliance, lifts up face piece, turns dial, opens door to water holder)
S: Ah, something you stick your face in.
I: Yes.
S: And it gives off heat or mist or something like that right?
I: Yes, right.
S: O.K.
I: You have got it all figured out there, what it is at least, now see if you can get it working.
S: Get it working? (puts down sauna and turns to frontal view)
I: Yes.
(Sean opens door to water holder)
S: So it is definitely not working right? (lifts up and examines)

The questioning that goes on above is to get a clear description of the task, as opposed to getting hints from the interviewer on how to do the task.

An instance in which Sean asks another question is with regards to finding out specific information about the sauna. The question is raised in the following context:

I: Mmh. Do you think that, that is safe enough?
S: I don't know see cause it might not be able to hold power from. Is there a circuit in this? (examines the inside of the sauna)
I: That is what I am thinking.
S: Yeah, cause it might get burnt out. Unless you, what, ah.

He then goes on to solve the possible problem of the wire burning out. His question is clearly for information that will allow him to perfect the task.

We will now examine Sean's dominant level of verbal knowledge during the interview which was the stating of facts, or the stating level. The following selected excerpts from task # 1 illustrates Sean's dominant level of verbal knowledge:

Transcript	Verbal Level

Task # 1 - Electric Circuit

Excerpt 1

I: . . . . I noticed that you are using lots of voltage on that.
S: Six volts. (looks at battery)
I: Do you need that for this set up, you think?
S: Depends on how much this is (examines sockets).
This here is only. This here takes one hundred and twenty five volts.
I: Are you sure?
S: It says a hundred and twenty five on it. (holds up bulb holder with reading on it)
I: On where?
S: Right here (points to bulb holder), or is that just the tester not the bulb.
I: Oh, yeah. No it does say that there but what about.
S: I can use any battery you want it's just.
I: No, it is up to you what do you think?
S: Ah, this one here might be a little bit too much I'd say. (removes six volt battery) **Level 2: Stating**

Excerpt 2

S: It should go a little bit brighter now (removes two batteries). Can I use this? (gets six volt battery). I guess I can use this. (unscrews terminals) It looks like a more powerful bulb than we used in the lab. **Level 2: Stating**

This pattern was typical throughout all the tasks that he did. He was constantly making statements which revealed something about his understanding of electricity. This was a sharp contrast to Sandra who rarely made such statements.

Sean was the subject who best displayed tinkering at the invention level. Since Sean was a master tinkerer such instances are most likely associated with high level tinkering. The following excerpts are illustrative of statements made during the interview that were at the invention level:

Excerpt 1

I: That doesn't seem a very good connection does it?

S: No. The wires aren't long enough. (twists wires that were originally joined at cap) (looks in box to side) Maybe if I, that should do. (picks up a copper wire)
I: What are you going to use that for?
S: I am going to use this (copper wire) as sort of a joiner so I can get a longer wire, like to get that, that there (points to location of switch) and that together, like that one there is so long and this one is so short (wire joined to switch) so I'll just take this (new copper wire) and tangle it around this and take this end and tangle around that (other wire in cord now disconnected) and I'll still have a good connection but I'll have extra wire to go around with.
I: Mmh. Do you think that, that is safe enough?
S: I don't know see cause it might not be able to hold power from. Is there a circuit in this? (examines inside of sauna)
I: That is what I am thinking.
S: Yeah, cause this might get burnt out. Unless you, what, ah. (looks in box, gets more wire and starts bending the wire)
S: If you double these wires over a couple of times, then used it like that then I'll have extra wire. Can't burnt out and it won't snap. It will be just as thick as that wire there. (bending wire) (pause) I think. Actually this here is going to be bigger so in a way it will be safer. (twists wires together)
I: Safer in what respect?
S: In the respect that the, like from this wire (points to new wire) it won't burn out cause it is bigger than that wire there, like it is thicker and can hold more power. And less chance of it catching on fire, I hope.

Excerpt 2
S: Ones that test batteries. I don't know if it is a galvometer [sic] but it is different than this. It is like one with the switch on it. (rubs magnets) Oh yeah going! There we are! Should, do you have a horseshoe magnet.
I: Yes.
S: It is easier with a horseshoe magnet. (reaches and gets a horse-shoe magnet from the box) (moves wire back and forth inside horse-shoe magnet)
S: You should be able to just rub it up and down like this shouldn't we?

Excerpt 3
S: It should work. It is probably the galvometer [sic]. (adjusts screw in the galvanometer)

Excerpt 4
S: Was I right?
I: Oh yes that is fine.
S: (starts to put top on plug)
I: Do you think you were right?
S: I don't know. What I would is I, like put if I had a voltmeter I'd put it on and take a battery wrap it on each side of the plug end. And then I would, I'd test it with the voltmeter and if the right amount of volts come out. Then I am right. If not I have to look at it and go through it again.

Sean also did make a unique move when he was asked to make the flashlight light in Task # 6. He made a switch from the wire and inserted it in the opening. He was the only student to do that. All the other students attempted to get the flashlight to light by repairing or re-inserting the original broken switch.

Sean's interview transcript provided data which was categorizable at all three levels of verbal knowledge. He was the only target subject who made statements at the invention level. However, his dominant level was the stating level. Given that those statements which were categorized at the invention level were always accompanied by inventive actions, it would be very unlikely that the inventive level would be the dominant level for any subject.

Synopsis of Verbal Knowledge Levels of Target Subjects based on Interview Data

Table 4-5 summarizes the level of verbal knowledge displayed by representative target subjects (novice, amateur, professional, and master tinkerers) while completing the assigned tasks during the interview.

The level of verbal knowledge displayed by the target subjects during the interview was quite varied. During the interview Sandra's level of verbal knowledge was mostly fixed at the questioning level. Although, she did on occasion make statements which were at the stating level. Paul's level of verbal knowledge was at both the stating and questioning levels. Jason showed a similar pattern. The difference was the richness of knowledge that Jason displayed in his statements, and he made more statements than did Paul. Sean's level of verbal knowledge was similar to Jason in the richness of

TABLE 4-5 Level of Verbal Knowledge Displayed During the Completion of Interview Tasks

Level	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Target Subject: Sandra (Novice Tinkerer)						
1	X	X	X	X	X	X
2	O	O	X	O	X	X
3	O	O	O	O	0	O
Target Subject: Paul (Amateur Tinkerer)						
1	X	X	X	X	X	X
2	X	X	X	X	X	X
3	O	O	O	O	O	O
Target Subject: Jason (Professional Tinkerer)						
1	X	X	X	X	X	X
2	X	X	X	X	X	X
3	O	O	O	O	O	O
Target Subject: Sean (Master Tinkerer)						
1	X	O	O	O	X	X
2	X	X	X	X	X	X
3	O	O	O	X	X	X

legend:
Level 1-Questioning
Level 2-Stating
Level 3-Invention

X-identified level of verbal knowledge
O-level of verbal knowledge not identified

knowledge. The distinct difference however was the inventiveness of the knowledge that he displayed during the completion of tasks four to six. Sean was the only target subject who displayed level 3 verbal knowledge during the interview. The other two target subjects Leann (novice tinkerer) and Haritha (amateur tinkerer) showed similar patterns in their display of verbal knowledge as did Sandra (novice tinkerer) and Paul (amateur tinkerer).

Verbal Knowledge Levels as Identified by Classroom Observations

A similar pattern was also noted in the classroom behavior of the target subjects. Table 4-6 provides a summary of the verbal knowledge levels displayed by target subjects during selected classroom activities.

The level of verbal knowledge displayed by master, professional, amateur and novice tinkerers during my classroom observations further supports the pattern in the interview data. During all my classroom observations Sandra did not get involved in the discussion of electricity, other than to seek directions from the teacher or other students. The level of verbal knowledge that she displayed was almost always at the questioning level. Paul, however, went beyond raising questions and made occasional statements about electricity. Jason and Sean went beyond making statements about electricity, in that their statements also indicated some specialized technical knowledge. Again, Sean was the only student in the class who was able to display verbal knowledge at the invention level.

TABLE 4-6 Levels of Verbal Knowledge Displayed During Classroom Activities

Level	Act. #1	Act. #2	Act #8	Act. #11	Act. #12
Target Subject Sandra (novice tinkerer)					
1	x	x	x	x	x
2	0	0	0	0	0
3	0	0	0	0	0
Target Subject Paul (amateur tinkerer)					
1	x	x	x	x	x
2	x	x	x	x	x
3	0	0	0	0	0
Target Subject Jason (professional tinkerer)					
1	x	x	x	x	x
2	x	x	x	x	x
3	0	0	0	0	0
Target Subject Sean (master tinkerer)					
1	x	x	x	x	x
2	x	x	x	x	x
3	x	0	x	0	x

legend:

Level 1-Questioning
Level 2-Stating
Level 3-Invention

x - level of verbal knowledge identified
0 - level of verbal knowledge not identified

Actional Knowledge

Classification of Actional Knowledge Levels of Tinkering

An analysis of the actions displayed by the master, professional, amateur and novice shows varying levels of performance competency, or actional knowledge. By examining the actions taken by four of the target students (Sean, Jason, Paul and Sandra) during the interview and in the classroom setting I constructed three actional knowledge levels for tinkering. Actional knowledge can therefore be described as existing at the following three levels:

Level 1: Actional knowledge is tentative or non-focused (formulating)

- relies on text and/or teacher for assistance
- shows lack of familiarity with equipment
- shows lack of familiarity with technique

Level 2: Actional knowledge is routine or part of repertoire (repertoiralizing)

- relies on prior experience to complete the task
- shows familiarity with equipment
- shows familiarity with technique

Level 3: Actional knowledge is creative or novel (inventing)

- is not only able to complete the task but is also able to assist others
- utilizes the equipment in a unique or novel way
- utilizes unique or novel techniques

Interview Data

Based on the above categorization, Table 4-7 gives a summary of the highest levels of actional knowledge displayed by the target subjects (Sean, Jason, Paul and Sandra) who were identified as representing the four proficiency levels of tinkering. An examination of the patterns in the table shows that the higher the proficiency level of the subject the higher the level of actional knowledge exhibited by the subject while engaged in the various tasks.

Classroom Data

A similar pattern of actional knowledge was also noted in the classroom behaviors of the same four subjects. Table 4-8 below provides the results of an analysis of the pattern of actions for the target subjects during classroom activities. The actions of the target subjects in the classroom setting displayed a wide range of actional knowledge in completing the assigned tasks. In the classroom, those subjects classified as novice and amateur showed a lower level of actional knowledge than did the professional and master.

Synopsis of Verbal and Actional Knowledge in Interview and Classroom Contexts

The target subjects' levels of actional knowledge as outlined in Tables 4-7 and 4-8 shows a strong relationship with their level of verbal knowledge as outlined earlier in Tables 4-5 and 4-6. The levels of verbal and actional knowledge identified for the target subjects further help to define the

TABLE 4-7 Level of Actional Knowledge Displayed During Interview Tasks

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Master Tinkerer: Sean						
Level	2	2	2	3	3	3
Professional Tinkerer: Jason						
Level	2	2	2	2	2	2
Amateur Tinkerer: Paul						
Level	1-2	1-2	1-2	1-2	1	1-2
Novice Tinkerer: Sandra						
Level	1	1	1	1	1	1-2

TABLE 4-8 Level of Actional Knowledge Displayed During Classroom Activities

Act. #	Description	Level of Actional Knowledge
	Master Tinkerer: Sean	
1	Electric Circuit	level 3
2	Electric Circuits	level 2
3	Household Bulb	level 3
4	Series & Parallel Circuits	level 3
5	Conductivity of Materials	level 2
6	Conductivity of Liquids	level 3
8	Chemical Cell	level 3
11	Charges & Forces	level 2
12	Electroscope	level 3
13	Magnetic Force of Electric Current	absent
14	Magnetic Force Produced by an Electric Current	no data
15	Electric Motor	level 2
16	Magnetism Produces an Electric Current	absent
	Professional Tinkerer: Jason	
1	Electric Circuit	level 2
2	Electric Circuits	level 2
3	Household Bulb	level 2
4	Series & Parallel Circuits	level 2
5	Conductivity of Materials	level 2
6	Conductivity of Liquids	level 2
8	Chemical Cell	level 2
11	Charges & Forces	level 2
12	Electroscope	level 2
13	Magnetic Force of Electric Current	level 2
15	Electric Motor	level 2
16	Magnetism Produces an Electric Current	level 2
	Amateur Tinkerer: Paul	
1	Electric Circuit	level 1-2
2	Electric Circuits	level 1-2
3	Household Bulb	level 1-2
4	Series & Parallel Circuits	level 1-2
5	Conductivity of Materials	level 2
6	Conductivity of Liquids	level 1-2
8	Chemical Cell	level 1-2

TABLE 4-8 Cont'd

11	Charges & Forces	level 2
12	Electroscope	level 2
13	Magnetic Force of Electric Current	level 2
14	Magnetic Force Produced by an Electric Current	level 1-2
15	Electric Motor	level 1
16	Magnetism Produces an Electric Current	level 1-2

Novice Tinkerer: Sandra

1	Electric Circuit	level 1
2	Electric Circuits	level 1
3	Household Bulb	level 1
4	Series & Parallel Circuits	level 1
5	Conductivity of Materials	level 1
6	Conductivity of Liquids	level 1
8	Chemical Cell	level 1
11	Charges & Forces	level 1-2
12	Electroscope	level 1
13	Magnetic Force of Electric Current	level 1
14	Magnetic Force Produced by an Electric Current	did not attempt or watch
15	Electric Motor	did not attempt or watch
16	Magnetism Produces an Electric Current	level 1

proficiency of tinkering being proposed. Novice and amateur showed lower levels of actional and verbal knowledge whereas the professional and master displayed higher levels of actional and verbal knowledge. This strong relationship between the level of actional and verbal knowledge for the subjects helps to further define their proficiency at tinkering. To better illustrate this relationship Table 4-9 reviews the target subjects range and highest levels of verbal and actional knowledge. Table 4-9 highlights the general pattern of actional and verbal knowledge levels for representative

TABLE 4-9 Review of the Verbal and Actional Knowledge Bases of Tinkering

SUBJECT	Verbal		Actional	
	RANGE	HIGHEST	RANGE	HIGHEST
SEAN MASTER TINKERER	1-3(2)*	3	2-3(2)	3
JASON PROFESSIONAL TINKERER	1-2(2)	2	1-2(2)	2
PAUL AMATUER TINKERER	1-2(1-2)	2	1-2(1-2)	2
HARITHA AMATUER TINKERER	1-2(1-2)	2	1-2(1-2)	2
LEANN NOVICE TINKERER	1-2(1)	2	1	1
SANDRA NOVICE TINKERER	1-2(1)	2	1	1

legend:

VERBAL LEVELS
1-Questioning
2-Stating
3-Invention

ACTIONAL LEVELS
1-actions new or novel
2-actions part of repertoire
3-actions are unique

* the dominant level within the range is noted within the brackets

subjects as discussed earlier. These patterns, based on the data collected, are not distinct levels but rather should be viewed as developmental.

Summary

This chapter has proposed that the characteristics of tinkering can be described by:

1. a typology consisting of types of tinkering, and having proficiency levels,
2. a problem solving process which goes through a number of phases, and
3. developmental levels of verbal and actional knowledge.

Through the statements and actions of the target subjects I was able to construct four types of tinkering: utilitarian, technological, scientific and pragmatic. The target subjects were described as exhibiting a proficiency of tinkering which was categorized as novice, amateur, professional and master.

Tinkering was described as a problem solving process. This process was described as consisting of four phases: (1) searching for the problem, (2) framing the problem, (3) solving the problem, and (4) testing the solution. These various phases were increasing illustrated by the novice, amateur, professional and master.

Tinkering was also described as consisting of two knowledge bases - verbal and actional knowledge. The verbal knowledge levels were referred to as questioning, stating, and invention. The actional knowledge levels were referred to as formulating, repertoiralizing, and inventing. The verbal and actional knowledge bases supported the proficiency of tinkering.

This chapter, in an attempt to develop a model of tinkering has illustrated that the characteristics of tinkering are both multi-faceted and complex.

Chapter five will explore the social, experiential, and personal factors influencing tinkering in an attempt to further develop a model of tinkering.

CHAPTER 5: THE APPRENTICESHIP: THE SOCIAL, EXPERIENTIAL, AND PERSONAL FACTORS OF TINKERING

Introduction

This chapter will analyze data which will provide further insight into the second research question:

Question # 2: What are the factors which influence tinkering?

2.1 What role do prior experiences play in tinkering?

2.2 What role do social relationships play in tinkering?

2.3 What role do personal interests play in tinkering?

Based on the analysis of data I will develop conjectures regarding the experiential, social, and personal factors of tinkering. This will be done by focusing on the subject's statements and actions in two settings (interview and classroom), and through the use of some data from the survey.

There are many factors which seem to encourage or discourage tinkering. One way of describing these three factors is through the use of a metaphor. I will present the notion of an apprenticeship metaphor to describe the experiential, social, and personal factors which influence tinkering. I believe this metaphor best describes how these factors influence the subjects to tinker. Throughout this chapter I will describe the apprenticeship by outlining how these factors appear to contribute to an apprenticeship in tinkering. A brief overview of the experiential, social, and personal factors now follows:

1. Experiential Factors

Experiential factors include those prior experiences with electrical phenomena to which subjects were exposed in their everyday life, both in and outside school. An examination of the depth of such experiences will determine the opportunity that a person has had to tinker. The experiential factors therefore describe the level of the apprenticeship.

2. Social Factors

I explored social factors by focusing on social relationships which seem to encourage or discourage tinkering, as they were revealed in the data collected on students' relationships with family, friends and school. Such social relationships can be described as contributing to the social construction of tinkering. I recognize the importance of these relationships to a larger social structure in influencing a subject to tinker. Data however were not collected on other social factors such as cultural norms.

3. Personal Factors

Personal factors include the personal responses that may indicate a person's interest or dislike for tinkering. Such personal factors were explored by focusing on statements or actions which appeared to indicate the subject's interest or dislike for tinkering. These personal responses suggest that tinkering is also personally constructed.

Chapter five therefore examines the experiential, social, and personal factors of tinkering for the target subjects. This chapter then raises conjectures about how these factors might influence tinkering. It should also be recognized this is a preliminary construction of the experiential, social, and personal factors which I will describe as apprenticeship factors. Based upon data on these factors, the model of tinkering developed in the previous chapter will be further elaborated.

The Experiential Factors Of Tinkering

Data Sources Used in Constructing the Experiential Factors

I explored each of the student's prior experiences with tinkering by using a number of techniques, including a survey of prior experiences with electricity, interview data and classroom observations. That is, not only did I survey the target students' prior experiences with electricity but also, within the context of the interview, their prior experiences with electricity were probed in depth. During classroom observations any evidence of prior experiences with electricity were noted. The analysis of data collected reveals that while the survey gives some idea of the amount of involvement in electrical activities, it does not give an indication the depth of involvement as was provided by the interview and classroom observations. I will now take representative target students who were classified earlier as master, professional, amateur and novice and examine their prior experiences with electricity as revealed in the survey, interview and classroom observations.

Survey

Introduction

The Survey of Electrical Experiences (Appendix A) consisted of two parts. Part I consisted of a general survey of science interests with a focus on electricity. The purpose of this was to get some indication of the subjects' interests and involvement in science related activities. Part II consisted of a survey of the depth of electrical experiences. This discussion will focus mainly on Part II because it was the part of the survey which proved to be most relevant to the study.

Survey of Electrical Experiences

The survey of electrical experiences was one of the three criteria used in the selection of target subjects. Specifically Part II of the survey included 35 items to which students were asked to respond, indicating their frequency of experiences with electricity. They indicated this frequency by selecting from a continuum how often they were involved in activities with some type of electrical phenomena. They were given the following options for response:

(3) quite often

(2) once or twice

(1) never

Such activities included using electrical tools, changing batteries, charging batteries, or making an electrical motor.

The criteria for item selection for the survey were:

1. to focus on electrical objects and events which were a part of the electricity unit, and
2. to select electrical objects and events that are part of everyday living.

Table 5-1 below gives a list of activity indices for the target subjects. Four of the target subjects who will be discussed in more detail in this section are highlighted. All of the students in the target class were surveyed as part of my initial criteria for selecting target subjects but only the results for the target subjects are presented here. An activity index was calculated based on the frequency with which subjects engaged in the specific activities listed in the survey.

TABLE 5-1 Activity Index Determined by the Survey of Electrical Experiences

Target Students	Depth of Tinkering	Activity Index
Sean*	**master**	129
Jason	**professional**	102
Paul	amateur	84
Haritha	**amateur**	91
Leann	novice	105
Sandra	**novice**	98

* Students highlighted will be discussed in detail in this section

The activity index gives an indication of exposure to electrical activities. A high activity index therefore suggests a high level of exposure to a wide range of electrical apparati. The four target subjects highlighted above had a varying range of activity indices. Other than for Sean, there was no strong relationship between proficiency level and the level of the activity index. A pattern however was noted for the target class. Those who were described as tinkerers by their teachers tended to have a higher activity index than those who were not described as tinkerers. There was nevertheless a range of activity indices within each of the two groups initially described as tinkerers and non-tinkerers.

The Survey of Electrical Experiences seems to indicate that Sean, Jason and Haritha viewed themselves as tinkerers whereas Sandra did not. While the activity indices may indicate something about experiences, whether or not someone views her or himself as a tinkerer is a matter of self-perception. Yet while Sean's and Jason's comments seemed to indicate extensive involvement with electrical objects and events this did not seem to be the case for Haritha. Still Haritha described herself as a tinkerer. However if we look at the activity indices, other than for Sean, there does not appear to be a high level of prior involvement with electricity. Even though Jason's activity index suggested moderate activity this did not correlate with Jason's description of himself in the general survey where he indicated that he was highly involved with electrical and electronic activities. The activity indices may give some indication of the frequency with which subjects were exposed to electrical objects in their daily lives. It does however not give any indication of the depth of exposure or the subject's actual involvement in activities. Therefore the activity indices should be regarded as insufficient data on which to make judgements about a subject's actual involvement with electricity. It may still be quite useful as a preliminary survey of students' experiences. One pattern I did notice was that those students whose teachers described them as tinkerers generally had a higher activity index than those they described as non-tinkerers. Still I would only use activity indices in conjunction with other data obtained from interviews and classroom observations to make a final judgement on a student's tinkering.

Some factors which may have influenced the results of the survey are or include:

1. subjects may not have taken the survey seriously, and
2. subjects may have viewed themselves as achievers and this may have influenced their response patterns. They may not have wanted to be perceived as underachieving by indicating a true or lower rate of participation.

Interview Data

Overview

This section will attempt to illustrate the experiential background for representative target subjects based on their response patterns in an interview setting. The analysis was based upon both the statements made by the target subjects and their actions during the interview. The statements were broken down into two types. Some were of a propositional nature which indicated the subject's knowledge of electricity. Others were simply verbal descriptions of prior experiences. Based on these two indicators the experiential context was described for each subject.

Sean (Master Tinkerer)

Level of experiential knowledge.

Throughout the interview Sean's behavior suggested that he had a lot experience with electrical objects. This was displayed both through his statements and actions in completing the tasks. The following dialogue at the beginning of the interview should give the reader some insight into Sean's prior experiences:

Task #1 - Electric Circuit

I: Sean have you worked much with this kind of stuff?
S: Yeah I have worked a nice bit.
I: Where? In school or out of school?
S: Mainly out of school. Like I use to take my electrical toys apart.

Right from the beginning of the interview it was obvious that Sean had worked with electrical apparati. Table 5-2 is a summary of the statements made by Sean during the interview which suggested he was familiar with a wide range and depth of prior experiences with electricity.

Level of experiences based on actional knowledge.

Table 5-3 presents an analysis of the actional knowledge displayed by Sean during the completion of the tasks. In analyzing Sean's actional knowledge one can only speculate about how prior experiences may have influenced his level of actional competency. Based on an analysis of Sean's actions, a synopsis of his actional competency was made for each task. A review of Sean's actional competency during the completion of tasks may

TABLE 5-2 Highlights of Sean's Prior Experiences

Description of Task	Statements of Prior Experiences
Task #1 - Electric circuit	- His propositional statements indicated a high level of familiarity with the electrical concepts. - His verbal accounts indicated that he had worked with electrical toys, electrical sockets and switches, and that he had done house wiring and telephone installation.
Task #2 - Production of a Magnetic Force	- His propositional statements indicated a high level of familiarity with the electrical concepts. - His verbal account had indicated that he had worked with compasses in a variety of settings.
Task #3 - The Production Electric Current	- His propositional statements indicated of an a high level of familiarity with the specific electrical apparati in this activity. - Sean's conversation indicated that he had worked with voltmeters, galvanometers and other meters. - He also indicated that he had done similar activities previously.
Task #4 - Two and Three Prong Plugs	- His propositional statements indicated a high level of familiarity with the electrical concepts involved. - His verbal accounts indicated that he had attached plugs to electrical wires, repaired the toaster, and used electrician's gloves.
Task #5 Facial Sauna	- His propositional statements indicated a high level of familiarity with the electrical concepts. This was indicated by his ability to freely converse about such things as safety caps, a wide variety of electrical switches, conductors and transformers, radio crystals, motor bike engines and microchips. In addition he also indicated that he had experiences with the above. - His verbal accounts also indicated that he had repaired appliances and electrical games such as pac man games, etc. Moreover, he also indicated that he had done house wiring and installed telephones. He had also soldered copper wires.

TABLE 5-2 Cont'd

Task #6	Flashlight	- His propositional statements indicated a familiarity with the concepts involved. - His verbal accounts indicated that he had worked with flashlights.

TABLE 5-3 Sean's Actional Competency in an Interview Setting

Task #	Description of Actional Competency
1	- completed task successfully within a short time - showed familiarity with equipment and procedure
2	- completed task successfully within a short time - showed familiarity with equipment and procedure
3	- completed task successfully within a short time - showed familiarity with equipment and procedure
4	- completed task successfully - showed familiarity with equipment - utilized unique procedure
5	- completed task successfully but did require some time - showed familiarity with equipment and procedure
6	- completed task successfully within a short time - showed familiarity with equipment - utilized unique procedure

provide the reader with some indication of Sean's prior experiences. Given Sean has verbally indicated prior experiences with electricity it is not surprising that his actions would also suggest prior experiences. Nevertheless I must acknowledge that there are certainly other factors involved which may also contribute to actional competency.

These descriptions of Sean's expertise in completing the tasks seem to indicate a very high level of actional competency. They suggest a high level of prior experiences with electricity. In addition, his actions were part of a well developed repertoire which also suggests a high level of prior experiences.

Jason (Professional Tinkerer)

Level of experiential knowledge.

It is obvious to an observer that Jason has had a lot of experience with electrical objects. This observation can be made based upon his statements and actions during the interview. I will now examine these two data bases to show how his experience may have contributed to his becoming a professional tinkerer.

Table 5-4 describes the statements made by Jason throughout the interview which indicated he had prior experiences with electrical apparati. Both Jason's verbal and propositional statements seem to show that he has had considerable prior experiences with electricity. He was familiar with a wide range of electrical apparati and concepts. In addition, he had described himself as being involved in a wide range of electrical activities.

TABLE 5-4 Highlights of Jason's Prior Experiences

Description of Task	Statements of Prior Experiences
Task # 1 - Electrical Circuit	- Propositional statements indicated specific knowledge as it relates to electric circuits. - Verbal accounts of prior experiences indicated that he had worked with electric sockets, and electric motors.
Task #2 - Magnetic Force	- Propositional statements indicated familiarity with the concepts involved. - Verbal account indicated that he had worked with compasses.
Task #3 - Electric Current	- Propositional statements indicated familiarity with the concepts involved. - Verbal discourse indicated that he had done a similar activity previously. He also indicated that he had used a battery tester, tested a wide variety of battery types and made an electromagnet.
Task # 4 - Electric Plugs	- Propositional statements indicated a familiarity with the concepts involved. - Verbal accounts indicated that he had repaired plugs.
Task #5 - Facial Sauna	- Propositional statements indicated a familiarity with the concepts involved. - Verbal accounts indicated that had repaired appliances such as toasters, and electrical toys such as remote control cars.
Task # 6 - Flashlight	- Propositional statements indicated a familiarity with the concepts involved. - Verbal accounts indicated that he had worked with flashlights.

Level of experiential knowledge based on actional knowledge.

Table 5-5 summarizes the level of actional competency displayed by Jason during the six tasks. This summary should provide the reader with an indication of Jason's depth of experience with electrical phenomena.

An analysis of Jason's actions suggests that he has had prior experiences with electricity. Even though the level of his actional competency was not as well developed as Sean's, it is obvious that Jason has a well developed repertoire of actional knowledge.

Haritha (Amateur Tinkerer)

Level of Experiential Knowledge.

Haritha's limited experience with electricity is confirmed by examining her approach to tasks in the interview setting, evident in both her statements and actions. Her limited experience seems to contribute to her status as an amateur tinkerer. Table 5-6 highlights Haritha's prior experiences based on the statements she made during the interview in relation to the tasks she was asked to do.

Haritha's verbal and propositional statements about electricity indicate that her prior experiences could best be described as restricted when compared to Sean's or to Jason's. This may be partly attributed to the fact she did not have as strong a mentor as they did. She did not get the same level of apprenticeship, in that her experiences were mainly restricted to watching her mentor. It was only on very rare occasions that she took her own things, or very old things apart.

TABLE 5-5 Jason's Actional Competency in an Interview Setting

Task #	Description of Actional Competency
1	- completed task successfully - showed familiarity with equipment and procedure
2	- completed task successfully - showed familiarity with equipment and procedure
3	- completed task successfully - showed familiarity with equipment and procedure
4	- completed task successfully - showed familiarity with equipment and procedure
5	- did not complete task successfully - showed some familiarity with equipment and procedure
6	- completed task successfully - showed familiarity with equipment and procedure

TABLE 5-6 Highlights of Haritha's Prior Experiences

Description of Task	Statements of Prior Experiences
Task # 1 - Electric Circuit	- Her propositional statements indicated some superficial awareness of electrical terminology. - Her verbal account indicated that she had on rare occasions worked with batteries and bulbs, electric switches, electromagnets.
Task #2 - Magnetic Force	- Her propositional statements indicated that she struggled with the electrical concepts involved in this task. - Her verbal account indicated some awareness of compasses and magnets but no prior experiences with 6 volt batteries or switches.
Task #3 - Electric Circuit	- Her propositional knowledge indicated that she struggled with the electrical concepts involved in this task. - Her verbal account indicated that she had worked with magnets but that she had no experience with galvanometers.
Task #4 - Electrical Plugs	- Her propositional statements indicated that she had a very limited conception of concepts involved. - Her verbal accounts indicated that she had worked with other types of plugs before, but not those in this specific task.
Task #5 - Facial Sauna	- Her propositional statements indicated that she had no idea of the concepts involved. - Her verbal account indicated that her experiences were restricted to examining the insides of calculators, alarm clocks, and battery operated radios. These items which were either discards or her own.
Task #6 -Flashlight	- Her propositional statements indicate that she had a limited understanding of the electrical concepts involved. - Her verbal account indicated that she had not worked with a flashlight before but that she had some limited exposure to batteries and bulbs.

Level of experiential knowledge based on actional knowledge.

Table 5-7 summarizes the actions displayed by Haritha in the completion of tasks 1-6. This summary provides the reader with some indication of her previous experience with electricity.

Haritha's actions seem to suggest that she has had limited experiences with electricity. The repertoire of actional knowledge that she brought to the tasks was very restricted, as indicated by her manual dexterity problems and her lack of familiarity with equipment and procedures.

Sandra (Novice Tinkerer)

Level of experiential knowledge.

Sandra has had very limited experiences with electricity. This is illustrated in the interview setting by both her statements and actions. Her very limited experience with electrical objects appears to have contributed to her status as a novice tinkerer. Table 5-8 summarizes statements made by Sandra during the interview which indicate her lack of experience with electrical objects and events.

A review of Sandra's propositional statements and verbal accounts during the completion of tasks 1-6, also seems to indicate she her limited experiences with electricity. She appears to have been even more restricted in her experiences than Haritha. This may be attributed to the fact that she did not have a mentor. In addition, the only access she had to tinkering was very limited opportunities to play with her brother's toys when she was a child.

TABLE 5-7 Haritha's Actional Competency in an Interview Setting

Task#	Description of Actional Competency
1	- did not complete task - was not familiar with equipment or procedure
2	- completed task - limited familiarity with equipment and procedure
3	- completed task - limited familiarity with equipment and procedure
4	- some success with task - limited familiarity with equipment but not procedure
5	- did not complete task - was not familiar with equipment or procedure - limited manual dexterity
6	- did not complete task - not familiar with equipment

TABLE 5-8 Highlights of Sandra's Prior Experiences

Description of Task	Statements of Prior Experiences
Task #1 - Electric Circuit	- Her propositional statements indicated very little or no conception of an electric circuit. - Her verbal account indicated that she had not made an electric circuit before nor was she familiar with the electrical apparati used.
Task #2 - Magnetic Force	- Her propositional statements indicated that she had no prior experiences with the concepts involved in the task. - Her verbal account indicated that she had not used a six volt battery or electrical switches before but that she had on one or two occasions used a compass.
Task #3 - Electric Current	- Her propositional statements indicated that she had little or no prior experiences with the concepts involved. - Her verbal account indicated that she had worked with magnets but not with galvanometers.
Task #4 - Electrical Plugs	- Her propositional statements indicated she had no prior experiences with the concepts involved. - Her verbal account indicated that she had no experiences working with electrical wires other than fixing a loose connection in her curling iron.
Task #5 - Facial Sauna	- Her propositional statements indicated that she had no prior experiences with examiningthe inside of a facial sauna. - Her verbal account indicated that she had not fixed anything besides her curling iron.
Task #6 - Flashlight	- Her propositional statements indicated that she had no prior experiences with the electrical concept involved in this activity. - Her verbal statements indicated that she had no experiences which involved the taking apart of a flashlight to examine how it operated.

Level of experiential knowledge based on actional knowledge.

Table 5-9 summarizes the actions displayed by Sandra during the completion of tasks 1-6. This summary of her level of actional competency in the completion of the tasks provides an indication of her depth of experience.

Sandra's very limited repertoire of actional knowledge seems to suggest a low level of prior experiences with electricity. Her limited repertoire was revealed by her low level of manual dexterity with apparati, and lack of familiarity with equipment and procedure.

Classroom Observations

Criteria Used in Determining Experiential Level

This section will provide an analysis of students' prior experiences with electricity based on classroom activities and discussions. As with the interview data I have relied on an analysis of the statements and actions of the target subjects. The depth of experience based on classroom behavior was determined by an analysis of subjects statements during classroom activities and discussions, and inferred through the level of actional competency displayed by the subjects during activities. Given that there were two types of data (statements and actions) used to describe a subject's level of experience within the classroom setting then this allowed for a cross check of any emerging patterns. The use of such indirect data (actional competency) to speculate about prior experiences is not without the acknowledgement that

TABLE 5-9 Sandra's Actional Competency in an Interview Setting

TASK #	Description of Actional Competency
1	- completed task after a long struggle - showed lack of familiarity with equipment and procedure - problems with manual dexterity
2	- completed task after a long struggle - showed lack of familiarity with equipment and procedure - problems with manual dexterity
3	- completed task after a long struggle - showed lack of familiarity with equipment and procedure - problems with manual dexterity
4	- did not complete task successfully - showed lack of familiarity with equipment and procedure - problems with manual dexterity
5	- did not complete task successfully - showed lack of familiarity with equipment and procedure - problems with manual dexterity
6	- did not complete task successfully - showed some familiarity with equipment but not with procedure - problems with manual dexterity

such a data base is mainly conjectural. Since all the subjects were successful academically, a low actional competency can not be attributed to low intellectual ability but rather to factors such as experience.

Based on the criteria outlined above, selected classroom activities and discussions were analyzed for each target subject. I was not able to tape record all of the small group conversations that took place at the same time. Only selected activities were analyzed for each subject. Representative subjects at the master, professional, amateur and novice levels will be discussed. The statements and actions of the master tinkerer will be presented in detail, with a summary for the professional, amateur and novice tinkerers.

Sean (Master Tinkerer).

Sean's familiarity with electrical apparatus and activities is evident from how he went about doing activities assigned during the unit. Not only was Sean able to do the assigned activities but he often acted as an assistant to his classmates. Table 5-10 illustrates Sean's statements and actions in the classroom which indicated his high level of prior experiences.

Sean's statements and actions in the classroom indicated he was not only able to carry out the tasks assigned him but that he had some unique talents as well. Sean was able to go beyond what was expected to successfully complete the tasks by extending the tasks, offering expert advice to the class and teacher, and assisting other students. His status as a master tinkerer appears to be attributable not only to his familiarity with a wide range of electrical equipment and procedures, but also to his use of novel techniques or materials to complete activities. Not only did he demonstrate he was able to complete tasks in unique ways, but he was also able to act as a consultant to his classmates.

Jason (Professional Tinkerer).

Jason, like Sean was able to carry out all the assigned activities. Throughout the unit he demonstrated, by both his statements and his actions, that he was familiar with electrical apparati and electrical activities. Based on an analysis of selected classroom events it was concluded that Jason's behavior patterns indicated a high level of prior experiences. Jason was able to carry out all the tasks assigned him. That is, he was able to do what was expected of him. He had no difficulty with the tasks and therefore carried out the tasks as a professional would. Although he was successful with his tasks he did not invent new techniques or utilize alternative materials to complete the task as Sean often did. One possible exception was where he substituted a beaker for a flask in the making of an electroscope. Jason's status as a professional seems to be linked to his familiarity with a wide range of electrical equipment and procedures.

Haritha (Amateur Tinkerer).

Haritha attempted all the activities assigned but she often ran into trouble and had to seek assistance. She was not familiar with a lot of the electrical apparati or activities. An analysis of Haritha's statements and actions during selected classroom events indicated her depth of experience ranged from low to moderate. The analysis suggested she was an amateur tinkerer. She did not have the same level of success as did Sean or Jason. She was however able to

Table 5-10 Sean's Depth of Experience Based on His Statements and Actions in the Classroom

	Statements	Actions
Activity 1	His familiarity with required equipment, and an awareness of substituting alternate equipment strongly suggested prior experiences.	- A high level of actional competency was indicated when he completed activity with alternate equipment.
Activity 3	He had knowledge of specialized equipment, such as a voltmeter. This suggests a high level of prior experiences.	- He demonstrated a high level of actional competency by being able to set up a circuit and use a voltmeter. He was also able to trouble shoot successfully.
Activity 4	He was aware of the concept of circuit overload and series and parallel circuits. This suggests a high level of prior experiences.	- He was able to set up both the series and parallel circuits. - He also assisted other students in setting up circuits. Such actions suggest a high level of actional competency.
Activity 8	He indicated knowledge of how a chemical cell works.	- He set up a chemical cell. - He explored the effect of KCrO2 on the system. - He assisted others. Such actions suggests a high level of actional competency.
Activity 11	While working on activity checking out electrostatic charges Sean extended the activity beyond the list suggested. He did this without prompting. This suggests he had a high level of prior experiences.	He went beyond the limits of the activity. His level of actional competency was high.

Table 5-10 Cont'd

Activity 12	Statements made by Sean suggested a high level of prior experiences: 1. When he was assigned the task of making an electroscope Sean inquired about the "electrostatics generator". 2. He suggested cigarette paper as an alternate material for making the leaves of the electroscope.	A high level of actional competency is indicated when he successfully completed activity with alternate materials.
Activity 16	He directed his classmates on how to make an electric motor. He did this without referring to a textbook. This suggests a high level of prior experiences.	A high level of actional competencywas suggested by his ability to: 1. set up an electric motor without referring to any directions. 2. to provide directions for others.

Note: For a description of activities above, please consult Table 3-1.

complete most of the activities after she was given advice or further directions. Her status as an amateur suggests she has had limited experiences with electrical apparati.

<u>Sandra (Novice Tinkerer)</u>.

Sandra had difficulty in setting up the activities assigned. She often required assistance to even get started. She was not familiar with most of the electrical apparati or activities. An analysis of Sandra's statements and actions during selected classroom events illustrated that her depth of experience was low. Specifically such an analysis indicated that Sandra was a novice. She constantly required assistance in order to be able to complete the tasks. While Haritha was able to complete the activities with advice and directions, Sandra needed further direct help. She required assistance in order to complete or to make any progress with the assigned work. Sandra's status as a novice appears to be linked with her lack of hands-on experience with electrical apparati.

A Review of Experiential Levels as Constructed from Classroom Data

Table 5-11 summarizes the depth of experience of the target subjects as constructed from their classroom actions and statements. This analysis of their actions and statements in the classroom setting shows a wide range in their level of prior experiences. It is clear from their actions and statements that Sean and Jason have had more experiences with electricity than either Haritha or Sandra. When trying to interpret the possible influence of prior experiences one must acknowledge that individual differences and other factors might also be considered in such an analysis.

A Review of Experiential Levels as Constructed from Three Data Bases

Table 5-12 provides a summary of the experiential levels for the target students as constructed from an analysis of actions and statements from two data sources, interview and classroom observations. The third data source, the survey, provided an activity index which indicated the student's prior exposure to electricity.

TABLE 5-11 A Review of Depth of Experience as Constructed by Statements and Actions in the Classroom

Subject	Summary of Actions and Statements	Depth of Experiences
Sean	Actions:	
	-did activities on own	Very High Level
(Master Tinkerer)	-provided assistance for others	
	-actions part of repertoire	
	-utilized unique moves in activities	
	-engaged in a wide range of activities	
	Statements:	
	-indicated familiarity with equipment and procedure	
	-indicated unique knowledge	Very High Level
Jason	Actions:	
	-did activities on own	High Level
(Professional Tinkerer)	-actions part of repertoire	
	-engaged in a wide range of activities	
	Statements:	
	-indicated familiarity with equipment and procedure	High Level
Haritha	Actions:	
	-attempted activities on own but often needed direction	Low-Moderate Level
(Amateur Tinkerer)	-most actions not part of repertoire	
	-engaged in a restricted range of activities	
	Statements:	
	-indicated some familiarity with equipment and procedure	Low-Moderate Level
Sandra	Actions:	
	-needed assistance to complete all tasks	Low Level
(Novice Tinkerer)	-actions not part of repertoire	
	-engaged in a very restricted range of activities	
	Statements:	
	-indicated that she was not familiar with equipment or procedure	Low Level

The three data sources help to build a profile of the depth of experiences of Sean, Jason, Haritha and Sandra. The richest sources were the interview and classroom observations. The survey was not as rich a source of information, however it did prove to be a useful tool in the preliminary identification of students with varying levels of experiences.

Prior experiences therefore appear to play a strong role in the informal apprenticeship of the target subjects. Subjects such as Sandra and Haritha have not had a high level of experiences with tinkering whereas Sean and Jason have had very rich experiences.

The Social Factors Influencing Tinkering

The Three Levels of Social Influence

At a societal level there are many factors which may encourage or discourage someone to tinker. An examination of the social relationships which exist for an individual can tell us something about the social influences on that individual. To illustrate this, I have selected four of the target students, one at each level of proficiency: master, professional, amateur and novice. I will now attempt to describe the specific social influences by showing how it may have encouraged or discouraged tinkering.

Societal influence can be described as existing at three levels, on the basis of the immediacy of the social influence. A first level of influence would be a relationship with a family member or significant other, with a second level of influence being friends, and the third level being community agencies such as the school, clubs, etc. These levels of influence define the

TABLE 5-12 Subject's Experiential Levels as Determined by Three Data Sources

Subject	Survey	Interview	Classroom
Sean	high level exposure	high depth involvement	high depth involvement
Jason	moderate level exposure	high depth involvement	high depth involvement
Haritha	moderate level exposure	moderate-low depth involvement	moderate-low depth involvement
Sandra	moderate level exposure	low depth involvement	low depth involvement

social component of the apprenticeship. The construction of this component was based on the social factors influencing the target subjects.

Sean's Social Influences

Overview of Social Influences

Sean is the only male child in all female household which consists of his mother and three sisters. His parents were divorced when he was quite young. He has a number of male cousins who are older than he, and with whom he has a close relationship. One cousin, described as about thirty years old, appears to play the role of a father figure in Sean's life. The following excerpt reveals something about this relationship:

I: So you have done some of that out of school have you?
S: Oh yes. And eh I am working with my cousin, he's got a house and I am helping him do his room, and I help him put in the light and phone and that.
I: You mean your cousin who is building a house.
S: He is not building it he is redoing his room. And I helped him. Helping him do it.
I: Mmh, mmh. That must be an older cousin is it? Not some one your age.
S: Mmh.
I: I don't think someone your age is into building a house or remodeling.
S: No, he is about thirty. He use to teach at this school a little while ago, last year.

Throughout the interview Sean makes other references to this relationship with his cousin. His cousin, therefore, appears to be playing the role of a significant other in terms of influencing Sean to tinker. Yet when I initially analyzed my data and began to see relationships for some of the target subjects between the role of a significant other and tinkering I could not identify such a person for Sean. This was because I was looking for someone within his immediate household. On a closer look at the interview transcript I noted references to his cousins.

The following dialogue indicates another male cousin who also appears to play an important role in terms of influencing Sean:

I: Do you have any friends, you who know a lot about this kind of stuff?
S: I have a couple. They don't like. I have my cousin, not Jim but Dave. He's Jim's brother. He's like took an electrical course in vocational school. So he's really good right. He's good at all kinds of things.

Sean is part of a cultural milieu where the extended family relationships are strong. Although his relationship with this particular cousin may have some influence he does not refer to this cousin (Dave) as often as he did the other cousin (Jim). Nevertheless, it was this reference to his cousins which lead me to conclude that they were playing the role of a significant other for Sean.

Based on his account in the interview he indicated that no one in his immediate household tinkered with electrical devices. The following excerpt from the interview supports this:

> I: . . . . . .Any one in your family into the kind of stuff you are into?
> S: No, just me.

At other points in the interview he also made reference to the fact that no one in his immediate household tinkers. He felt that this was probably why he became involved. His involvement at home was noted throughout the interview where he made reference to things he had repaired at home, such as the toaster and his own toys. Given that he lived in all female household this may have resulted in his forming a special relationship with his older male cousins, and with his cousin Jim in particular. Such relationships are all part of a cultural setting where extended family relationships are strong.

Friends appeared to be important in influencing Sean's interests in tinkering. During the interview he made reference to one such friend.

> I: What about cars and trucks? Are you into that?
> S: Yeah I got a friend who, who's got a car and he works on it a lot and I help him usually.
> I: At what kind of stuff?
> S: Like he got a sad junk car but what he does is he fixes it up and that like, changes the transmission and things like that.

Sean is obviously influenced by what his friends are involved in and sees it as an opportunity to become involved. Given his friend is involved with car repairs this suggests that his friend is possibly a little older than Sean. The legal age for a driver's license is sixteen so his friend must be at least sixteen years old. Sean however has already owned a motor bike and been involved with repairing it; so it is not surprising that cars repairs would also interest him.

School and other community agencies also appear to have helped influence Sean to become involved in tinkering. The following excerpt is illustrative of the type of reference Sean made to school during the interview:

> I: Have you worked with these sockets before?
> S: Yeah, down in the elementary school. We used the switches and things like that and the balance.

Other than school, there are other community agencies which appear to have had some influence on Sean. One such illustration is when he makes reference to some involvement in club activity.

> I: Have you worked much with compasses before?
> S: Yeah. Well not a whole lot, like I was in scouts or clubs and that. They taught me how to do it and last year for science we had to know.

In his mentioning of club activity he also makes reference to school. Throughout the interview he makes a number of references to things he has done in school. His former grade six teacher, a male teacher, was referred to a number of times. Although he refers to some school and club activities throughout the interview Sean does not seem to view such events as adding much to his repertoire of knowledge about electricity. Schools and other community agencies appear to not have had as strong a social influence on him as did his cousins and friends. Such dialogue however, indicates that there were opportunities for him to become involved at the school and community level.

A Synopsis of the Social Influences on Sean

Sean's strongest social influence does not seem to come from his immediate family but from his extended family. His male cousins appear to play a significant role in his tinkering. One of his cousins in particular appears to play a father figure role. Sean's parents are divorced, and he did not have a close relationship with his father so his older male cousin could have become a significant other.

At a second level of influence there are his male friends who engaged in activities such as car repairs which required tinkering. Such friends appeared to have had some influence on him becoming involved in activities with them. Cars are certainly a logical progression for Sean who has already been involved in motor bike repairs.

The school and other community agencies may have also influenced Sean. This influence, however, was not to the same extent as some male members of his extended family. Through his relationship with his extended family and his friends he seems to have had many opportunities to tinker. At the community level there appears to have been clubs, such as the boy scouts, which allowed him the opportunity to become involved in tinkering activities. School and other community agencies therefore provided Sean opportunities to tinker. These experiences seem dull when compared to his opportunities to engage in activities with his cousins and friends out of school. Nevertheless, for him personally the opportunities were there. Tinkering was therefore socially constructed at all three levels of social influence to have a positive effect on Sean.

Jason's Social Influences

Overview of Social Influences

Jason is the elder of two children, with the other child being female. He has worked in his dad's printing business and been involved with his dad in activities such as wood-working and mechanical repairs. Such activities have allowed Jason the opportunity to tinker. The following excerpt from the interview is an indication of his involvement in such activities:

> I: Does your dad do any of that kind of stuff too?
> J: Yeah. He built a, house last summer, the basement. I helped him out with a bit, of the stuff for that.
> I: The wood working, in the basement.
> J: Yeah most of the stuff like the plaster or something.
> I: Yeah. What about the wiring?
> J: No he didn't do the wiring. He had someone to come in and do it right, 'cause he wanted a good job done I suppose.

Although Jason was not involved in the electrical wiring in this particular project during the interview he did refer to other instances of his involvement with electrical projects, such as the installation of an electric light in his bedroom closet. What was noteworthy about Jason's relationship with his father was that there were opportunities for him to tinker both at home, and at his father's work place.

Jason made reference to the fact that he was sometimes called upon by his younger sister to fix things. At one point he noted that his sister would call upon him when her father and others could not fix something for her. The following dialogue indicates that he sometimes fixed things for her:

> I: So if your sister had something broken she usually brings it to you to repair or what?
> J: Well something, yeah, most of, if dad or someone can't fix it right.

Jason's involvement with doing things for his family members, such as his sister appears to have added to his status as a tinkerer. It also suggests that he was acknowledged by family members as someone who could repair things. He was allowed to engage in all sorts of activities at home, such as the installation of electric lights, motor bike repairs and stereo repairs. One develops the feeling from his interview that he was given status within the family for being involved in such activities.

Jason has a close relationship with his best friend and lab partner Frankie who is also a tinkerer. During the interview he made a number of references to Frankie. Frankie's dad owned a Honda bike dealership and the teachers said that Jason and Frankie spent a lot of time there. Jason was certainly involved in bike repairs so it is not surprising he spent time at the bike shop (the shop was involved not only in bike sales but repairs as well).

Although Jason and Frankie were classmates in science, they did come from different home rooms. This close friendship appears to have existed throughout their schooling. Jason and Frankie also had a close association with Sean. This relationship was observed both in and out of class.

The school has also provided an opportunity for Jason to acquire some of the skills necessary for the wood-working activities that he engaged in. He makes reference to this during the interview:

I: When did you start making things like that?
J: In elementary school I suppose, wood working started there, started to get into building stuff right.

In addition, at the community level Jason also had other social influences upon him to tinker. He was successful in obtaining summer jobs and part-time employment such as assembling bikes for the local Woolco store.

A Synopsis of the Social Influences on Jason

Jason certainly appears to have had a wide variety of social influences encouraging him to tinker. Within his family, his father has played a significant role both at home, and through part-time employment in his father's business. Other members of his family were also a potentially positive influence, such as his younger sister asking him to repair things for her.

His friends also seem supportive of his engaging in activities which required tinkering. The special relationship he had with his friend Frankie certainly fostered such activities.

Another encouraging social influence was the opportunity for Jason to enroll in various courses such as wood working at school. At the community level he was able to obtain part-time employment both with his father and other employers. This may have had a powerful social influence on him.

In conclusion, all three levels of social influence had a positive influence on Jason.

Haritha's Social Influences

Overview of Social Influences

Haritha is the second daughter in a two child family and a amateur tinkerer. She did not engage in a lot of tinkering activities outside of school when compared to Sean and Jason. She was however exposed to a female role model who did. The following excerpt is some indication that her mother tinkered:

I: You said your mom was into some, some of electric type stuff.
H: Oh no she just fixes stuff.
I: Like what?
H: Little things, like I don't know, like, she is just a housewife, like.
I: She is pretty important.
H: Yeah. And she just, I don't know, like she does other things like fixing things and stuff by watching other people. Sometimes, but if it is really bad we get, get the man whatever his name the electrician to do it.
I: Mmh, mmh. Would she fix home appliances and stuff like that?
H: Like I mean she changes the plug and stuff.
I: Yes.
H: She does that. But not, not open it up and repair the inside.

Although Haritha's mother did minor repairs at home it is clear from the above conversation that Haritha does not hold a high opinion of such activities. Nevertheless throughout the interview she does make a number of references to her mother's involvement in minor repair type activities at home which required some tinkering.

From the interview one forms the opinion that Haritha was not encouraged to tinker at home. The following excerpt is some indication of such restrictions:

I: Are you into electronic games and stuff like that?
H: Yeah.
I: You ever take it apart?
H: No! They would kill me.

Haritha clearly felt restricted in tinkering with objects in her household. She did however confess, after some probing, that she sometimes tinkered with her own toys on the sly. Such occasions nevertheless appeared to be rare because she lived in such fear of being caught. Sean and Jason also made reference to some restrictions but they did not appear to let such restrictions stop them as Haritha did. They did not seem to experience the same depth of fear as Haritha did.

Although Haritha's mother tinkered her father did not tinker except on very isolated occasions. Her father's lack of involvement in such activities is indicated in the following discussion:

I: What about your dad does he do any?
H: No, he is a doctor.
I: He is busy I guess.
H: Most of the time.
I: But in his free time if something goes wrong, a small thing or whatever, what does he fix it?
H: No.

Given her father did not tinker and her mother did, Haritha seems to have been influenced by her mother. That is, she saw it acceptable to engage in minor tasks at home, such as replacing electrical fuses and other minor electrical tasks. While she did not necessarily see such tasks as having a high value she nevertheless engaged in them.

The extended family relationship appears to have some influence on her behavior. Once when she was asked about the reason for her career choice she referred to the fact that her aunts and uncles were doctors and lawyers:

I: So you are personally interested in being a doctor or lawyer? Is that where your interests are?
H: Yes. I don't really want to be a doctor because you have to see guts. But eh, and the other reason is, cause most of my uncles and aunts are either doctors or lawyers.

Clearly one gets the feeling from such a discussion that Haritha is encouraged, both at home and from extended family relationships, to seek activities which are of a professional nature. Therefore, within her family, Haritha only gets very limited encouragement to tinker through her mother's influence as a minor role model.

There was no indication during the interview that any of her friends were involved in tinkering. If any of her friends were involved in such activities she made no reference to this. Based on my analysis of the behavior of all the female students in the class, I would describe Haritha as the one who was the most socially aware of the difference in the treatment of females and males by teachers. The following dialogue from the interview is some indication of her social awareness:

I: I noticed that you eh, you noticed that I was interviewing males first and you made a comment, ah, with regards to that. So are you conscious of how females are treated in school?
H: Yes. I am conscious of how everyone is treated in school. Cause teachers, if they need something moved or something, they usually call the boys. But they never call the girls. This is what they treat you. Or if they want to mind the little children or something they call the girls. And not the boys.
I: Mmh, mmh. Do you notice that a lot more here than in Ireland or?
H: More here.
I: More here?
H: Especially in Harbour B.
I: Mmh, mmh. Harbour B. worst than here.

H: Yes.
I: Do you think the other girls are aware of that?
H: No! They don't care. They only want to impress the boys.
I: Aah, aah. But you care.
H: Yeah!

Such conversation led me to believe that Haritha was probably more socially aware than her friends.

School appears to have had only a minor social influence on her to tinker. Throughout her interview she makes a number of references to things she has done previously in school. The following excerpt is one such reference:

I: Can you remember how much you have done with batteries and bulbs?
H: Only a bit with batteries a bit now, what was it now that we did? We made this switch like you put on and off and we'd (inaudible) with the wire and stuff like that and then we made this electromagnet. And then the wire goes around like that. And it had this battery or something and if you do something the magnet kind of pushes this a. What is it? Something iron piece which makes the light go on or the thing ring.
I: Aah, aah. So you have done some. Was that, did the teacher do it or did you make it, those things?
H: We made some and sometimes the teacher did it.

Haritha was the only target subject who did not study science as a subject until the grade seven. She attended school in Ireland where the formal study of science at her particular school did not begin until about the grade seven level. All the other students had been exposed to the STEM science program from kindergarten to the grade six level which was followed by the **Searching for Structure** program in grades seven to nine. Since Haritha had only been in Canada for two years prior to the time of my study her only formal exposure to science began at grade seven. The only reference she made to her involvement in science activities prior to the grade seven level, activities done by student teachers.

A Synopsis of the Social Influences on Haritha

Haritha appears to have been influenced to a limited extent by her mother whom she described as engaging in very minor repairs and maintenance at home. Such activities appear to have allowed very limited opportunities for her to tinker, other than with her own toys. Even with her own toys she was not allowed to take them apart. Her family seems to have had a strong influence on her seeking activities which could be regarded a part of the education of a professional rather engaging in such activities as tinkering.

There is no indication that any of her friends were involved in tinkering. This is a sharp contrast with Sean and Jason who were very much involved with friends who tinkered.

Given that her exposure to science in school was rather limited until the grade seven level, school appears to have had little or no social influence on her to tinker. Based on the interview data, I would conclude that there were no strong social influences to tinker at any level. The only social influence was a weak one with her mother. All three levels of social influence therefore had socially constructed tinkering to have very little or no meaning to her.

Sandra's Social Influences

Overview of Social Influences

Sandra is the younger in a two child household, with the other child being male. The specific family relationships that existed within her family may have contributed to her not tinkering. The following excerpt shows how she described her older brother, who from her descriptions was a tinkerer:

S: My brother really is always, fixing up these things and, I don't understand I am just watching him.
I: Your brother.
S: Yeah
I: What age is your brother?
S: He's in university.
I: He's in university, so you do, do watch your older brother.
S: He use to fix phones, speakers and wires and all kinds of things but I don't know how he does it.
I: Yeah, you use to watch him, so you have seen that kind of thing going on.
S: Yeah.
I: What about yourself?
S: Emh.
I: Do you do stuff like this?
S: I don't know how you does it.

Throughout the interview she makes frequent reference to her brother's constant involvement in everything, from photography to computer programming. At one point during the interview I raise the following question:

I: Why do you think your brother is into this kind of stuff like and you aren't?
S: I don't know. He had a chemistry set there was bottles with chemicals in and everything. He was always making them work. He would come home from school and he like mix baking soda and water and vinegar and. Shake it up and it explodes. He said don't tell Mom and he'd come home and do experiments and do experiments he did in school, where you take a bowl and you put a

> candle on it and you put a glass over it and he'd always come home with this idea, and with batteries he was always interested in that kind of stuff, with batteries and wires and bulbs, but I never took much notice how he did it.

Clearly her brother was not only given toys to play with but he also took advantage of every situation. He did not allow himself to be restricted by parental constraints. Sandra on the other hand, based on my conversation with her, appeared to readily accept such parental constraints.

Not only was her brother into tinkering, but her father as well. At a number of points in the interview she makes reference to that fact. The following excerpt is some indication of her father's involvement:

> I: Mmh, mmh. Do you usually watch when they do that kind of stuff?
> S: For a little while but eh don't.
> I: You are not that interested are you?
> S: No, well usually I only gets in the way. I'll walk on something and they will get angry, so I stay out of the way. Dad is saying one thing Neil is saying the other so, they stay **arguing** and don't get much done. So who wants to hear any one arguing.

Even though both Sandra's brother and her father were tinkerers she did not become an active participant in such activities. She did not want to be part of any activity with her father and brother because of the possibility of an argument. Also, it appears that within her family she was assigned the gofer role. She was taught to watch and pass materials to her brother and father rather than to do it herself. The gofer role was a role which she did not like to play. This is a contrast with Haritha who while restricted at home was allowed to do certain minor tasks. Sandra's mother discouraged her from becoming involved in tinkering. Specifically Sandra noted that her mother did not become involved in such activities. She observed that her mother refused to play the "gofer" role when the males in the household tinkered.

The following excerpt is another illustration which shows how Sandra was influenced by her home environment not to tinker:

I: You can't remember getting into any appliances and getting things to work or see how it worked when you were small.
S: I don't know. I never really had any except merlin.
I: Mmh. So you mean you never had any toys that it could happen to.
S: Well I had toys but I wasn't, all I had really was barbies and stuff like that. Neil had electronic, electronic tank. It was remote I never did understand how that used to work. If that was way over there and you got the thing holding onto the remote thing and it was not connected here how does it work?
I: Did you wish you had toys like that?
S: When I was small, or?
I: You enjoyed the toys.
S: I used to use his all the time when he wasn't around. He had the, this gun that you point at the wall, ghost come up or something and you shoot at it. I used to get at that.
I: So you used to play with his.
S: Mmh.
I: Did you give that up as you got older?
S: No, he got, an electronic concert game you know the organ and calculator and. All that stuff. He got that in grade ten or eleven. He never let me use it, so whenever he wasn't around I get it and use it.
I: Yeah but you used to use it. You found ways of getting to use it.
S: Yeah, I, Dad, like I use to come downstairs and cry when I was small cause he wouldn't let me have any of his toys so dad use to say wait until he goes out and go up and get it. So he use to go out and I would go up and get it.

The above excerpt illustrates how Sandra's family appears to have had a negative influence on her tinkering. Her brother in particular was given every opportunity. He was allowed to engage in all sorts of activities ranging from photography to chemistry. This opportunity existed for her brother from early childhood to the time she was interviewed. Within the family she seems to have played a subordinate role to her brother, in terms of opportunities to engage in hands-on activities. This existed even though within her household there was the richest possible environment for tinkering. She was strongly discouraged by her brother to engage in such activities because he withheld all his toys from her. She described her toys as being mainly dolls whereas her brother had electronic toys and games, photography equipment, and a computer. Given that his toys were far superior to Sandra's, in terms of providing opportunities to tinker, she appears to have been very much restricted. This possibly may have even influenced her to develop a negative attitude towards such activities. The following excerpt is an indication that her brother's negative influence on her has persisted beyond childhood to the present day situation:

I: Now that your brother is older is he still like that?
S: Like what?
I: He won't allow you to use the computer.
S: He tells me to read the book, the book and if I reads the book and goes by the book if I can use but if I can just put, programs in. He use to blackmail me. He says if don't put programs in I'll disconnect your phone again or. Wicked for blackmail.
I: Why would he want you to put programs in?
S: He wanted me to type it all in.
I: Oh he wanted you to do that.
S: He'd write it out and he'd go over it and then he'd help me to type it in. I usually types it in I was using the typewriter so, if I didn't want to do it he'd blackmail me.

Such a relationship would certainly not encourage a female subject such as Sandra to tinker. Therefore I will make the claim that Sandra's family may have had a negative influence on her tinkering.

Nowhere during the interview did Sandra refer to any special relationship that she had with any one who engaged in tinkering. Specifically she made no reference to any friends who engaged in such activities.

At the school and community level there appears to have been only a very minor influence on her to tinker. The school science fairs, alone of all her school experiences, appeared to have had some influence. The following excerpts tell us something about her school experiences:

> I: What about in school?
> S: Seeds or we did something in grades four or five, or something on electricity.
> I: Grades four or five. What about in grade seven and eight?
> S: Not that I can remember.

School provided the only opportunity for Sandra to become involved in activities which required some tinkering. Since such opportunities were very rare during her schooling experience school appears to have played a very minor role in influencing her to tinker.

A Synopsis of the Social Influences on Sandra

There is no indication that Sandra had a close relationship with a significant other such as her father, older brother, or any one else who would have encouraged her to tinker. Since her mother expressed such a disdain for such activities there appears to have been no positive encouragement within her immediate family for her to tinker. In fact the opposite might be the case in that she was very discouraged as a child, by not being permitted to tinker. Probably the most negative factor was the relationship that existed with her brother where Sandra was assigned the "gofer role". Also the utilization of blackmail tactics by her brother was very damaging to her self image as a tinkerer.

Again, as with Haritha, there was no indication that any of her friends tinkered. Throughout my data collection I also did not note any strong influences at school, or in the community which may have had a positive influence on her to tinker. I therefore conclude there was no social influence at any level which encouraged Sandra to tinker. In fact at the first level of influence, the family, there may have even been a negative influence. Tinkering was therefore socially constructed to have either little or no meaning to Sandra, or to have a negative image.

Review of the Social Factors Influencing Tinkering

Table 5-13 summarizes for each of the target students the pattern of social influences, another dimension of the apprenticeship. Based upon the data analysis there appear to be three identifiable levels of social influence on tinkering. Level one - the forming a close relationship with a significant other who shares a common interest. Level two - those influences that form a part of everyday living, such as with close friends. Level three - those relationships outside mentoring or family and friends which influence what a person does, such as the school and other community agencies.

Clearly Sean and Jason have had stronger social influences, on them at all levels, to tinker than did Haritha and Sandra. Sandra in particular appears to have had negative influences. The level of social influence is important in terms of impact on the subject. It is conjectured that a mentor has the greatest influence, with friends being next, and school and other agencies having less influence. That is, the further removed the experience is from the subject, in terms of level of influence, the less influence or impact that it is likely to have on a subject.

A brief review of the above data on the social factors influencing tinkering seems to indicate that Sean and Jason, and to a lesser extent Haritha are involved in an informal apprenticeship in tinkering. The strongest social influence on their apprenticeship appears to be the specific social relationships they have formed outside of school, with mentor or peers. What is most noticeable about the social influences is the stronger the social relationship with a mentor, the greater proficiency of tinkering there appears to be. The differences in social factors for the target students has resulted in differences in the social construction of tinkering.

Personal Factors Influencing Tinkering

Overview of Personal Factors

In this section I will develop the third dimension of the apprenticeship, the personal factors. It was not until data analysis that I was able to construct a category of personal factors. The creation of this category as an analytical framework was prompted by a number of questions that were asked of me during the study. People would often ask such questions as "How do we explain that two children can be raised in the same household, one will tinker and the other will not?" I would offer such explanations as, different social expectations and differential experiences for children of different sexes. Often this answer would satisfy most but some would probe further and ask

TABLE 5-13 **Three Identifiable Levels of Social Relationships**

Target Subject	Level-1 Mentor	Level-2 Family & Friends	Level-3 School & Other Agencies
Sean (Master Tinkerer)	male cousin (++)	home: lots of opportunity for activities (++)	lots of access to activities (++) clubs: some opportunity (+)
Jason (Professional Tinkerer)	father (++)	home: lots of opportunity (++)	lots of access to activities (++) clubs: no reference (0)
Haritha (Amateur Tinkerer)	mother (+)	home: some opportunity (+)	some access (+) clubs: no reference (0)
Sandra (Novice Tinkerer)	no (-) mentor	home: little opportunity (-)	school: some access (+) clubs: some reference (+)

legend:
(+) some influence (++) strong influence
(-) negative influence (0) no influence

such questions as "But what about two boys or two girls raised in an encouraging environment and one tinkers and the other one doesn't?" This question I found much more difficult to answer because such questions seems to indicate personality differences or differences in learning style. In examining my data and being bothered by such questions I noticed that the master, professional and amateur tinkerers expressed varying levels of interest in electricity whereas the novices expressed a lack of, or very little interest in the study of electricity. Specifically I noted varying levels indicated by the subjects' statements and actions. Such indications were especially noticeable during my classroom observations.

It is very difficult to explain this source of personal interest. The source could be very much influenced by the interaction of social and experiential factors, as much as personality factors. Nevertheless, it became obvious to me after some preliminary analysis that there were distinct differences in the target subjects. These differences could be described as personal differences.

The personal factors influencing tinkering constitute a critical dimension of the apprenticeship. Given that an apprenticeship in tinkering is undertaken informally the personal dimension is critical. Otherwise, no apprenticeship would be undertaken. In an attempt to construct the personal factors influencing tinkering I will now take each of the target students and examine the personal factors that may or may not have predisposed them to tinker. The personal factors influencing tinkering for the purpose of my study have been narrowly focused on personal interests, as expressed by the subjects' statements and implied through their actions. To do this analysis it was necessary to again examine the three data bases - survey, interview and classroom. The survey and interview data were analyzed for any statements made by the subjects which indicated an interest or lack of in the study of electricity. In addition, the classroom data provided (a) statements made by the subjects indicating their interest, and (b) descriptions of subjects' actions which were examined for a non-verbal portrayal of their interest level. Such data will be used to show how tinkering was personally constructed by the target subjects.

The Personal Interests of Sean (Master Tinkerer)

Survey

I have selected two survey questions which seem to indicate something about Sean's personal interest in the study of electricity:

Question: What would you like to learn about electricity this year?
Response: Nothing.

Question: Are you interested in electricity?
Response: Yes.

On the surface it might appear that Sean's responses are inconsistent. The first response seems to indicate he is not interested while the second response suggests that he is. A possible reason why Sean responded this way on the first question is that he viewed school electricity, as presented at the grade nine level, as basic which means he felt it would be useless to him. By basic, Sean meant that he will be studying electrical concepts he already knew. Since Sean was able to do electrical tasks much beyond those presented at the grade nine level he obviously would consider those concepts to be studied as basic. For the unit to be challenging or of interest to Sean, more advanced electrical concepts would had to have been presented. Also Sean preferred hands-on learning over lecturing or studying, which he may have interpreted question #1 to have meant. The high activity index on the survey however suggests that Sean had a high level of prior experiences with electricity. Generally when there is a high level of involvement this indicates interest. In addition, Sean indicated on the survey in response to an open-ended question that he tinkered.

Interview Data

One indication of Sean's personal interest in tinkering was illustrated by the kinds of out-of-school activities on whichhe voluntarily spent his time. Sean's interests in tinkering were broad in scope. The following excerpt is typical of such interests:

I: What about cars and trucks and stuff like that? Are you into much of that?
S: Yeah, I **really like**, like working around cars and trucks and things like that.
I: Mmh.
S: I **really like** to learn about that.

This high level of interest in tinkering is conveyed throughout the interview, by his indication of involvement in a wide scope of activities. At one point during the interview I probed him about this interest with the following conversation taking place:

I: Why do you think you do that?
S: I don't know, I **just like**, I **like** fooling around with electrical things and that.

Clearly Sean appeared to have a strong personal interest in activities that can be described as tinkering. His indication that he engaged in such activities out-of-school suggests a strong personal interest. Tinkering can be described as a hobby which Sean engaged in during his free time.

Given Sean was interested in the study of electricity and electronically related activities in general it is not surprising he would have related career interest. The following excerpt highlights his career plans which further illustrates another aspect of his interest:

I: What do you think you would be interested in for a career when you finish school?
S: Going into the air force.
I: Aah, aah. What would you do there?
S: Fly, jets.
I: Fly jets.
S: Mmh.
I: Aah, aah.
S: Or may be I just like, be a co-pilot.
I: Why do you think you would be interested in flying jets?
S: I don't know, I just like, like I when I fly planes I really, really enjoy it.
I: Anything else about it?
S: Well it has got a lot to do with computers and that, and I like to work with computers when I get older.

Such an example further illustrates that electrical and electronic type activities had a special appeal to Sean. His career plans typify the strong personal interest Sean had for such activities.

Sean's interest in tinkering may have influenced his interest in science. The following passage gives some idea of the status he gave science as a subject:

I: What is your favorite subject?
S: Science.
I: Why do you think science is your favorite subject?
S: I just like, the things that we do and the labs and that. I just like knowing things more about science.

Sean obviously assigned a high status to science. He particularly identified with hands-on activity and with areas of physical science such as electricity. While there may have been many reasons for his interest in science, tinkering appeared to have some relationship with this high level of interest.

Classroom Data

The classroom provided two types of data for analyzing Sean's interest in the study of electricity. These two data types included any statements made by Sean with respect to his interest in electricity and his actions during class activities.

All recorded dialogue during classroom discussions and lab activities showed a very high level of interest in the study of electricity. During classroom discussions he was at constant attention and he actively participated in all discussions. The lab activities provided an even better outlet for his enthusiasm for electricity. This was evidenced in his frequent discussions with his lab partner and his offering of advice to others. In both instances he was constantly seeking out new information about electricity.

Sean's actions in the classroom also indicated a very high interest level in the study of electricity. He was constantly interacting with the materials. He indulged in a lot of self-exploration with electrical objects. His actions were spontaneous and continuous. Table 5-14 summarizes Sean's classroom behavior.

Summary

All three data sources indicate that Sean had a very high level of personal interest in electricity. This interest was not focused on reading and writing but being involved in hands-on activity. His personal interests were displayed through his tinkering with electrical tasks both in and outside school. Sean had personally constructed tinkering to be very meaningful to him.

The Personal Interests of Jason (Professional Tinkerer)

Survey

The following two questions on the survey tell us something about Jason's interest in the study of electricity:

Question: What would you like to learn about electricity this year?
Response: I would like to know how capacitors and transformers work and their purpose. How to hook up flashing lights with a PC board, a 10 or 20 pin dish.

Question: Are you interested in electricity?
Response: Yes.

Table 5-14 An Overview of Sean's Personal Interest as Expressed by His Statements and Actions in the Classroom

Description of Actions	Interest Level
-lots of spontaneous engagement in activities -lots of self-exploration with activities -constantly hands-on	**VERY HIGH**

Description of Statements	Interest Level
-frequently seeking new information other than required -frequently offering advice -frequently engaging in off-task discussions focusing on electricity	**VERY HIGH**

Such responses seem to indicate that Jason is interested in the study of electricity. The first response suggests that his interests in electricity go beyond a superficial interest. Moreover he also indicated on the survey that he tinkered with electrical and electronic devices. A further examination of interview and classroom data will add support to the claim that Jason displayed a high level of personal interest in tinkering.

Interview

Jason was very interested in electricity and electronics-related activities as illustrated by the following excerpts of comments he made during the interview:

Excerpt #1
I: So are you into much of this kind of stuff at home?
J: Yeah I loves stereos. This summer I was working with my father and, the money that I made, I went and bought parts for a stereo.
Excerpt #2
I: You said you are into this kind of stuff out of school are you?
J: Oh yeah! **Loves** shagging around with stuff with electricity and that.
I: You do?
J: Yeah.
Excerpt #3
J: I likes experimenting and stuff.
Excerpt #4
I: So you're somewhat of a handy person.
J: What? Yeah I suppose, could say.
I: You like making things.
J: Oh, yeah! I loves doing stuff like that.

Such excerpts are illustrative of Jason's strong personal interest in tinkering with electrical and electronic equipment. His use of the word **loves** also conveyed his high interest level.

Jason was very interested in the study of science. The following statements are an indication of this interest:

I: What is your favorite subject in school?
J: Science.
I: You are just telling me this cause?
J: No serious, I get the best marks in science.
I: Mmh, mmh.
J: And, for some reason I used to like math too, but this year I am not too fussy about it, for some reason.
I: Mmh, mmh.
J: But seriously science, ah **I rather do science than anything.**
I: Mmh, mmh.
J: But I don't like dissecting that much, right.
I: Why?
J: I don't find it as interesting really, as things.

I: What kind of science would you prefer to do if given your choice?
J: This I would say.
I: Mmh, mmh. This you mean, electricity or?
J: What? Yeah electricity.

Given Jason had a strong interest in tinkering with science related activities it is not surprising he identified science as the school subject he liked best. He viewed the study of science as an opportunity to become involved in hands-on activity. The area of science that he obviously identified with is the physical sciences and with electricity in particular.

When Jason was asked what his career plans were he indicated an interest in a technical area which is related to the study of electricity:

I: Got any ideas what you would like to do when you finish school?
J: Technician. Electronic technician.
I: Electronic technician. Seems like Frankie mentioned that.
J: Did he? Yeah. Well every day when we does stuff like this, we always talk to each other about, wanting, about it right.

Clearly Jason planned to make a career of the kinds of activities he engages in out-of-school. Since Jason planned to become an electronics technician it is not surprising he tinkered with electrical apparati, nor that his personal interest level was high.

Jason was so interested in electricity that he was not discouraged by the risks involved in the informal study of electricity. The following excerpt indicates he was not afraid to get involved with electricity, even when there were some safety risks:

I: Earlier you said that you got a shock.
J: Yeah.
I: Did that scare you?
J: First when it hit me like, like it bothered me.
I: Will that stop you from going at it again?
J: Naah.
I: You have no fear. Is that what you are saying?

J: Yeah I suppose, or else I never really had a bad one now, probably if I do I'd still do that same thing again.

His personal interest in tinkering with electricity was so strong that even safety appears to be of a secondary concern to him. Like Sean, Jason's tinkering could be described as a hobby which he engages in during his free time.

Classroom Data

Jason's classroom behavior further supports the above pattern. Both in classroom discussions and lab activities Jason expressed a high level of interest in electricity. His interest was expressed by actively engaging in dialogue which focused on the study of electricity. Jason was observed throughout my study to engage actively in classroom activities that were hands-on. He spent a fair amount of time off-task in terms of what the teacher requested him to do but he was actively engaged in self-exploration with electrical apparati. His actions were spontaneous and continuous indicating a high level of interest in the study of electricity. Table 5-15 summarizes Jason's classroom behavior.

Summary

All three data sources appear to indicate that Jason had a high level of personal interest in tinkering. His level of interest appeared to be almost as strong as Sean's. He had personally constructed tinkering to be very meaningful to him.

The Personal Interests of Haritha (Amateur Tinkerer)

Survey

An examination of Haritha's responses to the following questions on the survey indicates her general interest in electricity:

Question: What would you like to learn about electricity this year?
Response: I would like to make it.

Question: Are you interested in electricity?
Response: Yes.

Haritha's responses on the survey showed an interest in the study of electricity. She also indicated on the survey that she tinkered. An examination of the interview and classroom data help to further evaluate her level of interest.

Interview

Haritha had a high level of interest in science. When asked if science is important she responded in the following manner:

I: Do you think science is important?
H: Yes.
I: Why?
H: Because if you want to get a good job you need to know about science.
I: So are you planning to study more science later on?
H: Yes.
I: Aah, aah. What career do you think you would be interested in?
H: Don't know doctor or lawyer?

Table 5-15 An Overview of Jason's Personal Interest as Expressed by His Statements and Actions in the Classroom

Description of Actions	Interest Level
-some spontaneous engagement in activities -lots of self-exploration with activities -constantly hands-on	HIGH
Description of Statements	**Interest Level**
-sometimes sought new information other than when required -sometimes offered advice -some off-task discussions focusing on electricity	HIGH

I: Why do you say doctor or lawyer?
H: Cause my dad is a doctor and and the lawyer. Seems a easy job. Like, you don't have to study awful stuff you just have to study words.
I: Mmh, mmh. What do you mean study words?
H: Like you just read something and you have learnt it off that is all.

She clearly regarded science as having a high status for future career opportunities. Beyond viewing science as having career potential Haritha did express some interest in the study of science. The following dialogue gives some idea of her specific interests as it relates to the study of science:

I: What do you think of science as a subject?
H: Ah, there, I think it is fun if you have a nice teacher. If you are interested in it or if you are allowed to do whatever you want. If you can mess with the stuff.

Haritha's interest in science appears to have been mainly focused on hands-on activity. This also agrees with her statement on the survey that she liked to tinker.

When I asked her about her favorite area of science she made the following comment:

I: What is your, favorite type of science?
H: Chemistry.
I: What other area?
H: Don't like biology anyway. And physics possibly.
I: Mmh, mmh. Why do you say chemistry is your favorite area?
H: Because it is a something, I don't know it is just interesting to watch things grow. Evaporate and.
I: Why, why physics?
H: Emh, it is just interesting.
I: Interesting what do you mean?
H: I don't know things like you see them everyday but you don't realize it is all physics.
I: You find physics helpful?
H: It is just I don't know. Ah, probably. Is this another clip in here?
I: Yes. Why do you dislike biology?
H: It is because it has got guts in it.

She was obviously more interested in the physical sciences than the biological sciences. This was also true of Sean and Jason who expressed a stronger interest in the physical sciences than the biological sciences. Even though she expressed a stronger interest in the physical sciences, her interests in electricity is at best moderate, as indicated in the following excerpts from different parts of the interview:

Excerpt #1
I: What about electricity what do you think about it?
H: It's o.k.

I: On a scale from one to ten how would you rank electricity?
H: Seven. I probably like (inaudible)
I: Why do you say think that is so?
H: Cause I don't know, I am not really great at that I guess.
I: You can mess with stuff in electricity.
H: Yeah but then not enough like. I don't know. I think that is it.
I: So electricity in terms of difficulty how would you rank it on a scale to ten?
H: Ah it is not difficult but then it is not easy. Probably eight.
I: In terms of difficulty or easy?
H: Easy.
I: Easy.

Excerpt #2

I: Do you like doing this kind of stuff?
H: I suppose it is o.k.

Excerpt #3

I: Are you interested in this kind of thing?
H: (inaudible)
I: Not much, don't seem like you are very interested.
H: Not really.
I: Would you say very interested, or moderate or low?
H: Moderate.

Such excerpts illustrate that her interest in electricity appeared to be at best moderate. Although such discussions appear to indicate she would like to tinker with electrical apparati, tinkering does not appear to have a strong appeal to her.

Haritha's interest in electricity and electronics appeared to be mainly restricted to minor involvement in electrical repairs and some limited involvement with her own personal belongings. Her interest was not such that she engaged in tinkering as a hobby out of school. The following excerpt will give the reader some indication of her interests during her free time:

I: What is your favorite things to do in your spare time?
H: I don't know. Do I have to do it now? (in response to the bell ringing)
I: No.
H: Watch TV, and sometimes I read, most of time I listen to music, and watch TV, I go out and play rounders with my friends.

Although Haritha identified with tinkering she did not engage in many activities outside of school that could be described as tinkering. Her personal interest in tinkering appears to be at best moderate when compared to Jason or Sean.

Classroom Data

The classroom data further supports the above pattern. During classroom discussions Haritha did not offer many comments unless requested by the teacher. She did however make notes and listen attentively. The transcripts from small group discussions show Haritha taking a more verbal role. Haritha's interest in studying electricity and tinkering with electrical apparati was evident throughout the study. Although she did not act out as strong an interest in tinkering with electrical apparati as did Sean or Jason she did take an active interest. While she did not go beyond the bounds of a given assignment she did some self-exploration with the materials at her disposal in the lab. Table 5-16 summarizes Haritha's classroom behavior.

Summary

Haritha's level of personal interest can be described as moderate. The final determination of her level required a close examination of all three data bases to form a complete picture. Although there was some indication of a possible interest in tinkering based on survey and interview data, it was data from the classroom observations that were most helpful in describing her probable level of interest.

The Personal Interests of Sandra (Novice Tinkerer)

Survey

I will now examine Sandra's response to a number of questions on the survey. The following responses provide some indication of her interest:

Question: What would you like to learn about electricity this year?
Response: I would like to learn about the safety and what you should and shouldn't do about electricity.

Question: Are you interested in electricity?
Response: Suppose.

Such responses suggest that Sandra may have a low interest level in the study of electricity unless it relates to health and safety issues. This is consistent with studies which have indicated that females are interested in health and safety issues related to the study of science. In addition, she also indicated on the survey that she did not tinker. An examination of other data however is necessary to support the claim that Sandra has a low level of interest in the traditional study of electricity as presented in junior high science curriculum.

Interview

Sandra is not very interested in the study of electricity and other areas of physical science. This lack of interest is obvious by examining the following excerpts from the interview:

Table 5-16 An Overview of Haritha's Personal Interest as Expressed by her Statements and Actions in the Classroom

Description of Actions	Interest Level
-no spontaneous engagement in activities -limited self-exploration with required activities -frequently hands-on	**MODERATE**

Description of Dialogue	Interest Level
-sometimes sought new information -frequently sought advice -rarely engaged in off-task discussions on electricity	**MODERATE**

Excerpt #1
I: What area of science do you like?
S: Biology.
I: Why do you think you are interested in biology?
S: I don't know.
I: It appeals to you, or is there any other reason?
S: I don't know. (shakes her head) It's just.

Excerpt #2
I: What about electricity? How well do you like it?
S: Well, it is hard to understand.
I: Mmh.
I: Why do you think it is hard to understand?
S: I don't know. I never did much with it before.

Such excerpts suggest Sandra was more interested in biology and did not identify with physical science areas such as electricity. She also indicated that it was probably because she had not tinkered with electricity.

Sandra's career interests, although science related are not in the physical sciences. The following excepts are some indication of her personal interests:

> I: Any idea what you would like to study when you finish?
> S: Well something with hospitals. I was going to go for a surgeon but it takes ten years of study. So I was going to go in for lab work.
> I: Why do you think you are interested in something to do with the hospital?
> S: I go there a lot. I don't know.

Again Sandra did not identify with the physical sciences as a potential area for future study or a career. She was however quite interested in the biological sciences, as indicated by her contemplation of a career in that area. Her career interest in the biological sciences was consistent with her school science interest in biology. Given she was interested in a science related career this suggests she was not completely turned off by school science. Her career focus may been influenced by her medical history which required frequent hospital visits. The fact that her mother was a nurse may also be a significant factor in her career interest.

Classroom Data

The pattern noted in the interview was also supported by classroom observations. Sandra only became involved in formal classroom discussions and activities when absolutely required. One strong factor there was that she was extremely shy. She did however make notes and was always very attentive during discussions. The data from the large group discussions therefore provide little or no insight into Sandra's interest in the study of electricity.

When she was a part of small group discussions during lab activities she did participate but she did not express any enthusiasm or interest in electricity. Her off-task discussions focused on discussing other topics rather than anything related to electricity. Sandra's lack of interest in tinkering with electric apparati was obvious from her lack of involvement with the materials provided her in the lab setting. She engaged in no self-exploration and did as little hands-on activity as possible. Table 5-17 summarizes Sandra's classroom behavior.

Summary

The three data bases suggest that Sandra's level of personal interest in tinkering was low. Her low level of personal interest is obviously interrelated with social and experiential factors which were not supportive in encouraging her to tinker. All these factors appears to have negatively contributed to her personal construction of tinkering.

Review of Representative Target Subjects' Interest Levels

Table 5-18 summarizes the personal context of tinkering for representative target subjects based on the survey, interview and classroom observations. The subject's level of interest in the interview and classroom settings was determined by examining any statements and actions which expressed an interest in electricity. Level of interest was not determined by the survey, but it was noted was if there was any interest expressed in response to the open-ended questions.

Table 5-17 An Overview of Sandra's Personal Interest as Expressed by her Statements and Actions in the Classroom

Description of Actions	Interest Level
-no spontaneous engagement in activities -no self-exploration, only required activity -only hands-on when absolutely required	LOW

Description of Dialogue	Interest Level
-only sought required information -never sought advice other than to do required work -never engaged in any off-task discussions on electricity	LOW

Table 5-18 summarizes the personal factors influencing an apprenticeship in tinkering. These data bases show the level of personal interests indicated by each of the target subjects for an informal apprenticeship in tinkering. Sean and Jason had the strongest personal interest in an informal apprenticeship. Haritha expressed some interest whereas Sandra expressed little or no interest. Based on the profile of interests in Table 5-18 there appears to be a strong relationship between the target subjects personal interests and their proficiency of tinkering.

TABLE 5-18 A Review of Subjects' Personal Interests in Tinkering as Determined by Three Data Sources

Target Subject	Data Source	Interest Indicated
Sean (Master Tinkerer)	Survey	Yes
	Interview	High Level
	Classroom	Very High Level
Jason (Professional Tinkerer)	Survey	Yes
	Interview	High Level
	Classroom	High Level
Haritha (Amateur Tinkerer)	Survey	Yes
	Interview	Moderate Level
	Classroom	Moderate Level
Sandra (Novice Tinkerer)	Survey	No
	Interview	Low Level
	Classroom	Low Level

The Apprenticeship as Defined by the Social, Experiential and Personal Factors

Table 5-19 presents a summary of the experiential, social, and personal factors of tinkering for each target student. On this basis, tinkering has been described as an apprenticeship where the experiential, social, and personal factors all appear to play a significant role. This chapter has attempted to illustrate how these factors contribute to what I have described as an apprenticeship in tinkering. While it may appear, based on the data collected, that the experiential and social factors are more significant one must acknowledge that without the personal desire to tinker no apprenticeship would be undertaken. These factors all appear to be interactive.

Based on the data collected Sean and Jason can be described as engaging in an informal apprenticeship. This means that without formal agreement, without probably even being conscious of the circumstances, all the elements of an apprenticeship were present. In both cases there was a strong positive influence of a significant other, they had a great depth of experiences with electrical objects and a very high level of personal interest. With all three factors having a positive influence on Sean and Jason, it is not surprising that their tinkering would be at the professional or master level.

Haritha had also undergone an apprenticeship. She had some experiences with electrical devices and she had a mother who tinkered. This apprenticeship was however somewhat weaker than Sean's or Jason's in that she did not value her mother's influence. Moreover, the level of expertise her mother was able to offer her was not at the same level as that which Sean and Jason received. Her mother's influence was therefore weak. In addition, Haritha's depth of experience with electrical activities was somewhat limited

TABLE 5-19 Three Components of the Apprenticeship: The Experiential, Social and Personal Factors of Tinkering

Target Subject	Component	Factor Level
Sean (Master Tinkerer)	Experiential	Very high depth of experience
	Social	Level 1 (mentor) - strong positive influence Level 2 (family & Friends) - strong positive influence Level 3 (community agencies) - positive influence
	Personal	Very high level of interest
Jason (Professional Tinkerer)	Experiential	High depth of experience
	Social	Level 1 (mentor) - strong positive influence Level 2 (family & friends) - strong positive influence Level 3 (community agencies) - strong positive influence
	Personal	High level of interest
Haritha (Amateur Tinkerer)	Experiential	Low depth of experience
	Social	Level 1 (mentor) - weak positive influence Level 2 (family & friends) - weak positive influence Level 3 (community agencies) - weak positive influence
	Personal	Moderate level of interest
Sandra (Novice Tinkerer)	Experiential	Low depth of experience
	Social	Level 1 (mentor) - negative influence Level 2 (family & friends) - negative influence Level 3 (community agencies) - weak positive influence
	Personal	Low level of interest

when compared to Sean or Jason. Her level of personal interest was also lower than Sean's or Jason's. This all seems to suggest that her status as an amateur was very much influenced by these factors.

Sandra however did not undergo an apprenticeship. She did not have a significant other. Her older brother and her father who could have played such a role did not. They could in fact be interpreted as having a negative influence on her. Even though she described the experiences with electrical activities as existing in her home, she was discouraged from engaging in such activities. Now at the junior high level she appeared to have no personal desire to do so. It is therefore not surprising that her status as a tinkerer was at the amateur level.

What is obvious is that each of the three factors has had varying effects on the target subjects. One of the most obvious differences involves gender differences, the focus on in the next chapter.

Summary

This chapter through the examination of the social, experiential, and personal factors of tinkering has proposed that tinkering be described as an apprenticeship. The result was an apprenticeship metaphor was proposed to describe the influence of these factors on tinkering. This adds to the characteristics of tinkering proposed in chapter four, further describing the model of tinkering.

Chapter six will discuss gender differences within the model of tinkering which has been constructed.

CHAPTER 6: A DISCUSSION OF GENDER AND TINKERING

Introduction

The aim of this chapter is to discuss at some length the secondary focus of my study, gender differences in tinkering. A discussion of gender differences is necessary given that my problem originated from a review of females and science literature. Specifically it has been conjectured in the literature that tinkering is a potential explanation for gender differences in the physical sciences. This chapter, through a review of gender differences in the characteristics and apprenticeship factors of tinkering, will show that female and male subjects brought different approaches to their study of electricity. Beyond that I will argue that tinkering is an activity that favors males and puts females at a disadvantage. This argument will be based upon the work of Belenky, Clinchy, Golberger and Tarule (1986) on "women's way of knowing". Their work provides a framework for viewing tinkering as "connected knowing" for males and "disconnected knowing" for females.

Given the number of subjects (three female and three male) used was extremely small, any patterns noted for gender differences should be regarded as preliminary conjectures. Nevertheless, given the thick descriptions this allows for some reasonable conjectures about gender differences in tinkering. Before undertaking a discussion of gender differences in the characteristics and apprenticeship factors of tinkering the next section will review some of the difficulties involved in selecting female target subjects.

Difficulty in Initially Selecting Female Target Subjects Who Were Described as Tinkerers

When initially selecting a target class, I did attempt to select subjects of both sexes who were described by their teachers as tinkerers. However, not one female subject in the classes observed (prior to making a final selection of a target class) was categorized as a tinkerer by former teachers. Whereas within the target class of 27 students twelve male students were described by their teachers as tinkerers. This opinion was supported by my observations. In addition, during my preliminary research and pilot studies there was no difficulty in locating male subjects prelabelled as tinkerers by their classroom teachers, whereas it was almost impossible to find female subjects who could be given such labels. In fact during the pilot study phase no female subject was described by the teachers or myself as being a tinkerer (for a subject to have been described as a tinkerer at that stage of my research, such a subject would likely have been a master or professional tinkerer).

Female tinkerers who could be described as master or professional appear to be rare. During the final selection process one of the elementary school science teachers I interviewed referred to a female that he once had as a student who was now studying engineering. This same student was also noted by another elementary school teacher. This was the only female student that was described as a tinkerer by any of the 15 elementary school teachers that I interviewed during the pilot study. The only other reference to a female tinkerer was during the preliminary phase of the study where I interviewed a student that was described by her physics teacher as a tinkerer.

Although the students referred to above were not target subjects in the final phase of my study some interesting information about these two subjects should be mentioned. This information may provide hypotheses for future studies. Both females were in all female sibling households and were described as having a close relationship with their fathers. This may have allowed for gender role cross-over or the acceptance of an activity that is perceived by the population at large as a masculine activity. Such statements are purely conjectural, conjectures that should be explored in future research.

Characteristics of Tinkering and Gender Differences

Typology of Tinkering

Gender Differences in Purposes for Tinkering

From the data collected four purposes for tinkering were identified: utilitarian, technological, scientific, and pragmatic. Based on such categories it appears that males and females brought different focuses to the study of electricity. The males were representative of a variety of types (scientific, technological, utilitarian) whereas the females were representative of one type, pragmatic tinkering.

Female tinkering appeared to be motivated by a desire to perform for grades whereas the males appeared to have a wider variety of motives for tinkering, such as wanting to fix something, being interested in technical complexity, or wanting to know the **how** and **why**. Haritha, however, did demonstrate a slight variation from the female pattern in that not only was she pragmatic, she was also interested in the how and why. Females such as Haritha may more readily engage in an activity which is perceived as masculine. She was an exception in that she was not too intimidated to engage in activities that are the more common among males than for females.

There were distinct gender differences among the target subjects in their purposes for tinkering. The type of tinkering practised by Sean, Jason and Paul seemed primarily geared for their own personal exploration; that is, these subjects focused on things beyond the evaluation requirements of instruction. The emphasis of Jason's behavior was utilitarian, with Paul's being scientific, and Sean's, technological. They all appeared to tinker for more personal or intrinsic reasons as opposed to performance for grades. This is a sharp contrast with Sandra and Leann who appeared to be mainly concerned about meeting the school requirements. Haritha, however, appeared to have both academic and personal reasons for tinkering. If tinkering is viewed as an activity that is more appropriate for males this may help to explain why males may develop more intrinsic reasons for tinkering than do females. Certainly one must also acknowledge that the electrical materials the students were required to work with were from the male sphere of experience.

Gender Differences in Proficiency

A review of the proficiency of tinkering shows the subjects were categorized as novice, amateur, professional, and master. In terms of this categorization system the males were at the higher end of the proficiency level whereas the females were at the lower end. That is, the females were not professional or master tinkerers, whereas some of the male target subjects were. The fact that males were the professional and master tinkerers may be related to their reasons for tinkering. The males tinkered for utilitarian, technological and scientific reasons. Since females were primarily school-focused or engaged in pragmatic tinkering it is very unlikely that such females would be encouraged to become professional or master tinkerers. Success in science as defined by school examinations, does not require a mastery of hands-on activity. Rather, it tends to focus on an ability to master the content that is presented. The target females were masters at the art of reading the teacher's requirements for school science, so therefore it was not necessary for them to focus on hands-on activity to be successful. They had learnt to be successful by simply observing hands-on activity. The female subjects constantly displayed this strategy throughout my observations whether they were asked to observe teacher demonstrations or take part in activities. Their talent appeared to lie in their ability to abstract the correct responses from the teacher's instructional objectives.

Within the class the male students tended to work with students at their own proficiency level and to avoid female partners. That is, the professionals consulted with other professionals or the master tinkerer. They did not consult with amateurs or novices. The amateurs and novices on the other hand worked mainly with other subjects who were also at their own proficiency level. This often resulted in the females who were predominately amateurs and novices running into difficulties which required assistance from the teacher. This classroom pattern was illustrated by Sean who worked with his lab partner Gary (a professional), Jason who worked with his lab partner Frankie (a professional), and Paul (a amateur) working with his lab partner Trent (a professional). The result was these three lab groups were often the focus of laboratory activity because they frequently shared information and interacted as a group. In fact, at points during my observations these three groups often formed into one or two larger groups to work on an activity. Such events occurred spontaneously and no such pattern was observed within the female groups. Whether one interprets the activity as a gender split or proficiency split the tinkering power base within the target class was obviously male.

There may exist females who are at the status of professional and master tinkerers and with similar purposes for tinkering as the male subjects. My preliminary research and pilot studies however indicate that such females would be very rare. On the other hand, all stages of my research appear to indicate that males at the professional tinkerer status may be fairly common. Because males have displayed greater proficiency at tinkering it has come to be viewed as an appropriate activity for males and conversely an inappropriate activity for females. Therefore unless we do something to alter the proficiency imbalance is very unlikely we would expect to find many females engaged in tinkering.

Gender Differences in the Phases of Tinkering

What is clear from the analysis of interview and classroom data (as presented in Tables 4-5 and 4-6) on the phases of tinkering is that males made greater progress when tinkering than did females. The process of tinkering was defined as a problem solving process consisting of four phases:

1. searching for the problem,
2. framing the problem,
3. solving the problem, and
4. evaluating the solution.

The target males exhibited more advanced phases of the tinkering process than the target females. While there was variation within the female and male subjects, the greatest difference between target subjects appears to be on the basis of gender. If males exhibit a more advanced phase of tinkering, this might explain why males have more success with their tinkering than females. If tinkering is a successful activity for males and not for females, this may also explain why more males engage in tinkering.

Gender Differences in the Knowledge Bases of Tinkering

The construction of the proficiency and process components of tinkering was based on the verbal and actional knowledge displayed by the target subjects. Table 4-11 in chapter four presented a summary of the target subjects' range and highest levels of actional and verbal knowledge based on interview and classroom data. The male target subjects showed a higher level of actional and verbal knowledge levels than the female target subjects. In addition, the dominant level of actional and verbal knowledge was higher for the male subjects. Again this pattern is consistent with gender differences in the phases and proficiency of tinkering discussed earlier. If master and professional tinkerers are predominantly male, one would expect males to practise a higher level of actional and verbal knowledge both during the interview and in the classroom setting. Likewise, if females are novice and amateur tinkerers we would expect them to practise a lower level of actional and verbal knowledge.

Given that the construction of the components of tinkering relied on data from two knowledge bases - verbal and actional knowledge - and that there were noted gender differences, a more detailed review of these two knowledge bases is necessary. Belenky et al. (1986) in their discussion of women's ways of knowing provide an appropriate framework for the interpretation such differences.

An Examination of the Verbal Knowledge Base of Tinkering for Ways of Knowing

The Status of Female and Male Verbal Knowledge.

If we examine the verbal knowledge utilized by the target subjects when tinkering, we note different levels of knowledge were displayed by the master, professional, amateur and novice tinkerers. We also note that, in the context of my study, males were the masters and professionals whereas females tended to be the amateurs and novices. Within the class based on my observations there were males whom I categorized as amateurs; however, there were no females who could have been described as masters or professionals. That is, in terms of their level of verbal knowledge of electricity, males in the class tended to range along the whole spectrum from amateur to master tinkerer whereas females tended to be amateur or novice in status.

The Focus of Female and Male Verbal Knowledge.

Since all the target students were achievers in terms of school criteria and were described as being of average or above academic ability, what were the sources of their verbal knowledge? A review of data I collected shows verbal knowledge can be categorized as emanating from two sources, out-of-school experiences and in-school experiences. Specifically the pragmatically focused female target subjects (Sandra, Leann and Haritha) can be described as relying primarily on knowledge largely acquired through in-school experiences. The male target subjects Sean (technological) and Jason (utilitarian) however, tended to rely primarily on knowledge from out-of-school experiences with hands-on activities. Paul who was scientifically focused was able to bridge two experiential worlds. While he highly valued knowledge derived from the in-school experiences, he saw the importance of knowledge derived from out-of-school experiences. Although he had fewer out-of-school experiences related to tinkering than Sean and Jason, he was part of a well informed male network within the classroom. Paul was very much valued within this male network for his high level of school-based knowledge. He was very well liked by all his classmates and they viewed him as an intellectual. This was also the perception held by the teacher. Haritha who had a weak scientific focus attempted to bridge two worlds but her out-of-school knowledge was limited. Also, only her in-school knowledge was valued within the female network. The result was that Haritha was encouraged to focus on the in-school knowledge. This illustrates that networks among students and segregation by sex are obviously very powerful influences on their tinkering.

The above argument suggests that females and males brought different types of verbal knowledge to a classroom context which required tinkering. Because of this their verbal knowledge not only differed in proficiency but also in the focus of their interest. Overall males relied more on themselves and their own experiences, whereas females relied on the text and the teacher. Therefore it can be concluded that the verbal knowledge presented within the classroom was more crucial for females than for males. This focus on knowledge also takes precedence on classroom exams. .

It is also important to analyze how female and male subjects utilized various types of verbal knowledge in their study of electricity. If we view knowledge derived from tinkering within the realm of commonsense knowledge, and the formal study of electricity as school science, then the males appeared to show a greater preference for commonsense knowledge whereas the females preferred school science. The fact that commonsense knowledge is more likely to be picked up out-of-school, and school science within in-school experience, further highlights the gender differences in verbal knowledge. It also seems to suggest that females and males brought different focuses to their study of electricity. This difference in focus on knowledge, as it relates to the study of electricity, favoured males when tinkering was required. Moreover, since males displayed higher levels of verbal knowledge as it relates to tinkering, this might lead one to view tinkering as an activity which favored the male subjects.

The Actional Knowledge Base of Tinkering and Different Ways of Knowing

The Status of Female and Male Actional Knowledge.

The target subjects showed a wide range of diversity in terms of actional knowledge. Specifically, the master and professional tinkerers had a greater depth of actional knowledge than did the amateur and novice. That is, target males had a greater depth of actional knowledge than target females. The result was the reliance of the female amateur and novice tinkerers on verbal knowledge which was primarily text-book based. The males (Sean, Jason) however had a greater actional knowledge base to draw upon. They therefore did not need to rely upon the school-based knowledge which focused primarily on verbal knowledge. Paul was the only male subject to utilize both actional and verbal knowledge. Haritha, on the other hand, attempted to improve her actional knowledge but she did not make the same level of progress as Paul. She was not part of the male network. Her gender appeared to be a barrier, whereas it was not for Paul. Again this illustrates that networks among students and segregation by sex are significant factors.

Female and Male Actional Knowledge in Classroom Setting.

The female and male subjects brought varying levels of actional knowledge to a classroom context which required tinkering. Compared to the females, the overall pattern of actional knowledge noted for the male target subjects was at a higher level. The actional method taken by the females was clearly an observational approach to the study of electricity. The males followed a hands-on actional method. Specifically, the approach taken by Sean and Jason was hands-on or "learning by doing", whereas Leann and Sandra took an observational approach or "learning by watching". Paul's and Haritha's methods overlapped both the hands-on and observational approaches. Paul however was able, through his male network, to be more successful with a hands-on approach than was Haritha. Although Paul did not complete all of the actional requirements on his own, he was party to a well informed male network. Haritha, on the other hand, had to struggle with no support or encouragement from her female classmates. Her lab partner, Leann, was so focused on performance for grades that she would not entertain any "messing around" from Haritha. This pattern is illustrated in the transcript of small group discussions, Appendix C when Leann demanded that Haritha be always on task as defined by the text or the teacher. There were often minor disagreements between the two because of this difference. Such a pattern suggests that it was difficult for Haritha to move outside the more established patterns of female classroom behavior.

There may be many explanations for differences in approach to electrical activity. It appears that some females (Leann, Sandra) may have developed a phobia for electrical devices. Their prime interest in fact appeared to be focused on understanding the requirements for school science or safety issues, all of which can be accomplished through observation. Haritha's phobia for electrical devices was not as pronounced as that of Leann and Sandra; she was however fearful of some electrical activities. Males on the other hand did not display any fear of electrical devices.

One noticeable behavior pattern for male target subjects was their tendency to monopolize the equipment. They were the first to obtain the available equipment required for the activities. This tendency was especially noticeable if the equipment was in short supply. The female subjects appeared to play a marginal role in the hands-on study of electricity. Whenever there was a shortage of equipment females were the most disadvantaged because they usually were last to pick up equipment. An instance which illustrated this behavior occurred when the class was assigned activity #4 on series and parallel circuits. In this case there was a shortage of electrical sockets and switches and because the males were the first to pick up the equipment. Sandra and her lab partner therefore took a longer time to complete the activity because they were short on the number of electrical sockets required. Alternately, Sean acquired extra sockets and batteries to further explore the limits of the circuits and went beyond the requirements for the assigned activity. Overall the females tended to take a less active role than did the male target subjects. This distinct pattern for female and male subjects was often repeated throughout my observations. Based on these observations, the school context appears to provide an environment which favors an inequitable distribution of resources which puts the females at a disadvantage.

Females and males also appeared to be at different ends on a continuum ranging from abstaining to compulsive involvement in the activities, with the females abstaining and the males compulsive. Sean, Jason, and Paul tended to be constantly involved in hands-on activity whether on-task or off-task. Their counterparts (Sandra, Leann and Haritha) took mainly an observational route concentrating on doing only what the teacher absolutely required. Often they completed the assigned tasks by just doing the necessary paper requirements. Even Haritha, who displayed the greatest interest in hands-on activities, took primarily an observational approach to the study of electricity.

Also, Haritha was handicapped by Leann, her lab partner who did not value any other approach than that of observation.

Females by taking an observational approach tended to "follow the leaders" in completing the assigned activities. The leaders, in this case, were either the male master and professional tinkerers or the teacher. While the females did not actively take part in the hands-on activity and remained segregated they observed the results from a distance. The approach taken by the female subjects therefore is in sharp contrast to the males. In terms of actions the male subjects displayed dominant leadership by using a hands-on approach; the females through their observational approach could be referred to as the non-dominant actional group. The result was that the level of actional knowledge displayed by males was more advanced than females. Males were seen as playing a leadership role. This was especially true for Sean who played the role of class consultant. The female subjects who lacked the actional skills necessary to become actively involved were forced into an observing or seeking assistance role rather than actively exploring the activities for themselves. Therefore, in terms of actional knowledge, female target subjects were forced to play a marginal role. Male subjects were a part of an established informed actional network; the females were a part of an uninformed nonactional network.

The male preference for actional knowledge was also obvious even when actional knowledge was not the dominant mode of instruction. Whenever the teacher used demonstrations or large group activities to illustrate specific electrical concepts, males were always in the inner circle near the teacher and equipment whereas females were in the outer circle. Within the classroom context there were also distinct gender differences in the actions taken in response to situations that allowed for tinkering. Throughout my observations notes were made of such responses focusing specifically on the target students. Such data suggest that males had a preference for actional knowledge whereas females preferred verbal knowledge. Moreover, it also supports the earlier claim that males prefer a hands-on approach whereas females prefer an observational approach. This pattern also favors males and puts females at a disadvantage when tinkering is required.

Female and Male Actional Knowledge in the Interview Setting.

The overall pattern noted for the level of actional knowledge within the interview context was very similar to the classroom. Male subjects displayed a higher level of actional knowledge whereas female subjects displayed a lower level of actional knowledge. Since the interview format strongly encouraged students to display actional knowledge the patterns noted in the interview encouraged the display of actional knowledge as the dominant mode of response. Within the interview context all the subjects were placed in a position where they were required to perform for the interviewer. Sean and Jason explored beyond the limits of the tasks and tried out new investigative ideas. Leann and Sandra however attempted to concentrate on meeting only the stated requirements for completing the tasks. The hands-on approach to completing the task during the interview session was a comfortable mode of performance for Sean and Jason. Sean seemed fascinated by any technical complexity or novelty while Jason displayed a flare for fixing things. Tinkering with electricity for Jason in his view was being useful. Sean, Jason and Paul were much less focused on the textbook requirements than the female target subjects. Haritha was even more textbook focused during the interview than she was during my classroom observations. This difference may be largely attributed to the fact that Haritha, like the other female students, could have easily interpreted the interview as more of a testing situation. The conclusion that might be made is that during the interview males were focused on the task (actional knowledge), whereas females focused on the text (verbal knowledge).

One distinct difference between the classroom and interview was that the very structure of the interview forced all subjects into a hands-on approach. Given what is now known about these subjects, the hands-on approach provided a handicap for the females. This was especially true for Leann and Sandra. In Haritha's case, while she was open to the hands-on approach, she was, nevertheless, extremely handicapped by this investigative mode in terms of achieving success with the task requirements. Also, during the interview she was placed in a situation which required her to perform with a dominant focus on the task and not the text. While she had less difficulty in being task focused compared to Leann and Sandra, she did not complete most of the tasks to her own satisfaction. That is, the tasks caused her a high level of frustration, as they did for Leann and Sandra.

A notable observation during the interview phase was a difference in the level of frustration experienced by female and male subjects. Males generally showed little evidence of feeling frustrated whereas the females showed a high level of frustration. This was evidenced by their facial expressions and verbal utterances during the interview. This gender difference was also noted in the classroom observations. Given that the males appeared to have a preference for actional knowledge and females for verbal knowledge, one conclusion that might be reached is that this accounted for the males being less frustrated.

A Synopsis of Target Subjects' Tinkering Based on an Analysis of Knowledge Bases

Males and females took on a different focus when asked to engage in electrical activities. The males saw the activities as an opportunity to develop their personal or commonsense knowledge of electricity, whereas the females saw the assigned task as a requirement for school science. Their focus during the electricity unit appeared to concentrate on the activity for grading purposes only - what the teacher and text wanted. The male subjects (Sean and Jason and to a lesser extent Paul) focused on further development of an expertise in the area of electricity (actional knowledge). The males appeared to have intrinsic reasons (pleasing self or self-rewarding ventures) for tinkering, whereas the focus of female behavior appeared to be on extrinsic reasons (pleasing others or school rewarding). Females did not appear to be motivated to develop a personal expertise in electricity although they showed determination to do well in school. So while the males were busy figuring out and extending the process, the females concentrated on discovering what the teacher wanted or they focused on the content. Commonsense knowledge acquired through actions played a larger role for the males than it did for the females. The often verbalized mode of school science had a greater appeal for female subjects than male subjects possibly because the verbalized mode was the only avenue of access for the female subjects. This focus was the only personal meaning that the females could bring to the study of electricity.

The female and male target subjects had distinct ways of knowing which were gender-related. The female interests were predominantly **text (verbal knowledge)** focused whereas the males were predominantly **task (actional knowledge)** focused. Also linked with this gender-related focus was the male interest in pleasing self and the female subject's interest in pleasing others, especially the teacher. This difference in behavior in the laboratory is best summarized by Alison Kelly (1987) who notes:

> Boys bring with them to science lessons a conception of masculinity which includes toughness, aggression, activity and disdain for girls; girls bring with them a conception of feminity which includes timidity, conscientiousness, deference, person orientation and a concern for appearance. These self-definitions lead girls and boys to behave in different ways, such that boys come to dominate the laboratory and establish it as their territory. Gender differentiated behaviour outside school leads to gender differentiated behaviour in science lessons, which in turn leads to science acquiring a masculine image. The in-school and out-of-school behaviours are by no means identical, but they have a common source in children's gender identity. . . . (p. 75)

During the study of electricity when tinkering or actional knowledge was dominant the female subjects had little or no voice. They were often under what Belenky et al. (1986) refer to as a "veil of silence". The target males, on the other hand, were active participants and were at "center stage". For the females, tinkering was not part of their "sphere of experience" and was thus a new mode of investigation whereas for the males tinkering was a "shared experience". The result was that during the activities the females did not interact with electrical objects as did the males.

Belenky et al. (1986) talk of intellectual growth as the giving of voice. In my study the only avenue for the giving of voice for the female target students engaged in the study of electricity was through verbal knowledge. The males had voice both through their verbal and actional knowledge.

Belenky et al. (1986) also talk about females favoring "connected knowing" versus "separated knowing". The evidence from both the interview and classroom contexts suggest that in the study of electricity the female subjects were forced into accepting "separated knowing". Females seemed to have had no previous knowledge about electricity and reacted only to the precautionary aspect of the subject, such as safety. There appeared to be only isolated incidents in the female's experiences that prompted some exploration of electricity (for example Sandra's curling iron). Tinkering, therefore, can be viewed as an activity which favors males and does not allow females who have no previous tinkering to engage in what Belenky describes as a "female way of knowing". The "female way of knowing" involves being connected to the experience which was not the case for the females, whereas it was for the males. The males had experienced similar activities in their out-of-school experiences. While in other spheres of experiences females may engage in "connected knowing" this was not possible for them in the study of electricity. This puts the males in an advantage because the study of electricity for the males was "connected knowing"[1] plus it is also perceived of as an appropriate activity for males. So not only were the females inexperienced but they had to engage in activities that were perceived as masculine.

[1] Although the Belenky et al. (1986) study was of females subjects they did not claim that the categories of "connected knowing" and "separated knowing" were only applicable to women.

Experiential, Social, and Personal Factors: The Background to Gender Differences in Tinkering

The Apprenticeship

Chapter five described the relationship between the three sets of background factors and tinkering. The apprenticeship metaphor was used to describe these factors. A synopsis of the apprenticeship is provided in Table 5-19. Here a review of patterns in gender differences for the experiential, social and personal factors will be given. This review will examine how these three components of the apprenticeship may have contributed to gender differences in tinkering.

The Experiential Factors

Table 5-12 summarizes the experiences females and males have in tinkering. Based on data from the survey, the interview and the classroom observations males had more opportunities to tinker than females. Male subjects generally had a greater range and depth of experience than females. If we consider these experiences as an apprenticeship then males can be described as actively engaged in an informal apprenticeship with their mentors.

Analysis of the survey of electrical experiences revealed a general pattern for the out-of-school experiences of female and male subjects: males have had more out-of-school experience with electrical objects than have females. This pattern is also consistent with other studies (Johnson, Murphy, Driver, Head & Palacio, 1983; Johnson, & Murphy, 1984; Johnson, 1986; Kahle & Lakes, 1983; Lie & Bryhni, 1983). Such studies, however, were only general surveys and do not focus on an indepth analysis of experiences with electricity as was attempted in my study by the construction of a proficiency of tinkering. We need to consider the fact that experience with electrical devices does not necessarily translate directly into tinkering. However, the fact that males had more experiences with electrical activities and that they also displayed a greater proficiency at tinkering it can be argued that there may be an interaction between proficiency of tinkering and prior experiences.

In an examination of the "sphere of experience" for the subjects it is noted that females had a narrower "sphere of experience" than did males. To illustrate, the experiential backgrounds of Sandra and Sean will be reviewed. Sandra's tinkering experiences seemed to be mainly restricted to such activities as repairing her curling iron while Sean had a wide sphere of experience, ranging from repairing his own toys to car repairs.. In particular, Sandra referred to a lack of toys that may have allowed her to tinker while Sean referred to an abundance of such toys. Based on the data obtained it can be argued that, in terms of experience, females and males have not only had different spheres of experience but the males have had a greater depth of such experiences. Specifically males have had more actional experiences than females.

Gender differences were also evident in the selection of some of the in-school experiences selected by the male and female subjects. For example, the selection of elective courses in grades seven and eight showed an interesting pattern. The male subjects had enrolled in an elective course in computer studies at the grade seven and eight levels. Haritha was the only female target subject who had elected to do computer studies. Not only was there a difference in enrollment patterns but in the interviews the males voluntarily referred to their interest in computers. Females did not volunteer this information unless asked. Within the same context, Sandra expressed what appeared to be a fear of computer studies. This is a sharp contrast to Sean who was extremely interested in computers and showed no indication of fear of playing around with them. The differential experiences for Sandra and Sean, both out-of-school and in school, may have resulted in their different levels of actional knowledge. Clearly, it is obvious that some females and males have had different experiences with technological devices such as computers.

In conclusion, it appears that the males had greater opportunities to tinker and have also taken advantage of such opportunities. The experiential context of tinkering therefore provided males with a headstart..

Social Factors

An Overview

The social factors that influence females and males to tinker appear to be very different. Table 5-13 summarized the social influences of mentors, family and friends, and social agencies on each of the target subjects. A review of these social influences in terms of positive and negative instances, reveals that the male subjects had far more positive encouragement to tinker than did the females. The most powerful social influence was mentoring which appears to have played a much stronger role for males than for females.

Specifically, all target males in my study had mentors, whereas, Haritha was the only female target subject who had a mentor.

Sandra is the best illustration of a subject whose social influences may have contributed to influencing her not to tinker. The social influences on Sandra appeared to have been more of a constraining nature than a positive influence. Based on the data collected, it is possible to put forward the conjecture that her older male sibling may have had a negative impact on her. Support for this conjecture is not only based on data from my study but also from the science education literature. Van Vonderen and Dijkstra (1987), in an examination of the positive factors which contribute to a female's choice of a technical discipline, note that the absence of brothers was significantly related to that decision. That is, females were more likely to select a technical discipline if there was not an older brother in the same household. Conversely if a female had an older brother who was involved in a technical discipline she would be least likely to select a technical discipline as a field of study. This situation appears to be applicable in Sandra's case. Sandra's older brother was a tinkerer who, at the time of my study, was a second year computer studies student at university.

Sean is probably the best example of a male subject whose social influences encouraged him to tinker. All levels of social influences had a positive effect on Sean to tinker. This is in sharp contrast with Sandra who had no such positive social influences.

With the possible exception of Haritha who had a mentor, no female subjects had the same advantage as the males who were obviously mentored. In Haritha's case, her mentor did not have as much an impact. This situation may be attributed to the fact that Haritha did not value her mentor. In addition, her mentor did not appear to have the same level of expertise as that of Sean's or Jason's. Paul's mentor was his uncle whose level of expertise was greatly appreciated by Paul. Paul, however, did not spend a lot of time with his uncle so therefore he did not develop the same level of expertise as Jason or Sean who spent more time with their respective mentors.

The role of the mentor in the apprenticeship of male subjects is an important gender difference. The subjects who were at a professional level or above had a close relationship with a significant other who encouraged them to tinker. Haritha and Paul who were both amateur tinkerers had a weaker relationship with a mentor. A speculation might be that if females had a strong mentoring relationship they could be professional and master tinkerers. There is support for this speculation in that during my preliminary study Jean, a grade 12 female student whom I interviewed was identified by her physics teacher as a tinkerer. What was also interesting about this student was the fact that she was the second daughter in a two-sibling household and her older sister was an engineering student. Jean described her family relationships as non-stereotypical. She also talked about a close relationship with her father, a mathematics teacher. Jean like Sean and Jason could be described as having had a mentoring relationship. In Jean's case her father and older sister were her mentors. Based on my conversation with her, Jean's father appeared to have been the most influential. However, having an older sister studying engineering was another powerful social influence. Jean at the time of the interview was contemplating a career in kinesiology or engineering. In addition, she had selected elective courses in electricity at the secondary level to enrich her potential of becoming a future engineer. Jean is in sharp contrast with the female target subjects (Haritha, Leann, and Sandra). Based on my observations to date, Jean is indeed an exception.

Not only did males have a stronger mentoring relationship than females, but males also received far more positive encouragement from family and friends. The strongest social influence on females to tinker came primarily from social agencies such as clubs and school. These did not have as much an influence as a mentor, or family and friends. Even though this was the strongest level of social influence for females, it still appears evident that even at this level males received more encouragement than did females.

The Social Influence of Female and Male Networks in the Classroom

A powerful social influence which was observable at the classroom level was networking. Males in the target class generally were more successful in completing the electrical activities than the females. Even though Paul was an amateur he was party to a male network which was very knowledgeable (for example Sean and Jason were there for consultation). The females, (Haritha, Leann and Sandra) however, were not party to an informed network; as a result these subjects had to completely rely on the teacher or the text. If we consider that students learn from each other within the classroom context and that informal networks are set up mostly within gender groups, then amateur male tinkerers within an informed network should function more effectively than amateur female tinkerers within an uninformed group. Haritha did make numerous attempts during classroom activities to be a part of the male network but was limited in her success. She was the only female target subject who consistently made such attempts. Her endeavor to become party to the dominant male group was often meet with ridicule and frustration. The males often viewed such attempts as an opportunity to play pranks on her or to slow down her progress. Some illustrations of this were:

1. One occasion when she went to collect materials during an electrostatics activity she was chased away by Sean with a piece of fur.
2. On other occasions the dominant (male) groups refused to loan her equipment when there was a short supply of specific equipment. One such illustration was during the activity on series and parallel circuits they refused to loan her electrical sockets.

There also appeared to be different routes of approval for females and males in the classroom. The study of electricity for Sean and Jason provided opportunities for them to tinker and by doing so to develop their personal knowledge, yet at the same time to meet the school requirements. Conversely, the study of electricity for Haritha, Leann and Sandra appeared to be an opportunity to do what was required for success in school science. The result was that there were different routes for approval for females and males. The more school-focused females tinkered less than the non-school focused males. Paul and, to a lesser extent, Haritha were able to actively participate in both camps. Haritha was the only female subject in the target class who was aware of the difference in roles of female and male students. She could be in fact described as being aware of stereotyping. Jean (grade 12 physics student discussed earlier) was also socially aware of sex roles.

The Social Influence of Male Networks Out-of-School

Another potentially powerful social influence was the male network which existed out of school. Not only was there a strong male network in school but there was indication that there was a strong male network out of school. Sean, for example, had male cousins and male friends as a support network. Jason also had a strong male network out-of-school with his father, his friend, and even part-time employers. In contrast, the female subjects did not have an out-of-school network which encouraged tinkering. The only female who had any form of out-of-school experiences tinkering with electricity was Haritha who, as indicated earlier, had a weak apprenticeship relationship with her mother.

Summary Statement on Social Influences

This examination of the various social influences on the target subjects suggests that males have been more encouraged to tinker than females. At every level, social influences (mentor, family & friends, and school & other agencies) contributed to an apprenticeship in tinkering which favoured the male subjects. This seems to support for the argument that tinkering is socially constructed as an appropriate activity for males and conversely inappropriate for females.

Personal Factors

Gender Differences in Personal Interests

Table 5-18 summarized the target subjects' interest in the study of electricity and also gave some indication of their disposition to tinker. What is interesting to note from a gender perspective is that all data sources indicated that males displayed a higher personal interest in tinkering than did females. It therefore seems reasonable to conclude that male subjects displayed a greater personal commitment to tinkering than did female subjects. The source of this commitment however is difficult to isolate. Within the context of the study it is impossible to isolate the influence of socialization and experiences on this personal commitment.

When the target subjects' feelings toward electricity are analyzed gender patterns are evident. All target males were interested in the study of electricity whereas the females, with the exception of Haritha, were not. Also noticeable was the difference in interests males and females have in electricity. Females, in particular, expressed interest in the issue of safety surrounding electricity whereas males showed very little interest in this issue. The fact that females listed safety as one of the topics that should be presented in electricity may be related to their fear of electricity. No male subjects expressed fear of electricity. For example, Sean often stated during the interview that he was not afraid of electricity. Jason also expressed no fear of electricity. The fact that males may not show fear of electricity or have a concern about safety issues may have a logical explanation. Either the males had knowledge of safety procedures or were not concerned about electrical safety as an issue. Alison Kelly (1987) comments:

> One of the key components of adolescent masculinity is toughness. This takes many forms from physical rough and tumble to bravado and self-confidence and it is clearly evident in the science laboratory. Almost any piece of apparatus can be used or abused to demonstrate a boys' toughness, as these extracts from my field notes from the GIST project show.
> One example of force was a very strong magnet. Handed to boy to pass round, he and another boy immediately started a tug of war with it, only passed on at teacher's insistence. Periodically throughout lesson boys would try with it, girls never.
> Spring balance used as a catapult (boys).
> Boys try to give each other shocks (with 6V battery!).
> One group [of boys] mimic an interrogation using ray box as bright light.
> This type of example could be multiplied endlessly. It happened in virtually every lesson where apparatus was used, which in the post-Nuffield era means virtually every science lesson. (p. 69)

It is also interesting to note a study which shown that safety is an area of electricity in which females excel. Science assessments, such as the 1986 B. C. Science Assessment have identified safety as one of the areas where females outperform males.

When asked about out-of-school involvement in tinkering the females expressed a fear of being punished for doing something wrong. Sandra made several references to this during the interview. Males on the other hand acknowledged that they were sometimes restricted by their parents but admitted quite openly that they disobeyed such restrictions. From these revelations it can be assumed that even if the same level of interest in tinkering existed for both sexes at an early age, females felt more restricted than the males.

Interest in classroom activities was noticeably different for females and males. Males tended to focus on actional knowledge while females relied more on the verbal knowledge which is typically required for school science. Females, in particular, paid more attention to taking notes and listening to the teacher. Sean and Jason did not do much note-taking and only appeared to listen superficially to the teacher. Paul was somewhat of an exception in that he was attentive, yet remained part of the actional scene.

An interesting pattern was also noted in classroom dialogue. Males tended to focus their off-task dialogue around electricity. Females did not. Males often used street language or informal language when talking about electricity but females used only textbook language. One such illustration was when Sean referred to electrical output as "juice" and Leann corrected him for using such language. The use of such language by males seems to indicate that electrical concepts are a part of their everyday culture while usage of textbook language was the operating mode for females. Moreover, textbook language is often all that females are familiar with or know. The fact that males were able to use informal language seems to indicate that the male subjects had a higher level of personal attachment to tinkering.

The type of tinkering that each of the subjects engaged in out-of-school also tells us more about the personal interests of the female and male subjects. Males possessed a wide range of interests while females seemed to have had a very narrow range of interests. The curriculum presented in the electricity unit was in the realm of the male experience and therefore catered more to male than female interest. Electricity units which provide opportunities for tinkering therefore are more likely to generate a higher level of personal interest on the part of males than females. This difference in interests further supports the argument that tinkering is "connected knowing" for males and "disconnected knowing" for females.

Personal Interests as Indicated by the Status Assigned to Tinkering

An analysis of the target subjects' personal interest revealed that males gave a high status to tinkering, unlike females. Although the female subjects expressed little interest in tinkering, some data seem to suggest that this lack of interest may not have been so evident in early childhood. For example Sandra described herself as being interested in tinkering when she was a child. During her interview she gave some indication of her past interests in electronic toys. However, an examination of Sandra's behavior in the classroom was a sharp contrast with the behaviors she ascribed to herself as a child. Her childhood interest was amazing given the fact that she was obviously stifled by her older brother. Sandra's former teachers (grades 4-8) did not describe Sandra as a tinkerer. Not only was Sandra's tinkering at an amateur level but she also showed reluctance to engage in such activities. Throughout the classroom observations I was able to document in my field notebook incidents of Sandra's refusal to engage in activities which required tinkering. A general overall synopsis of Sandra's classroom behavior leads to the conclusion that she displayed very little or no interest in tinkering. Although as a child she may have been interested in tinkering there was no indication of that interest during any of my classroom observations.

Sean is a sharp contrast to Sandra in that he displayed a high level of personal interest in tinkering. Moreover, Sean's behavior in class was consistent with his early descriptions of himself. During the interview he had described himself as actively engaging in tinkering in his early childhood. It is interesting to note that all of Sean's former (grades 4-8) teachers described him as a tinkerer. All data sources therefore seem to indicate that Sean had a high level of personal interest in tinkering.

The personal interests of other target subjects showed similar patterns along gender lines. The females had constructed a negative status for tinkering whereas the males had constructed a positive status. In conclusion the personal construction of tinkering by female and male target subjects showed pronounced gender differences.

Experiential, Social, and Personal Factors and Different Ways of Knowing

Given the gender differences in the apprenticeship, there is reason to suggest that these differences have influenced the development of different ways of knowing for both sexes. Specifically the differences in level of experience, and the social and personal construction of the study of electricity resulted in females and males displaying different ways of knowing. These differences I have described as "connected knowing" for males and "disconnected knowing" for females. The apprenticeship factors appear to have influenced males to develop greater expertise in tinkering as displayed by a higher proficiency level and more advanced phases. In addition, these factors appear to have influenced different ways of knowing as defined by the actional and verbal knowledge components of tinkering. While both males and females had an opportunity to engage in the same set of activities within the classroom, the sexes interpreted these experiences differently. The distinct gender differences in interpretation of science activities strongly suggest that males and females go about science in different ways. The typology of tinkering that was constructed allows us to see different ways in which males and females "know" or "do science". While these differences seem to account for differences in tinkering such differences were not reflected in school grades since all the target subjects were successful in school.

Within the interview and classroom context, the type and amount of activities that females and males participated in was noticeably quite different. The interview and classroom observations showed that males engaged in more tinkering than females. In addition, the difference in the activity index for females and males indicates that males had greater opportunity to tinker in their out-of-school activities. Gender differences in ways of knowing may therefore be as much attributable to their out-of-school experiences as their in-school experiences. Those pronounced experiential differences appear to account for gender differences as it relates to tinkering.

Summary Statement on the Relationship between Gender and Tinkering

Table 6-1 reviews the overall gender patterns that were noted for the female and male subjects. Specifically, it summarizes the gender differences within the characteristics of tinkering (type, proficiency, process, and knowledge bases) and apprenticeship factors (experiential, social, personal) of tinkering. Based on the analysis of characteristics and apprenticeship factors of tinkering the target females and males demonstrated distinct gender

TABLE 6-1 A Review of the Relationship Between Tinkering and Gender

Characteristics	**Factors**		
	Experiential	**Social**	**Personal**
Sandra (Novice) Pragmatic Verbal	Low	Weak -Negative	Low
Leann (Novice) Pragmatic Verbal	Low	Weak	Low
Haritha (Amateur) Pragmatic/Scientific Verbal/Actional	Low	Weak -Moderate	Low-Moderate
Paul (Amateur) Scientific Verbal/Actional	Low	Weak -Moderate	Moderate
Jason (Professional) Utilitarian Actional	High	Strong	High
Sean (Master) Technological Actional	Very High	Strong	Very High

differences in approach. I have interpreted these differences as different ways of knowing. Specifically tinkering has been described as an activity which favors males and is hence "connected knowing" for males and "disconnected knowing" for females. These conjectures have been substantiated not only on the basis of (a) the data collected but also (b) the literature review presented earlier. The fact that tinkering can be described as an activity which favors males suggests that a feminine way of knowing was probably unlikely to be visible during the study of electricity, especially when the study focused on tinkering.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

Introduction

Children's science has been defined in my study as the intuitive scientific **concepts** and **methods** children learn from everyday experience. The focus, however, was not to explore further children's conceptions but to investigate some aspects of a method that children use in their everyday experience. Specifically, the focus was on the informal methods by which some children acquire knowledge, namely tinkering. The basic assumption was that we can better understand some aspects of *children's science* through the study of tinkering. The specific problem I investigated was: to describe and interpret tinkering as a phenomenon or practice, within the context of the study of electricity at the grade nine level. My problem was particularized by asking the following two research questions:

1. What are the characteristics of tinkering?
2. What are the factors influencing tinkering?

The above questions formed the primary focus of my research. A secondary focus examined the issue of gender differences in tinkering. This resulted in the development of a model of tinkering which is not only important in our further understanding of *children's science* but also provides a useful framework for further exploration of gender differences. Given the nature of a naturalistic study all questions posed evolved over time as the research progressed through preliminary research, pilot studies, data collection, and analysis.

A model of tinkering was constructed from multi-sourced data bases collected on grade nine students engaged in the study of electricity. The methodology consisted of six weeks of observation prior to the selection of a class for a more indepth study. This was followed by extensive data collection over a two month period on ten students with six target students being used in the final data analysis.

Based on the analysis of data, a model of tinkering has been developed consisting of various characteristics which are influenced by various experiential, social, and personal factors. These factors have been described as an apprenticeship. The data collected also allowed for the posing of some conjectures on gender differences in tinkering.

In answering the two research questions this chapter will review the conclusions of my study and discuss some of the implications of these findings. This will be then followed by recommendations for further research.

Conclusions of the Study

Characteristics of Tinkering

Three characteristics of tinkering were constructed based on an analysis of the data collected. These characteristics can be described in terms of (a) a typology (purposes and proficiency), (b) phases of a problem solving process, and (c) the two types of knowledge bases that are generated. Table 7-1 gives a general overview of these three characteristics. A brief synopsis of each characteristic will now be presented.

Typology of Tinkering

A typology of tinkering was constructed which consisted of two ways of categorizing the data. One centered around the purposes or motivation which seemed to orient the students and the other was based upon their proficiency in the process.

Purposes for Tinkering.

The subjects were categorized as displaying four purposes for engaging in tinkering: utilitarian (useful), technological (application), scientific (theory) and pragmatic (performance). While it is argued that these four purposes tinkering describe the dominant behaviors of target subjects, these categories are not claimed to be exhaustive or universally applicable.

Proficiency of Tinkering.

Tinkering is an activity the target subjects engaged in with varying degrees of success. Based on the subject's degree of success on tasks presented in interview and classroom activities, proficiency levels were identified for each target subject and these levels were given the name of master, professional, amateur and novice. Proficiency of tinkering proved to be the most useful category developed in that it provided connecting linkages in the overall analysis of the data. The purposes for tinkering may also prove useful for overall analysis if a larger data base were obtained. On the basis of the very limited data base, master and professional tinkerers would more likely be utilitarian or technological types.

The Process of Tinkering (Problem Solving)

A second component of the model focussed upon tinkering as a problem solving process. This process, based on the subjects studied, was described as consisting of four phases namely (a) searching for the problem, (b) framing of the problem, (c) solving the problem, and (d) evaluating the problem. Subjects described as novice and amateur only exhibited the initial phases of this process whereas those described as master and professional exhibited more advanced phases. The greater a subject's proficiency at tinkering the more likely it is for the subject to be able to solve problems which require tinkering.

The Knowledge Bases of Tinkering.

It was argued in chapter four that there are two types of knowledge involved in tinkering. These two types of knowledge were labelled as verbal and actional knowledge bases Verbal knowledge included any statements made by the target subjects during the interview or in the classroom which indicated something about their propositional knowledge of electricity. Actional knowledge, on the other hand, was indicated by the actions taken by target subjects in completing the electrical tasks assigned during the interview or in the classroom situation.

Verbal Knowledge.

Verbal knowledge was described as consisting of three levels: questioning (level one), stating (level two) and inventing (level three). The pattern noted was the higher the proficiency level of the subject, the more advanced was the level of verbal knowledge displayed.

Actional Knowledge.

Actional knowledge can be described as existing at levels: formulating (level one), repertoiralizing (level two) and inventing (level three). Again the higher the proficiency level of the subject, the more advanced was the level of actional knowledge displayed. In completing the assigned tasks, the target subjects, both in the interview and classroom settings, showed a wide range of actional knowledge. Those categorized as novice and amateur showed a lower levels of actional knowledge than those categorized as professional and master. Their level of actional knowledge also showed a strong relationship to their level of verbal knowledge, suggesting a strong relationship between their level of actional and verbal knowledge and their proficiency at tinkering.

TABLE 7-1 The Characteristics of Tinkering

1. TYPOLOGY	
Purposes	**Proficiency**
- scientific	- master
- technological	- professional
- utilitarian	- amateur
- pragmatic	- novice

2. PROBLEM SOLVING PROCESS

Phase 1 - searching for the problem

Phase 2 - framing the problem

Phase 3 - solving the problem

Phase 4 - evaluating the problem

3. KNOWLEDGE BASES	
Verbal	Actional
Level 1 - questioning	Level 1 - formulating
Level 2 - stating	Level 2 - repertoiralizing
Level 3 - inventing	Level 3 - inventing

Some Implications of the Characteristics of Tinkering

The construction of the characteristics of tinkering provides a conceptual framework for the interpretation of tinkering as one of the methods which children use to make sense of their everyday experiences. Beyond providing this framework it helps to expand our understanding of *children's science*. Our understanding needs to be broadened because research in this area of science education has been narrowly focused on children's conceptions of scientific phenomena. Even though researchers such as Hewson (1980), Osborne, Bell and Gilbert (1983), Perez and Carrascosca (1985), Tasker (1980, 1981), Stead (1981) and others have identified other areas of *children's science*, such as children's methods that need to be explored, such research has not taken place. My study therefore provides a conceptual framework for further exploration of children's methods within the context of school science.

The construction of the characteristics of tinkering has provided not only a basis for further research but it also has a practical significance for instruction at the classroom level. The characteristics of tinkering identified allows the classroom teacher to make sense of tinkering as a phenomena which takes place within the classroom. Teachers have always had a commonsense understanding of tinkering so the description that I have constructed will provide them with a framework for making sense. Specifically my study provides a framework for instruction which focuses on the development of children's actions. This gives significance to children's actions which have been very much under rated within the context of school science.

The Apprenticeship Factors of Tinkering

There are many factors which may encourage or discourage tinkering. My study described experiential, social, and personal factors which seemed to play an important role in determining the extent and kind of tinkering in which the students engaged. The metaphor that was used to describe some possible influences on students' tinkering activities was that of an apprenticeship. The claims should be considered as conjectures and not be interpreted as being universally applicable. Nevertheless, the data base from which the conjectures have been made is extensive.

Table 7-2 summarizes these factors which were identified as being important in the personal lives of the students included in my study. From the collected data, the master and professional tinkerers can be described as engaging in an informal apprenticeship. In both cases there was a very strong positive influence of a significant other, they had a high depth and frequency of experiences and they also displayed a high level of personal interest. The amateur tinkerer however had a somewhat weaker apprenticeship, with the novice not having any elements of an apprenticeship. Each of the factors in the apprenticeship will now be reviewed.

Experiential Factors

Experiential factors include those prior experiences with electrical phenomena to which a person has been exposed in everyday life, both inside and outside of school. In other words the level of the apprenticeship undertaken was defined by the depth and frequency of experiences for the subjects. Three data sources were drawn upon: survey, interview, and classroom observations. When all data bases were analyzed the pattern which emerged for subjects was the higher the proficiency level the greater the depth of experiences.

Social Factors

For the purpose of this investigation social factors should be interpreted to mean those social influences which may encourage or discourage tinkering. They do not include other social factors such as the role of cultural norms, language, gender-role stereotyping, etc., but rather are restricted to the data collected on students' relationships with family, friends, and school. It was acknowledged that the influence of these other social factors on tinkering was undoubtedly significant, but it was not possible to include these factors in the present analysis.

Societal influence was described as existing at three levels based upon the degree of influence or the immediacy of the experience. A first level of influence is a relationship with a family member or significant other, the second level of influence being friends, and the third level was community agencies such as school, clubs, etc.

Personal Factors

Personal factors included the personal interests or dislikes that may influence a person's tinkering. These personal factors were constructed from statements or actions during the interview and in the classroom which seemed to indicate a subject's interest in tinkering. Again, subjects with a higher proficiency of tinkering displayed a higher level of personal interest.

Some Implications of the Apprenticeship Factors

If we wish to formalize an apprenticeship which normally takes place informally we need to consider the conditions that are necessary to generate an apprenticeship in tinkering. The most critical factors appear to be the experiential and social factors so if we wish for tinkering to happen within the classroom context we have to provide an instruction program to encorporate such factors. The experiential component of the apprenticeship is critical for it actually determines whether or not an apprenticeship in tinkering has taken place. We therefore need to provide lots of opportunities for students to tinker. Beyond that the social factors obviously play an important role in that students are socially influenced to construct their own significance of tinkering. The most critical social variable in the construction appears to be the role of the mentor. The role of the mentor is especially significant when we consider that the apprenticeship takes place informally. Mentoring should likewise be provided for as part of the instructional program.

In conclusion, if we wish to promote tinkering within the classroom context we need to provide rich experiences that encourages it. Moreover social factors such as mentoring will need to be formalized. We will also have to design instructional programs which provide for students who have varying levels of apprenticeship in tinkering. Given that this variation is most pronounced along gender lines the next section on gender differences will address this issue.

TABLE 7-2 The Experiential, Social and Personal Factors of Tinkering for Target Subjects at Representative Proficiency Levels

Proficiency Level	Factors	Factor Level
Master Tinkerer	Experiential	Very High Depth of Experience
	Social	Level 1 (mentor) - strong positive influence Level 2 (family & friends)- strong positive influence Level 3 (community agencies) - strong positive influence
	Personal	Very High Level of Interest
Professional Tinkerer	Experiential	High Depth of Experience
	Social	Level 1 (mentor) - strong positive influence Level 2 (family & friends) - strong positive influence Level 3 (community agencies) - strong positive influence
	Personal	High Level of Interest
Amateur Tinkerer	Experiential	Low Depth of Experience
	Social	Level 1 (mentor) - weak positive influence Level 2 (family & friends) - weak positive influence Level 3 (community agencies) -weak positive influence
	Personal	Moderate Level of Interest
Novice Tinkerer	Experiential	Low Depth of Experience
	Social	Level 1 (mentor) - negative influence Level 2 (family & friends) - negative influence Level 3 (community agencies) - weak positive influence
	Personal	Low Level of Interest

Gender Differences in Tinkering

My investigation of tinkering evolved out of a review of the literature on females and science. In the literature review a consistent conjecture that females do not tinker was raised by researchers to explain the reason why females underachieve and are under represented in the physical sciences. Because of the generality associated with these claims, it was decided to first clarify the issues associated with the nature of tinkering My study, therefore, became primarily an investigation of tinkering. Nevertheless, my exploration of tinkering has allowed for some subsequent conjectures to be made on gender differences in tinkering within the context of school science. Table 6-6 summarized the gender differences found "males are better than females at tinkering."

A review of these findings will now be presented:

- First, females were categorized exclusively as pragmatic tinkerers emphasizing performance for grades or extrinsic rewards. Males tended to represent a variety of types of tinkerers such as utilitarian, technological, and scientific emphasizing intrinsic rewards.
- Males brought a greater range of proficiency to tinkering and were therefore categorized from amateur to professional to master tinkerers. Females were categorized as novice or amateur tinkerers.
- Females tended to express themselves more in terms of verbal knowledge whereas males were more likely to engage in a form of actional knowledge.

The experiential, social, and personal factors influencing tinkering have been described as an informal apprenticeship which favoured males. The following synopsis can be made based on these factors:

- Experiential Factors

All data sources indicate that males have had a greater opportunity to tinker. Based on this data, the experiential context of tinkering has therefore been described as favoring males.

- Social Factors

  At all levels of social influence (mentor, family and friends, and school and other agencies) males got more encouragement to tinker than females. This appears to have contributed to an informal apprenticeship in tinkering which favoured males. Social factors, as defined, support the argument that tinkering is socially constructed as a masculine activity.

- Personal Factors

  Analysis of personal factors revealed that males displayed a greater interest in a wider range of related activities, and that males gave tinkering a higher status than females. That is, there were distinct gender differences in the personal construction of tinkering. Moreover, the electricity curriculum as it is presented in schools caters more to male interest since it is within the male sphere of experiences.

The discussion of gender differences in tinkering has resulted in my argument that tinkering with electrical objects is largely perceived to be a masculine activity. The result is I have described tinkering as: "connected knowing" for males and "disconnected knowing" for females, and as a result an activity which favors males. These findings of my research also lend support for the argument that the electricity curriculum as presently presented in school science is more suitable for males than females. Electricity, as an area of physical science has been constructed with a masculine bias. Given such a gender imbalance we need to consider how to correct this imbalance because it is unfair to female students. We need to provide female students with the background in electricity that they lack, mentors to help them grow, and an electricity curriculum that has more appeal to female students. That is, we need to formalize for females an apprenticeship in tinkering which normally happens informally for males.

Recommendations

Recommendations for Science Instruction

Educators should be aware that students bring their own methods to the study of science. This was illustrated, with respect to tinkering, in various sets of characteristics of tinkering and the factors which influence tinkering. This variation suggests when planning science instruction, we should take such variation into consideration.

If we accept that students bring their own ideas about physical phenomena to instruction, the results of my study suggests that they not only bring their own ideas but their own methods. If students apply their own methods to the study of electricity, this has implications at the practical or classroom level for science instruction. If school science is to evolve beyond a mere content focus the actional component must be considered. A science program that fails to do so cheats its students of a complete science program. This is especially true for female students who do not get the informal apprenticeship in science that males often receive.

Given that students may have a different purposes for tinkering (scientific, technological, utilitarian, and pragmatic) teachers should be cognizant of the fact that students may bring different foci to the study of electricity. The selection of curriculum materials and the planning of instruction should ideally take such typologies into account. If instructional objectives are go beyond a content focus to include the actional aspects then the typologies of tinkering need to be taken into consideration. Students with technological, scientific, utilitarian or pragmatic perspectives will have to be drawn into the instruction. Students with a pragmatic focus, for example, could be drawn into tinkering if such actions were a required part of the evaluation for academic success. If teachers are to involve students in activities that require tinkering we may expect varying levels of student success. Again instruction should be designed to allow the novice and amateur to develop and, at the same time, to challenge the master and professional.

If science instruction is to present a more authentic view of science (Osborne, Bell & Gilbert, 1983) we must consider the development of children's methods (such as tinkering) as being critical. To do this, we must move from a content focus to a broader view of children's science in our science programs. Since only some students acquire such knowledge out-of-school, it is important that school science provide opportunities especially for those who have not acquired such skills elsewhere. Otherwise some students, in particular female students, will be disadvantaged in the physical sciences (Bateson & Parsons-Chatman, 1989). The following techniques, although not exhaustive, could be useful in the development of a student's tinkering:

1. a careful selection of real world electrical activities that are a part of the everyday female and male experience,
2. the selection of activities for the curriculum which require building, modelling,
3. the limiting of teacher talk and the setting aside of time for the actual doing of hands-on activities,
4. the utilization of students teaching students within cooperative groupings,

5. the assigning of multi-age groupings for group work with hands-on activities,
6. the choosing of partners in such a way as to encourage all students to develop expertise,
7. the encouragement of student utilization of garbage can science or recyclable materials
8. the showing of discrepancy events and asking students to make it work,
9. the teaching of mechanical or electronic routines (the actional science),
10. the evaluation of the actual lab (the doing) - not product (lab book) (a focus on how they are doing),
11. a display of lots of equipment around the room to promote impromptu tinkering, and
12. the development of a mentoring program for those students who are novice and amateur tinkerers.

Recommendations for Females and Tinkering

I am able to make some preliminary recommendations based on gender-related differences in tinkering. Generally males have an advantage over females when it comes to the practical component of a electricity unit. Since the study of electricity is important for success in the physical sciences we must attempt to ensure that females are successful in doing the hands-on component. This calls for intervention at an early stage where females are provided with opportunities to tinker. Given that tinkering with electrical objects is viewed as a masculine activity at the classroom level we must develop strategies to encourage the participation of females. Above all, we should create a gender-fair classroom environment where it is socially acceptable for females to tinker.

Based on the model of tinkering constructed, an intervention program could be developed. What my study has provided is a conceptual framework for the development of such a program. We must not merely provide electrical activities for students and hope that, as a result, they will tinker. We have to develop a instructional plan that allows a student to move from a novice to a more advanced stage. Moreover, we need to take a look at the kind of science that is presented to females. Eliminate, where possible, any area of electricity which shows content biases favouring male students. Evelyn Fox Keller's argument that not only has science has science and gender been socially constructed but science has been constructed in a masculine image certainly appears to apply to the study of electricity. This argument is supported by my data suggesting that males have an unfair advantage over females. Therefore, if we wish to move toward gender equality in the physical sciences we need to eliminate such gender biases in the curriculum. This calls for the electricity curriculum to become more gender-fair by providing less stereotyped curriculum materials.

Since the target females tended to have a pragmatic focus to the study of electricity, they might be encouraged to become better tinkers if the actional component were a part of the evaluation procedure. This emphasis on evaluating the actional component of science should occur as early as possible in the school experience.

The experiential, social, and personal factors influencing tinkering have been described as an apprenticeship. Since each of these factors appear to contribute to males engaging in an informal apprenticeship we should attempt to provide the same apprenticeship for female students. A brief review of these three factors is useful in defining what such an apprenticeship might look like.

The experiential component of the apprenticeship suggests that we need to provide females with a richer sphere of experiences in areas of science such as electricity. Given that out-of-school experiences appear to play such a strong role females need to be encouraged at an early age to pursue such activities. This encouragement must come from the home environment, through siblings and parents. As educators we can give some direction to parents through a parent-awareness programme and the development of appropriate materials. Since we can have limited influence on the out-of-school experiences, the greatest impact may be an enrichment of in-school experiences for female students. In-school experiences for female students should therefore be as rich as possible.

The three levels of social influence (mentor, family and friends, and schools and other agencies) are necessary ingredients of the apprenticeship. Since females rarely have mentors who encourage tinkering with electrical equipment schools may have to provide mentoring programs. While, as educators, we can exert little influence on the family and friends of female students, there is something that we can do through educational awareness. In terms of school and other agencies, there is probably much to do in terms of providing gender-fair curricula, and providing instruction which aids in the development of tinkering. Although the school may not have the impact of a mentor, family, or friends, it was still the strongest social influence for female students. This illustrates the importance of schooling for females.

A review of the personal factors influencing tinkering reveals females tended to display a very low level of interest in tinkering. While this may be due in part to personal disposition, it also appears to be influenced by social and experiential factors. An improvement in these two factors may also improve their level of personal interest. Nevertheless, females need to be encouraged to tinker both inside and outside school time.

Recommendations for Future Research

Further Exploration of Children's Science

The results have implications for further research both in the development of a model of tinkering and future investigations into *children's science*. The outcome seems to support an earlier claim that children not only bring their own concepts but their own methods to the study of science. The study provides a tentative model of tinkering from which to explore children's methods. Based on the model proposed, tinkering is a complex process. It is through the study of the informal methods such as tinkering, utilized by children in the study of science, that we can come to understand some of the complexities involved in a meaningful understanding of *children's science*. My study suggests *children's science* is not just a catalogue of conceptions that children hold on a series of scientific concepts but it has a much broader scope which includes methods and attitudes.

My investigation focused on expanding the definition of *children's science* by exploring a method by which some children acquire their science. The model of tinkering developed suggests that children's methods are indeed quite complex and as such require further study beyond the exploratory level. It is only through future studies which might expand our view of *children's science* that we can come to visualize the rich diversity that children bring to science.

Further Development of a Model of Tinkering

The model of tinkering developed is a preliminary attempt and as such leaves important questions unanswered. Given that my study was exploratory, the findings are preliminary suggesting that more research is required to further develop a model of tinkering. Some of the questions unanswered were: To what extent can the proposed model of tinkering be applied to other settings? To what extent can the model of tinkering be used to interpret and understand classroom behavior? These kinds of questions need to be pursued in classroom settings.

My investigation also raises a number of questions which need to be pursued in classroom settings. Are teachers aware of tinkering? If so, do they see it as an asset or obstacle to learning? To what extent are students aware of their own tinkering? To what extent do teachers take tinkering into account during instruction? Clearly, there is still more work required to clarify the notion of tinkering and its implications for classroom instruction. If we are to make informed decisions about the most effective forms of instruction from a *children's science* perspective, we must devote some of our research efforts to systematically study the relationships between tinkering and classroom instruction.

The model of tinkering which was developed needs to be examined in different settings and with larger populations before any generalizations can be made. As the findings rest on data collected on a small sample, the need for more extensive research is obvious. My study did not focus on any possible link between tinkering and school performance. Based on the model proposed, this relationship could be explored in future research.

This was an investigation of children's science and has implications for further research in that area. If we are to better understand the prior science children bring to the classroom we must not only concentrate on studies of their prior concepts, but we must also begin to examine the methods by which they acquire their scientific knowledge. By developing a model of tinkering my study was an attempt to understand one such method. The research described here is a first step at describing the notion of tinkering suggesting that the model proposed needs to be explored further. The model proposed will also hopefully provide a vehicle for further exploration of the gender issue. By focusing on tinkering I have in fact raised more questions about *children's science* than I have answered. These questions however need to be raised if we are to advance our understanding of *children's science*.

Gender Differences in Tinkering

Tinkering, as the result of preliminary analysis, can be viewed as: an activity which favors males, and hence "connected knowing" for males and "disconnected knowing" for females. Future research should therefore explore the female way of knowing as it relates to the study of electricity. Since my study focused on the development of a model of tinkering, and females did not do much tinkering, it was very unlikely that a female way of knowing would be disclosed. But how do females understand science? This is a question that needs to be explored.

We need to explore the possibility of making areas of science such as electricity more appealing to females. Clearly electricity has been considered a masculine area of science. This masculinization is evident in the performance of males on standardized achievement test and the predominance of males in related occupational fields. Since electricity is a required component of the junior level science program, it is important that it appeal to female as well as male students; therefore, the idea of making the study of electricity more appealing to female students by using material drawn from their sphere of experience or interest should be explored. Research focused on such explorations would be quite useful.

The fact that gender differences was not a specific question of my research suggests that conjectures raised about gender differences should become the focus for future research. A study which might focus entirely on females and electricity with respect to feminine ways of knowing is just one possibility.

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APPENDIX A: SURVEY OF ELECTRICAL EXPERIENCES

Part 1

Student Profile

Name: ____

Complete the following questions:

1. How do you like to spend your time? (Give examples of hobbies, sports, books read, favourite subjects, T.V. shows, etc.)

____
____
____
____
____
____
____
____
____
____

2. What experiences have you previously had with electricity?

____
____
____
____
____

3. What would you like to learn about electricity this year?

____
____
____
____
____

4. (a) Have you studied electricity before? Yes ____ No ____
   (b) If yes, what have you studied?

____
____
____
____

Survey of Electrical Experiences

Part II

Directions: Please answer the following questions by noting how often you have been involved in the listed activities.

(1) never, (2) once or twice, (3) quite often

1. used electrical tools ____
2. changed a battery (car or motor bike) ____
3. charged a battery (car or motor bike) ____
4. measured voltage in a battery ____
5. measured electrical current ____
6. repaired an electrical appliance or equipment ____
7. repaired an electrical game or toy ____
8. change a bulb in:
   (a) flashlight ____
   (b) the house ____
   (c) the car ____
   (d) toy or game ____
9. changed fuses in:
   (a) house ____
   (b) car ____
10. re-set a circuit breaker ____
11. did some house wiring ____
12. (a) set up a computer ____ (b) used a computer ____
13. tested the conductivity of materials ____
14. changed spark plugs in an engine ____
15. made a model of an electric circuit ____
16. made a model of an electric motor ____
17. made an electro-magnet ____
18. set up stereo equipment ____
19. used a stereo ____
20. set up a T.V. for Cable T.V. ____
21. set up VCR equipment ____
22. Viewed the insides of:
   (a) radio ____
   (b) computer ____
   (c) stereo ____
   (d) electronic game ____

(e) T.V. ____

23. attached a plug to an electrical cord ____
24. made a video recording ____
25. made a tape recording ____
26. used wire strippers ____
27. read a house meter ____
28. worked with batteries and bulbs ____
29. charged an object such as a balloon ____
30. made an object attract another ____
31. made an object repel another ____
32. fixed something electrical ____
33. fixed something mechanical ____
34. designed and built things ____
35. worked with electronics ____

Part III

Directions: Please answer the following questions in the space provided.

36. Have you ever had an electric shock? ____
    (a) current ____
    (b) static ____
37. Are you afraid of electricity? ____
38. Are you interested in electricity? ____
39. Are you interested in other areas of science? ____ Which areas?

____

____

40. Do you tinker (that is, get involved in hands-on activities outside school hours)? ____ If yes, why?

____

____

41. Are you interested in finding out how things work, such as toys?

____

____

42. Which of the following extra-curricular or non-required science activities have you spent some time on:

    (a) science article--magazine ____
    (b) science article--newspaper ____

(c) watched science shows on T.V. ____
(d) gone to science lectures ____
(e) talked science with friends ____
(f) done science projects ____
(g) worked with science hobbies ____
(h) read books on science ____
(i) field trip activities ____
(j) club activities ____

43. What was your favourite electric toy or game as a young child?

____

____

44. What is your favourite electric toy or game now?

____

____

45. What electrical tools do you know how to operate?

____

____

____

____

46. What experience(s) have you had with magnets?

____

____

____

____

47. What experiences(s) have you had with compasses?

____

____

____

____

APPENDIX B: TRANSCRIPT OF INTERVIEW WITH SEAN

Interview with Sean

Sean was videotaped while he completed a series of six electrical tasks. The following transcript should provide the reader with a description of what he said and did during the interview. I represents interviewer, S represents Sean and those words italicized show some incidents when Sean did his thinking out loud.

Task # 1 (school-type): Construct an Electric Tester

Before activity begins Sean puts bulb holder on table, gets some wire and untangles it.

Transcript	**Comments**
I: Sean have you worked much with this kind of stuff?	
S: Yeah, I have worked a nice bit. (gets six volt battery)	**prior experiences**
I: Where in school or out of school?	
S: Mainly out of school, like I use to take apart my electrical toys.	
I: Mmh, mmh. Why do you think you do that?	
S: I don't know I just like. I like fooling around with electric things and that. (cuts wire)	
I: Mmh, mmh. Why do you think that you are particularly interested in electrical?	**typology**(technological) criterion 1 - is interested in electrical and electronic hardware or the application of knowledge of electricity.
S: I don't know it is the way it makes things run and that right.	
I: Mmh, mmh, mmh.	
S: Same thing with motors and like engines and things like that.	
I: Mmh.	
S: Does this battery work? (attaches wire to battery terminal)	**verbal knowledge** - questioning)
I: Ah, it probability does. I notice that you are using lots of voltage on that.	
S: Six volts. (looks at battery)	**verbal knowledge** - stating)
I: Do you need that for this set up, you think?	
S: Depends on how much this is. This here is only. This here takes one hundred and twenty five volts. (looks at bulb holder)	

I: Are you sure?
S: It says a hundred and twenty five on it.
(holds up bulb to show 125 volt reading on it)
I: On where?
S: Right here (points to bulb holder), or is that just the tester not the bulb.
I: Oh, yeah. It does say that there but what about.
S: I can use any battery you want it's just.
(moves toward box)
I: No, it is up to you what do you think?
S: Ah, this one here might be a little bit too much I'd say. (removes six volt battery)
I: It does say that on there. That is interesting.
S: I guess that is how much the wire inside it can take and not the bulb.
I: Oh, I see.
S: *These here.*
I: Even though that might take it, the bulb is what you are talking about is it? (gets one 1.5 volt battery)
S: Yeah. (gets screwdriver and unscrews screw in socket)
I: Have you worked with these sockets before?
S: Yeah, down in the elementary school. **prior experiences**
I: Mmh.
S: We used the switches and things like that and the balance. (puts back srewdriver)
I: Yeah so you have done some of that out of school have you?
S: Oh, yes. And eh I am working with my cousin, he's got a house and I am helping him do his room, and I help him put in the light and phone and all that. (cuts wire) **social influence** mentor (level 1)
I: You mean your cousin who is building a house.
S: He is not building it he is redoing his room.
I: Yes.
S: And I helped him. Helping him do it.
I: Mmh, mmh. That must be an older cousin is it?
S: Mmh.
I: Not some one your age.
S: Mmh. (bends wire and puts around loosened screw)
I: I don't think some one your age is into building a house or remodeling.
S: No, he is about thirty. He use to teach at this school a little while ago, last year.
I: Mmh.
S: Jim H. .
I: Oh, yes. He is your cousin is he?
S: Yeah. (tightens screw in socket with screwdriver)
I: So do people seek you out or do you seek out jobs like that to do.
S: Well he came to me because like him and I are

really good friends. (bends wire)
I: Mmh, mmh.
S: And he knows that I use to pick apart my (technological) things and that. **typology** - criterion 1
I: Mmh, mmh.
S: So he decided to help me, like. (puts around screw in socket)
I: Yeah.
S Give me something to do.
I: Yeah. It is interesting that you use the word pick apart your things.
S: Yeah.
I: How long have you been doing that? (tightens with screwdriver)
S: I'd say ever since I have been about six or seven. **prior experiences**
I: Not before?
S: Well I use to break them before.
I: What do you mean by break them?
S: The same thing they use to say I beat up things?
I: Ah, you were destructive. (puts down the screwdriver)
S: Yeah, or that is what my mother says.
I: Are you sure you weren't picking things apart?
S: I don't know. (picks up one wire and attaches it to socket)
I: So you have been doing this kind of thing since you have been about what? **prior experiences**
S: About six years old. (straightens end of wire and puts underneath battery)
I: Mmh, mmh. What did you start with first?
S: A little toy fire engine. (puts other wire on top of battery)
I: Mmh, mmh.
S: Just barely going. (gets another 1.5 volt battery)
I: Mmh, mmh.
(he puts battery in place)
S: It should go a little bit brighter now (removes two batteries). Can I use this? (gets a six volt battery)
I: Mmh.
S: I guess I can use this. (unscrews terminals)
I: Mmh, mmh.
S: It looks like a more powerful bulb than we used in the lab.
I: Mmh, mmh.
(he connects terminals and bulb lights)
I: If we wanted to set up a circuit tester how could we do it from what you have there?
S: A circuit tester. **verbal knowledge - questioning**
I: Yes.

S: Like eh, test what?
I: Test substances to see.
S: O.K..
I: If they let electricity through them.
S: Well what you would do is you touch this wire to here. (holds up plastic tube and points it to one battery terminal) — **verbal knowledge - stating**
I: Mmh, mmh.
S: And touch that there. (points to other battery terminal)
I: Mmh, mmh.
S: And if it's, if it's, eh conductor then the light will go on. (points to light) — **verbal knowledge - stating**
I: Mmh, mmh.
S: But it is a insulator so it don't go on. (puts tube back in box)
I: So what kind of things are conductors do you think?
S: Conductors are like steel things, water, eh, all kinds of minerals, not all minerals but most of them, like for instance the knife. (tries knife and light comes on)
I: Mmh, mmh, mmh.
S: Plastic isn't though. (tries plastic handle on screwdriver)

Additional Comments:

Phases of Tinkering - he displayed all four phases of tinkering (searching, framing, solving, and evaluating)

Actional Knowledge - he displayed two levels of actional knowledge (formative and repertoiral)

END OF TASK

Task # 2 (school-type) To make an electromagnet

Interview begins with stand on table with ring clamp attached halfway up the retort stand with cardboard on it. On the table there is a screwdriver, two clamps with one hole stoppers, wire and compasses. Sean is attaching one of the clamps.

I: Have you worked much with compasses before?
S: Yeah. Well not a whole lot like I was in scouts, clubs and that. — **prior experiences**
I: Mmh, mmh.
S: They taught me how to do it and last year for science we had to know.

I: Mmh, mmh. (he untangles wire)	
I: Have you played with compasses or worked with them out of school?	
S: Couple of times like when I went out camping or anything like this you know I was fooling around with it.	
I: Got any idea how a compass works?	
S: Eh, yeah there's sort of like a magnetic force in the world and the compass arrow points towards. Hold it now, yell the compass arrow points towards the north, or magnetic north or something like that. (puts wire up through one hole in rubber stopper in bottom clamp)	verbal knowledge - stating
I: Mmh, mmh. (he pulls wire through hole in center of cardboard on ring clamp and then pulls wire through one hole rubber stopper in top clamp)	
I: What effect you think electricity might have on compasses? (he adjusts wire)	
S: Well where there is electric force. When there is electric, where there is electric force it will make a magnet, or sort of like a magnet and then the arrow point towards the wire cause of the electricity running through.	Verbal knowledge - stating
I: Mmh, mmh. (he unscrews battery terminals and attaches wire)	
I: You have enough space there to work in?	
S: Yeah. That is fine.	
I: You said that the electricity produces the magnetic.	
S: Yeah.	
I: Force.	
S: Force. (attaches other wire, he does not use a switch to set up circuit)	
I: Have you done anything or read anything about that before?	
S: We used to make electric magnets and that.	prior experiences
I: Eh.	
S: And this here is sort of like the same idea.	
I: So where did you make electromagnets?	
S: I have made them at home. I have made them in school.	
I: Mmh, mmh.	
S: Should have put these on first. (puts two compasses on cardboard)	
I: About how long have you been making these things?	
S: Making?	

I: Making electromagnets.	
S: I say I have been doing it around, ever since grade four or five, five. (puts two compasses on cardboard)	**prior experiences**
I: Mmh, mmh. (he gets more compasses from box)	
I: What is happening to the compasses now?	
S: They are all going to. Not that one that one is broke. They are all going to a certain, point. Well most of them are except for one. I don't know why that one is not going (checks on compasses). Oh yes it is, it is pointing now. (looks at compasses)	**verbal knowledge - stating**
I: At a certain point you mean, you mean different directions or same direction. (puts more compasses on cardboard)	
S: They are all going to the same direction. Except for one. (looks at compasses)	
I: Mmh, mmh.	
S: They are all pointing that way. (points to wall)	
I: Mmh, mmh.	
S: Now, yes they are all pointing the same direction, that way. (points to wall)	
I: Mmh, mmh.	
S: So. I guess that would mean that there is definitely a electric current going through there.	
I: You think so?	
S: Yeah. Going through that wire. And, yeah. (disconnects one wire from battery)	
I: Did you notice, did you notice any change when you try it back and forth?	
S: Yeah a couple of them go off different, like they go out of the way. (reconnects wire and checks on compasses) Yeah it is different like one minute it will point that way (points in a direction) when I got it off and then it will point this way. (points to the wall)	**Verbal knowledge - stating**
I: Mmh, mmh.	
S: Want another one done? (disconnects battery)	
I: Yes. You don't have to speed up to get them all done.	

Additional Comments:

Phases of Tinkering - he displayed all four phases of tinkering.

Actional Knowledge - he displayed the first two levels of actional knowledge.

END OF TASK

Task # 3 (school-type) To demonstrate electromagnetic induction

Interview begins with galvanometer on the table.

I: Have you worked with a voltmeter before?	
S: Yeah.	prior experiences
I: Or galvanometer.	
S: Yeah a couple of years ago we did this exact same experiment.	
I: That right?	
S: Yeah. I am going to do it with. It is not insulated wire is it? (gets a wire from box to the side)	
I: What do you think? (he untangles wire and attaches one wire to terminal)	
I: Does whether or not the wire is insulated make a difference.	
S: I think it will make just a little bit of a difference. Eh you make get more power out of it a non-insulated wire than an insulated one.	verbal knowledge - stating
I: Mmh.	
S: Because the magnets go directly to the wire.	
I: Mmh. (he attaches other end of wire)	
S: Is this the one from our school? If it is it might not work.	prior experiences
I: Is that right?	
S: Yeah.	
I: You've used eh.	
S: I've used the ones around here but they have a couple here don't they? (reaches to remove something from box)	
I: Mmh.	
S: Eh I now I get, black tape. (puts black tape in box, gets two bar magnets from box and checks text briefly)	
I: So you say you have done this activity before.	
S: Yeah.	prior experiences
I: As a regular activity or as an extra thing you have tried? (he rubs magnets)	
S: Both as a regular activity from, from school and as (adjusts center screw on galvanometer with screwdriver) that is not right on there now. (refers to needle being centered) Like the galvometer[sic].	
I: Mmh.	
S: It is off. (checks text briefly)	

I:	Do you work with any kind of meters outside of school?	
S:	Ones that test batteries. I don't know if it is a galvometer [sic] but it is different than this it is like one with the switch on it. (rubs magnets) Oh yeah going. There we are. Should, do you have a horseshoe magnet?	**prior experiences**
I:	Yes.	
S:	It is easier with. (gets a horseshoe magnet from the box, moves wire back and forth inside horseshoe magnet)	**verbal knowledge** - stating
S:	You should be able to just rub it up and down like this shouldn't we?	**verbal knowledge** - questioning
I:	Mmh, mmh.	
S:	I get it going but I don't see any.	
I:	Mmh.	
S:	Anything coming out.	
I:	Mmh , mmh. (pause) It should work.	
S:	It should work. It is probablely the galvometer[sic]. (adjusts screw on galvanometer) I'll try the other one. (disconnects wire)	**verbal knowledge** - stating
I:	Do you eh. Eh, you said you are working with your cousin.	
S:	Yeah.	
I:	And doing some house wiring and putting in telephone and that kind of stuff.	**prior experiences**
S:	Yeah.	
I:	Do you do any other kind of things?	
S:	Well eh. (gets voltmeter with variable adjustment) Some times I do like if when my electrical games break down or anything I usually can fix it, like a walkie talkie or anything like that. (connects one wire)	**prior experiences**
I:	Mmh, mmh. What science is your favorite area of science?	
S:	Eh, chemistry I'd say. Chemistry or physics.	**personal interest**
I:	Mmh, mmh. Why?	
S:	I don't know I like chemistry like you know being able to use different chemicals and things like that.	
I:	Mmh, mmh. Why physics?	
S:	Cause it is like, sort of problem solving and that. (moves wire up and down in horseshoe magnet)	
I:	Mmh.	
S:	And it is like sort of like a thinking, thinking, thinking for yourself. It is not like you got to write down your different ideas and things about it.	
I:	Mmh. (he readjusts wire to another terminal	

on voltmeter his original set up was 30 volts)
I: You are trying different setups there I notice.
S: Yeah because the first one is thirty that shouldn't work because it is extra high. I would have to have mechanical hands or something. — **verbal knowledge - stating**
I: You are saying the current there would definitely be smaller. (he moves to another terminal
S: Yeah I'd say it is very, very small. — **verbal knowledge - stating**
I: Why?
S: Because it is only one wire and it is a small wire and I am not putting it through the magnet very fast. (moves wire) — **verbal knowledge - stating**
I: Mmh.
S: Now that should just barely show up. I have no idea why it is not though. I know I will use an insulated wire and see if that will make a difference. (disconnects wire) — **verbal knowledge - stating**
I: So you are saying that wire is not insulated, the one that you are using there.
S: No it is not it is just plain copper or metal. (gets another wire) — **verbal knowledge - stating**
I: Mmh.
S: It is a bit too long. (gets another wire, attaches to terminals)Not only that may be that one over there was too long because it loses energy as it goes through. (referring to other wire) — **verbal knowledge - stating**
I: Mmh, mmh. So you think the length of the wire makes a difference. Is that what you think?
S: Yeah. (moves wire back and forth)
S: It is going up a tiny, tiny bit. After it moved a tiny bit it came out. (wire came loose)
I: Mmh, mmh. Are you sure it is not the vibrations that is sending it up?
S: I don't know. It could be. I don't know why it is not working though. — **prior experiences**
It worked before when Mr. Day taught me how to do it. (readjusts wire) — **social influences**
I: Mmh.
S: Try it again. (moves wire back and forth)
S: No moved up a bit.
I: Mmh.
(he moves wire back and forth)
I: It moved?
S: Just a tiny little bit extra. Probably it is the vibrations that did it.

I: Mmh. So are you pleased with that?
S: What?
I: With your results.
S: Not really I was hoping it would usually
it would work a little bit more.
(puts wire and voltmeter aside)
I: Mmh, mmh. What about the second setup
there would you try that with the coil.
S: Oh yeah o.k. this stuff here will probably
do a bit better. (gets voltmeter and wire
and makes a coil, begins to attach wire to voltmeter)
I: You are inserting the wire in the center there.
S: Yeah in that little hole.
I: Mmh, mmh.
(he inserts wire in hole in voltmeter terminal)
I: Is that wire coated or uncoated you are using?
S: Uncoated.
I: Mmh, mmh.
(he wraps wire around battery)
I: You are wrapping it around the battery.
S: Yeah then I will take the battery out and
also have my coil.
I: Mmh.
S: My little coil.
I: Mmh, mmh. You have made coils like
that before.
S: I think so. I do know where like you know — **prior experiences**
but I have, I have seen it done.
I: What do you think will happen?
S: Well I should get a little electricity. — **verbal knowledge**
(moves bar magnet through coil) Yeah, — - stating
just barely rocking every time I move it
in and out, see. (brings apparatus such
that interviewer can see)
I: Oh yeah there is a slight.
(he moves magnet back and forth)
S: Slight, little tiny. If I had more coil. — **verbal knowledge**
I: Mmh. — - stating
S: If I had more coil, stronger.
I: Mmh.
S: Magnet and I was doing it faster it — **verbal knowledge**
would go up a lot higher. — - stating
I: Mmh, mmh. So given more time
you are saying you could get that working.
S: Yeah I could get to have a nice bit of — **verbal knowledge**
electricity. — - stating
I: Like how much you think?
(disconnects wire)
S: I say I could probably get quite far — **verbal knowledge**
but I don't know what the volt. — - stating
I: Mmh.
S: It is not that much but it is.
I: Mmh.
S: But it is a nice bit.

I: Mmh, mmh. So do you like doing this kind of stuff.	
S: Yeah.	**personal interest**
I: Why do you think you like it?	
S: It is just well it is better than, I like staying home and doing it and checking things out and that. Well it is something for me to do so that I don't get bored.	
I: Mmh.	
S: Like you know if it is a rainy day, or something and if I have got nothing to do.	
I: Mmh.	
S: And if, it is just something to do like it is better than going out in the cold all the time.	
I: Mmh. What are your favorite things to do in your spare time?	
S: Do in my spare time.	
I: Mmh.	
S: My favorite thing of all is going out with my friends.	
I: Mmh, mmh.	
S: And then I like going up to my cousin's.	
I: Mmh.	
S: And helping him with his house, and I like fooling around with my computer.	**social influence**
I: Mmh.	
S: I like lifting weights and I like listening to my ghetto blaster.	
I: Mmh, mmh, mmh. Ah, your computer what do you like about the computer?	
S: It is something like that I can control right.	**typology** (technological)
I: Mmh.	- criterion 3
S: And it is something that like I can make it do a lot of things and that, like play games and things like that with it.	
I: Mmh. Do you write your own programs?	**prior experiences**
S: Mmh.	
I: O.K. what about getting inside of the computer.	
S: Like taking things apart.	
I: Have you done that?	
S: I have taken the cover off and that was it.	**prior experiences**
I: Why? Why haven't you got inside it?	
S: Because I don't know much about it.	
I: Aah, aah.	
S: I only know basic electricity and that.	**prior experiences**
I: Aah, aah.	
S: But I could if I had the right materials I could give it more memory by getting inside and that.	**typology** (technological)
I: Mmh, mmh.	
S: That is like a basic job.	**prior experiences**
I: Mmh. What do you mean a easy job or.	

S: All you need to do is to go out and buy some microchips.
verbal knowledge
- stating

I: Mmh.
S: And take out the old ones and put in the new ones.
verbal knowledge
- stating

I: And you would do that yourself.
S: Mmh.
I: Why do you think people stay away from the computer, from the inside of it?
S: Computer phobia, they're afraid of what it is going to do to them, like they're afraid. Well people my age are that they will turn into spases.
I: What's that?
S: Like a person who don't go any where and they just stay home with the computer all the time and things like that, and they don't know anything about it and if they fool up their mothers will kill them.
I: The mothers is it?
S: Yeah.
I: What about the fathers?
S: And the fathers.
I: Aah, aah, aah. So getting into the computer then is, you've got restrictions have you?
S: Yeah. Not only that there is F.C.C. laws.
verbal knowledge
- stating

I: Which are what?
S: Like I don't know what they are but says you are not allowed to fool around with certain computers and that. It is against the law.
verbal knowledge
- stating

I: Mmh, mmh. Would you like to?
S: I'd really like to know a lot about electricity and things like that.
personal interest

I: Mmh, mmh. So what is an interesting thing to you about the computer?
S: Most interesting thing, is the way you can make it do things, like make it program things like if you had enough things you could make it walk or talk or do anything.
typology (technological)
- criterion

I: Do you like the idea of things doing things?
S: Mmh.
I: Does that take a lot of patience?
S: Yeah! The computer takes a lot of patience.
I: Mmh, mmh.
(school bell rings)
S: Like one program
S: Just to make it do simple things take you a long time.
I: Mmh, mmh o.k. . I probably better let you go to recess.

Additional Comments:

Phases of Tinkering - he displayed all four phases of tinkering (searching, framing, solving and evaluating)

Actional Knowledge - he displayed two levels of actional knowledge (formative and repertoiral)

END OF TASK

Task # 4 (non-school type): To attach two and three prong plugs to electrical wires

I: What I would like for you to do. Have you ever attached plugs to electrical wires before?	
S: I think I did once or twice.	**prior experiences**
I: O.K. (interviewer passes bag of plugs and wires to Sean)	
S: I can usually figure things out like this any way.	**prior experiences**
I: Ah, ah. (Sean takes wires and plugs apart and begins to untangle the wires then he discovers that a plug is missing)	
S: Where did the other plug go to?	
I: Eh. (interviewer removes three prong plug from the bag)	
S: Oh. (continues to untangle wires)	
I: There is a couple of plugs there I want you to pick out a couple of wires and attach them. (pause) You said you have done something like this before or you haven't?	
S: With the toaster. (examines three prong wire)	**prior experiences**
I: With the toaster.	
S: Yeah.	
I: What happened?	
S: Then I threw it away.	
I: What happened with the toaster?	
S: The wire eventually got frayed and that. So I just put the plug back on for a little while then I threw it away. (puts three prong wire aside)	
I: Mmh, mmh, mmh. (examines two prong wires and plugs)	
S: *One, two, that's two so I need one with three.* (looking at plugs) (puts two prong wire aside)	**verbal knowledge** - stating
I: I hear you mentioning one and two and three. Is that important? Why?	
S: Yeah. (selects three prong wire)	
I: Why?	
S: Ground.	**verbal knowledge**

I:	Why?	- stating
S:	O.K. cause like if there is ever an over load	**verbal knowledge**
	or anything like, it touched water or	- stating
	anything the wire could ground itself out.	
	(starts separating wires in three prong wire)	
I:	Mmh.	
S:	So what I have to do I have to connect the two	**verbal knowledge**
	power lines.	- stating
I:	Mmh.	
S:	And then I have to connect it to a ground.	**verbal knowledge**
I:	Mmh. How do you know which one is the	- stating
	ground?	
S:	Well, usually black is ground.	**verbal knowledge**
I:	Usually black.	- stating
S:	Yeah. I think it is almost always black is	**verbal knowledge**
	ground.	- stating
I:	Mmh.	
S:	And the other two are power wires.	**verbal knowledge**
	(looks at box which contains electrical supplies)	- stating
I:	Mmh. What do you mean by power wires?	
	(examines bottom part of three prong plug)	
S:	Like negative and positive.	**verbal knowledge**
I:	Ah, ah. (gets screwdriver from box)	- stating
S:	Start this right here o.k. .	
I:	Yes.	
	(he unscrews screws in three prong plug)	
S:	But in the mean while it is not safe to have	**verbal knowledge**
	it like this any way, cause like it is still	- stating
	frayed. If it gets frayed you should just go	
	out and buy one any way, right.	
I:	Mmh, mmh. When you say not safe what do	
	you mean?	
S:	Like, you should really get new wire because	**verbal knowledge**
	all this is still frayed and you will never have	- stating
	a perfect one hundred percent connection	
	unless you go out and buy a new one.	
	(picks up three prong wire)	
I:	Mmh. Why, why not?	
S:	Because when I wrap this around this here	**verbal knowledge**
	now there is still this wire left and any body	- stating
	could touch it or anything like that and get	
	a shock. (wraps one wire around loosened	
	screw)	
I:	Yes. Why would you do it that way?	
S:	What?	
I:	Can't you repair it?	
S:	You could tape I suppose but it still would	**verbal knowledge**
	be safer to buy, to go out and buy a new, wire.	- stating
	(tightens with screwdriver)	
I:	Mmh, mmh, mmh.	
S:	Like just use this a temporary thing.	
I:	Mmh, mmh. Are you afraid of electricity?	
S:	No. As long as I like, being protected right.	**verbal knowledge**
I:	Mmh, mmh.	- stating

S:	Like if I am wearing a glove or if I got, if I'm wearing insulated gloves or anything.	
I:	Mmh.	
S:	Then I am not really afraid of it, no. (separates two remaining wires)	
I:	Mmh, mmh. So what do you mean by insulated gloves?	
S:	Like electricians gloves, they're, they're with rubber. (begins to screw in place second wire)	verbal knowledge - stating
I:	Mmh.	
S:	And then you can't get a shock. Well you could if there was enough electricity.	verbal knowledge - stating
I:	Like how much?	
S:	Like I say if you went out and grabbed a telephone wire or some thing then you could probably get a shock.	verbal knowledge - stating
I:	Mmh. What about household wiring?	
S:	No I don't think so not with electrical, not with electrician's gloves. Where's the other screwdriver? (gets another screwdriver from box and tightens screw) You got to have a lot of patience with this stuff.	verbal knowledge - stating
I:	Have you?	
S:	Yeah.	
I:	Why do you think?	
S:	Cause if it don't go right then you have got to do the whole thing over again.	
I:	Does that happen often?	
S:	With me yeah. (puts other wire in place and tightens screw)	prior experiences
S:	There that should work. You don't need this now? (holds up two prong plug)	verbal knowledge - stating
I:	Would you leave it like that?	
S:	No, I always wrap tape around here, and.	prior experiences
I:	Aah.	
S:	Like I put a lot of tape around, electrician's tape. (points to where bare wire is visible near the top of the plug)	verbal knowledge - stating
I:	Mmh.	
S:	Cause, like you, if some one, plug anything in they could stick it in the back and get electrocuted. (Sean appears to be waiting for further directions)	verbal knowledge - stating
I:	So what about the other plug?	
S:	This plug here.	
I:	Mmh. Or are you finished with that one?	
S:	Wait now. Yeah. Do you want me to go all the way and fix it like I would normally. (picks up black tape)	prior experiences
I:	Yes. How would you fix that normally any how?	
S:	Normally I would just I would put a lot of tape around it so there's absolutely no way any body	prior experiences / verbal knowledge

	getting any shock. (picks up three prong wire with attached plug)	- stating
I:	Mmh..	
S:	And then I would probably take something like this (picks up an object from the table) and I'd stick it on so it would keep the tape secure to the thing.	**verbal knowledge** - stating
I:	Mmh, mmh, mmh.	
S:	Do you want me to do that?	
I:	No, that's o.k. we will leave it and go on to the next thing.	
S:	This is definitely it I did not see this. (discovers top of three prong plug)	**verbal knowledge** - stating
I:	What is it?	
S:	It is the cover for the plug.	**verbal knowledge**
I:	Is that better?	- stating
S:	Oh yeah! It's way better instead of using tape. (attempts to put cover on plug, using a screwdriver to help it in place, works on fitting the top in place for awhile)	**verbal knowledge** - stating
I:	That hard to go on.	
S:	Very! Eh! I almost got it in.	
I:	Is there a trick to that or are you using strength?	
S:	Strength.	
I:	Strength.	
S:	Lots of strength.	
I:	Aah, aah.	
S:	Either that or I think I got it , I got a little too much wire in there like I didn't coil it enough around.	
I:	Mmh, mmh, mmh. (he continues to work on attaching the top of plug with screwdriver)	
S:	Here we are.	
I:	Mmh.	
S:	Aah! Now. (puts clamp in place and tightens with screwdriver)	
I:	So what are you doing now?	
S:	I am getting this clamp on for, getting loosening itself to go over.	**verbal knowledge** - stating
I:	So is that important?	
S:	Yeah it keeps the cover on the wire and it keeps all the wires in place.	
I:	Mmh. (he adjusts clamp)	
I:	What do you think you would be interested in for a career when you finish school?	
S:	Going into the air force.	**personal interest**
I:	Aah, aah. What would you do there?	
S:	Fly jets.	
I:	Fly, jets.	
S:	Mmh.	
I:	Aah, aah.	
S:	Or may be I just like, be a co-pilot.	

I: Mmh, mmh, mmh. Why do you think you would be interested in flying jets?

S: I don't know I just like, like I when I fly in planes I really, really enjoy it.

personal interest

I: Mmh, mmh, mmh. Anything else about it?

S: Well it has got a lot to do with computers and that and I like to work with computers when I get older.

personal interest

I: Mmh.
(he finishes tightening clamp)

S: Here.

I: Mmh. It looks very good.

S: You want this plug done to?

I: Yes.
(he gets two prong plug)

I: Have you seen one like that before?

S: No. (pause) O.K.

prior experiences

I: I noticed you took it apart.

S: Yeah, o.k. I know what it does. I know how to get it. I can take things apart very easy.

typology(technological)
- criterion 2

I: Is that right?

S: Yeah.

I: Are you, why do you say that?

S: I don't know I just I am good at just looking at things and then just being able to see how you can take them apart. (attempts to put wires* of the two prong wire with attachment in center of plug)

typology(technological)
- criterion 2

* wires in two prong wire has been previously stripped

I: Mmh.
(he adjusts wires)

S: Now this one here might not work. I don't know.

verbal knowledge
- questioning

I: Why do you say that it might not work?

S: Because I am not sure about what I am doing.

verbal knowledge
- questioning

I: Mmh, mmh, mmh.

S: *This goes here (pause) and these in there.* (removes wire from plug and gets knife from box, puts wire through side hole in top of plug)

S: Does this one work?

I: Mmh, oh yes! Just go ahead. Why? Why would you want to?

S: Because I don't know I just can't seem to get the wire all the way in.
(cuts coating on wire)

verbal knowledge
- questioning

I: Is that knife any good?

S: Yeah it is fine. It is not the sharpest knife in the world but it is better than

if I have to use my teeth.
(he pulls two wires apart,cuts coating on wires and pulls off excess coating)

I:	Are some specific tools helpful with this?	
S:	Wire cutters.	**verbal knowledge**
I:	Aah, aah.	- stating
S:	They are good for almost anything you can just stick it in and turn it around. (shows how with hand)	**verbal knowledge** - stating
I:	Mmh.	
S:	Just pull out.	
I:	Aah, aah. Do you have your own tools at home.	
S:	I got a couple.	**prior experiences**
I:	Mmh, mmh.	
S:	Just the basics stuff though. (recuts coating)	
I:	Mmh, mmh. Do you need much for doing the kind of things you do?	
S:	Not really, but like more tools would help right. (pulls off excess)	**verbal knowledge** - stating
I:	Mmh, mmh, mmh. Any one in your family into the kind of stuff you are into? (inserts wire into top of plug)	
S:	No, just me.	**social influences**
I:	Mmh. What does your dad do?	
S:	He's general foreman at W. Mines. (ties to insert wire in plug)	
I:	Mmh, mmh. So he doesn't stay that much in G. F. he is gone a fair amount.	
S:	Yeah.	
I:	O.K. and your mom is she into any kind of stuff like this.	
S:	She's a nurse.	
I:	Mmh.	
S:	Can I use this? (picks up black tape)	
I:	Oh yes sure. Why do you want to use it?	
S:	Because if you plugged this in it would be dangerous because there is still.	**Verbal knowledge** - stating
I:	What did you do with the wires?	
S:	What I did was I put them up, back of the plug.	**verbal knowledge** - stating
I:	What do you mean by the back of the plug?	
S:	O.K. I will show you.	
I:	Yes because I sort of missed it. (he opens plug)	
S:	Oops.	
I:	Oh.	
S:	You put it back up here. (points to center of plug)	**verbal knowledge** - stating
I:	Oh you mean in the center.	
S:	Yeah.	
I:	Aah, aah interesting.	
S:	Was I right?	

I:	Oh yes that is fine. (he starts to put top on plug)	
I:	Do you think you are right?	
S:	I don't know. What I would is I, like put if I had a voltmeter I'd put it on and take a battery wrap it on each side of the plug end.	**verbal knowledge** - inventing
I:	Mmh.	
S:	And then I would, I'd test it with the voltmeter and if the right amount of volts come out.	**verbal knowledge** - inventing
I:	Mmh.	
S:	Then I am right if not I have to look at it and go through it again.	**verbal knowledge** - stating
I:	Mmh. Are you into motor bikes and stuff like that? (pulls off some black tape, cuts with fingernails and wraps around bare wire just above plugin)	
S:	Yeah. I had one this year but I sold it and I am going to get another one when I am sixteen.	**prior experiences**
I:	Mmh. What do you do with your motor bike?	
S:	Race. Like well I was racing mine but the one that I am going to be getting is going to be a street bike so I don't say I'll be doing much racing with that.	**prior experiences**
I:	Mmh, mmh. Did you get into the engine and that kind of stuff?	
S:	Yeah. Couple of times, like I was changing the air filter, the oil and doing things like that with it?	**prior experiences**
I:	What about the motor?	
S:	I was into the motor once. It is just your normal gas engine right.	**prior experiences**
I:	Mmh.	
S:	Tell you what I would do. (gets a six volt battery from the box to the side)	**verbal knowledge** - inventing
I:	Mmh.	
S:	Is I'd try to get it like a battery here.	**verbal knowledge**
I:	Mmh. (he gets two pieces of wire from the box and begins to attach one wire to the battery terminal)	- inventing
I:	What about cars and trucks are you into that?	
S:	Yeah I got a friend who, who's got a car and he works on it a lot and I help him usually. (attaches other wire)	**prior experiences/ social influences**
I:	At what kind of stuff?	
S:	Like he got a sad junk car but he what he does is he fixes it up and that like changes the transmission and things like that. (reaches for voltmeter)	**social influences**
I:	What are you doing there now?	

S:	Right now I am just going to measure how much the battery gives out. (loosens terminals on voltmeter)	verbal knowledge - inventing
I:	Aah, aah.	
S:	To see if it is very good and then I will hook the wires up to this (points to terminals of voltmeter) and then put. Oh, oh (laughs- surprised about attachment at end of two prong plug). I put two wires into here (points to attachment on two prong plug) and then put it up to here (points to terminals) and see if I have made a good connection. (begins to attach wire to terminals of voltmeter)	verbal knowledge - inventing
I:	Oh, I see. Where have you seen that kind of thing done?	
S:	Just made it up, just then as a matter of fact.	verbal knowledge - inventing
I:	Mmh.	
S:	To make sure I did a good job.	personal interest
I:	Is it important to you to do a good job? (attaches second wire to terminals of voltmeter)	
S:	Very.	
I:	Why?	
S:	I don't know it is just I think that it is no good to do anything unless you do a good job.	personal interest
I:	Mmh.	
S:	*So it is definitely that one (pause) it's about this much, a little tiny bit.* (looking at voltmeter)	verbal knowledge - stating
I:	So which one are you going to use there?	
S:	I am going to use the thirty because I want to see how much I get here now I use the thirty and then I will check with the three too.	verbal knowledge - inventing
I:	Mmh.	
S:	So.	
I:	You are going to check out the plugs.	
S:	Yeah, to see if I have got them hooked up good enough. (inserts wires from battery to the attachment end of plug)	verbal knowledge - inventing
I:	Where do you think you have learnt the most about electricity?	
S:	Aah.	
I:	In school or out of school.	
S:	Out of school.	prior experiences
I:	Mmh, mmh.	
S:	Cause in school they just do basic things like things that I knew before and things like that. (gets another wire and a knife from the box)	verbal knowledge - stating
I:	Mmh, mmh. What about the electricity	

unit that you are doing now do you think you will get anything from that?
S: What?
I: The electricity unit that you are doing in class.
S: No I don't think that I will get much from that, because it is just like mainly things that I have learned before. It is just going to go into it in greater detail. — **verbal knowledge** - stating
I: Mmh, mmh.
(he cuts off the end of the wire that he just obtained from the box)
I: What is your favorite subject?
S: Science. — **personal interest**
I: Why do you think science is your favorite subject?
S: I just like, the **things** that we do and the labs and that. I just like knowing **things** more about science. — **typology**(technological)
I: Mmh.
(he puts knife back in box, he inserts one wire in one of the hole in the attachment end of the plug)
S: *Oh I haven't got enough wire.* (looks on table and picks up wire) *Oh I'll take one out.* (gets wire in box) — **verbal knowledge** - stating
I: You are sticking with your color coding.
S: Well this one has got a bigger base of wire like its a, inside it is just one big wire. (cuts some wire off with knife) — **verbal knowledge** - stating
I: Mmh.
S: Instead of a bunch of little ones. — **verbal knowledge** - stating
I: Mmh, mmh in the class just then did you draw the diagram on the board on there?
S: One of them, yeah. (inserts wire in the other hole of attachment end of plug)
I: Why did you draw it on the board?
S: Cause Mr. Woolridge told me to.
I: O.k. He wanted you to draw something. (he removes one wire from attachment on plug)
S: Yeah. (cuts wire in two, attaches wire to voltmeter terminal) Now this should work. Looks a bit messy. (picks up attachment end of plug and in the one vacant space inserts wire attached to voltmeter terminal, and then connects up other wire which he has earlier inserted in attachment to the other voltmeter terminal)
S: Ugh, ugh. I don't seem to be getting any power. (reads voltmeter) — **verbal knowledge** - inventing
I: That right.
S: That means I made a bad connection in — **verbal knowledge**

	the plug.	- inventing
I:	That right.	
S:	Either that or I am not making a good connection in here (examines attachment and puts aside). So I will check it out with the other plug (picks up three prong plug). So that plug don't work (puts the two prong plug aside).	**verbal knowledge** - inventing
I:	Mmh, mmh.	
S:	Now I am not going to use the ground here because you can't short out cause I got only a little six volt battery. (attempts to attach two wires of the three prong wire to the battery terminals)	**verbal knowledge** - inventing
I:	Mmh, mmh, mmh.	
S:	Now I said black was, the ground.	**verbal knowledge**
I:	So you are cutting that. (Sean cuts coating off the bare end of the three prong wire)	- stating
S:	Yeah because the wire that I want is, right there. (points to the center where a wire is short, cuts external coating to expose center wire then cuts coating on wires and removes)	**verbal knowledge** - inventing
I:	I notice that you were rushed with the other tasks or activities.	
S:	Yeah.	
I:	And you take more time now with this.	
S:	That is because it is like this here the other stuff was like little tiny jobs and that.	**personal interest**
I:	Mmh.	
S:	And this here is a bigger job and like I doing it as if I would really do it in my house right.	**personal interest**
I:	Aah, aah. So it is important to you that not only you do it.	
S:	That I do it really right.	**personal interest**
I:	Mmh.	
	(he works on three prong wire)	
I:	Why do you think you want to do it really right?	
S:	Cause some one can get hurt.	
I:	Mmh, mmh.	
	(he loosens terminals on voltmeter and attaches two wires from the three prong plug)	
S:	Yeah I am getting power. (reads voltmeter)	**verbal knowledge**
I:	Is that right what are you getting there? What is it reading?	- stating
S:	It is reading. What one are you talking about cause right. O.K. point five it's up all, one point five it's up all the way up top of the scale.	**verbal knowledge** - inventing
I:	Mmh.	
S:	At three it is off the scale and at thirty it	**verbal knowledge**

reads (pause) wait now six volts. Wait now, one, two, three volts. - inventing

I: Mmh.

S: Wait now, no, no one, two, three, four, five, six, seven, eight, nine, ten so it is reading at six volts. **verbal knowledge** - inventing

I: Aah, aah, mmh.

S: So my other plug did not work but this one here is o.k. . (loosens terminals on battery) **verbal knowledge** - stating

I: Mmh, mmh, mmh.
(he dismantles apparatus)

S: You want me to put this back in the box?

I: Pardon me.

S: You want me to put this back in there?

I: Yes.

Additional Comments:

Phases of Tinkering - he displayed all four phases of tinkering (searching, framing, solving and evaluating).

Actional Knowledge - he displayed all three levels of actional knowledge (formative, repertoiral and inventive).

END OF TASK # 4

TASK # 5 (non-school type) To repair an electrical appliance (facial sauna)

I: What I would like to do with you now, is I have got an appliance here that I would like for you to take a look at and see what you think of it. It is not working definitely, not working.

S: What is it? (looks at appliance) **verbal knowledge** - questioning

I: Well won't you take a look at it first and see.
(interviewer passes appliance to Sean)
(he examines appliance, lifts up face piece, turns dial at front of sauna and opens door to water holder)

S: Eh, something you sticks your face in. (lifts up sauna) **verbal knowledge** - stating

I: Yes.

S: And it gives off heat. **verbal knowledge** - stating

I: Eh.

S: Or mist or something like that right. **verbal knowledge** - stating

I: Yes, right.

S: O.K.

I: You have got it all figured out there, what it is at least, now see if you can get it working. (puts sauna down and turns to a frontal view of the sauna)

S: Get it working.

I:	Yeah. (he opens door to water holder)	
S:	So it is definitely not working right now. (lifts up sauna and examines further)	**verbal knowledge** - questioning
I:	Right. Are you use to repairing, appliances?	
S:	I've done like, plug and I've done my walkie talkie and things like that right and that is about it. (turns over sauna, begins to unscrew screws in the back and places screws in a pile on the table)	**prior experiences**
I:	Mmh. What about electronic games you said earlier?	
S:	Eh, yeah like my pacman game and things like that.	**prior experiences**
I:	Mmh, mmh. Comes out fairly easily. Do you have long finger nails?	
S:	No.	
I:	You have got them short.	
S:	Yeah. I always keep my nails short.	
I:	Why?	
S:	It is clean.	
I:	Yes that is true. (he lifts off back of sauna)	
S:	No power right.	**verbal knowledge**
I:	Right. (he looks inside sauna)	- questioning
S:	*O.K. now. (pause) The connection is there, the connection is there.* (examines wire)	**verbal knowledge** - stating
I:	I wonder if you can turn it around so I can see it inside. (he turns around sauna to face camera)	**verbal knowledge**
S:	*O.K., this is here (pause) o.k. I got it here. Here's our problem.* (lifts out disconnected wire and examines it)	- stating
I:	Aah, aah.	
S:	Here is one of our problems, the negative or the positive isn't getting in to where it is suppose to be. (examines wires and looks inside sauna)	**verbal knowledge** - stating
I:	Where is it suppose to get into?	
S:	I have no idea yet (laughs). I will find out though, o.k. yellow wire orange wire.	**verbal knowledge** - questioning
I:	Mmh.	
S:	Looks like it has fixed a lot times before.	**prior experiences**
I:	Mmh.	
S:	O.K.	
I:	How can you tell that?	
S:	Cause there is tape in, like usually nothing on the back there manufactures do use tape. (he examines wires, looks inside sauna and then re-examines wires)	**verbal knowledge** - stating
I:	Lot of tape around that bulb I guess is that what you.	
S:	Yes, seem like all this tape there.	**verbal knowledge**

	That there is nothing but a light, that goes right in here.	- stating
I:	What are you checking out now there?	
S:	What?	
I:	Your checking, I heard you mention light.	
S:	Yeah that was nothing but a light that tells when it is on.	**verbal knowledge** - stating
I:	Mmh.	
S:	Nothing serious. O.K. (gets a screwdriver)	
I:	What are you taking apart now? (begins to unscrew back of switch)	
S:	I am taking this here (disconnected wire) out so that I can get at that there (switch) better because this here goes into, that there like that but I (inaudible) It is nothing, that serious, eh. See that black box there (points with screwdriver to switch).	**verbal knowledge** - stating
I:	Mmh.	
S:	O.K..	
I:	What's the black box?	
S:	That there is the switching system o.k. And in this switching system the, o.k., the positive power is already hooked up to this right here (points to location of switch)	**verbal knowledge** - stating
I:	Mmh.	
S:	But the negative power has to go into this right here.	**verbal knowledge** - stating
I:	Mmh.	
S:	But it is not in there right, so I say what it is there only this screw right here (points to switch with screwdriver), and you just wrap that wire around the screw and then it should be fixed.	**verbal knowledge** - stating
I:	Aah.	
S:	But the thing is these little clips here, are hard to get at. (unscrews switch)	
I:	Mmh, mmh. Can you get at them from the outside?	
S:	What? (examines front of sauna)	
I:	What about from the outside? Will that work from the outside?	
S:	No. Can't get at it from the outside.	
I:	Can't get at it from the outside because sometimes you can. (he begins to unscrew switch)	
S:	Yeah. (works at unscrewing switch) Here we are. (loosens front of switch but back of switch is still attached; dial falls off)	
I:	So you have only repaired. Oh, yeah, the little dial on the outside come off.	
S:	Yes. (begins to work on wires inside the sauna)	

I: Mmh.
S: Did it come out completely?
I: Yes, but that's no problem really it will go back in again.
S: Yeah, I know.
I: Mmh.
(he turns around sauna and examines front of sauna)
I: It is probably easier to work to with it. I guess it would have to come out, would it?
S: I am not sure see. (turns over sauna and begins to work inside again taking it apart) *O.K. I got that, there it should leave right there.* — **verbal knowledge** - stating
I: Mmh.
S: Now. *O.K. now that goes in under, so (pause) and leave it there.* (places front part of switch on table)
I: Mmh. Yeah, some people would open that and they would not know where, the switch was, for instance how come you know what a switch is.
S: Just heard people saying things about it and that before right. (looks inside sauna) — **prior experiences**
I: Is there always four wires like it is into that one into a switch?
S: Four wires? (hold switch in hand and begins to examine)
I: Yes.
S: No, no.
I: Yeah.
S: Sometimes there is two, other times there is one and two and, yeah I have found the problem here. (points to location where wire is missing) — **verbal knowledge** - stating
I: Mmh.
S: Yeah there should be another one of those bendy things you can bend (referring to clip).
I: What kind of bendy things?
S: See that. (looks at the inside of the table and points to clip)
I: Yeah.
S: A little steel thing that is a.
I: It fell out did it?
S: I don't know if it fell out or not see. (looks in box and examines switch)
I: Mmh. What are they in there for those little.
S: That there is for the power and then you just hook it back on and it should work (lifts up sauna, looks inside sauna). Now o.k. I have found it (picks up clip inside sauna). *Now that goes in there (puts in clip), and this wire (picks up disconnected wire) goes here (pause) goes down like that,* — **verbal knowledge** - stating

this wire right here should go, in here, like that (pushes clip in place). (clip falls out) Sugar. (tries to get clip in place) There is a lot of other loose connections here too.
I: Is there?
S: Yeah. *That goes there .*
I: And with the loose connections that makes it what?
S: That, there will like, then the electricity can not get all the way around. **verbal knowledge** - stating
I: Mmh, mmh.
(he works on switch)
S: *Now that.*
I: Is this much like repairing a pacman game?
S: No not much because usually the pacman game is only something like one little loose wire on the outside where it has been dropped or something. **prior experiences**
I: Mmh.
S: This here is totally different. This here has got like, an inside and another inside and it keeps going on in like that. **verbal knowledge** - stating
I: Mmh, mmh. So this, eh, what kind of difficulty low medium or high?
S: About medium.
I: Mmh.
S: *That should go there.* (fits dial components in switch)
I: Do you get into things that are high difficulty level?
S: And I usually don't get them fixed.
I: You usually don't.
S: No.
I: So what kinds of ones do you usually get fixed.
S: Ones that are lower or medium. I am not even sure if this here will get fixed. Now I am not one hundred percent sure.
I: Right.
(he puts dial through from front holding inside components in place)
S: *That bunch down (pause) darn.*
(he twists end of loose wire and puts components in place inside switch)
S: *There. Yeah it.*
(he tries to insert wire in switch and adjusts clip)
S: This is the thing that is starting to fool me up now, this little copper thing.
I: Why?
S: Just because I didn't notice the way it was in the first place. (twists wire end)
I: Mmh, mmh. Does that help?
S: Yeah it helps a lot. Actually usually when **prior experiences**

	things like this break it is only wire out like this and then you look at the way it was, and this just go off by. (gets knife from box)	
I:	Mmh.	
S:	And then just put the wire back on like you see the others. (begins to remove coating from wire)	verbal knowledge - stating
I:	Mmh. You are taking off some more coating.	
S:	Yeah because I don't have enough bulk in the wire.	verbal knowledge - stating
I:	Mmh.	
	(he cuts coating on wire and while doing so the front dial falls out)	
S:	Let me guess the switch fell off right. (continues to cut wire)	
I:	Yeah, not serious.	
S:	No.	
I:	So no one at home does this kind of stuff.	
S:	No. It is probably why I learned.	social influences
I:	Mmh, mmh. What about, your cousin.	
S:	Well. (twists wire end)	
I:	Is he close to you in age isn't he? Not that, that.	social influences - mentor
S:	He's about thirty five, thirty six. Could be a little bit older.	social influences - mentor
I:	Mmh. Does he do this kind of stuff?	
S:	Eh, sometimes. When he is in the mood for it, like he's good for fixing things like wooden things like around the house like if his roof leaks or something he's good at fixing that. (removes more coating from the wire)	social influences - mentor
I:	Mmh. Are you good at that stuff?	
S:	Well I am just learning now right from my cousin. (twists end of wire)	social influences - family
I:	Mmh, mmh. So he is into some of that kind of stuff.	
S:	Yeah.	
I:	What you are into.	
	(he examines switch)	
I:	What about older brothers, or sisters.	
S:	Haven't got any. (adjusts clip)	social influences - family
I:	Sisters.	
S:	Three.	
I:	Are they into this kind of stuff?	
	(he puts end of wire in switch)	
S:	No. (adjusts switch and then gets a screwdriver and adjusts further)	social influences
I:	So are you the oldest or?	
S:	Eldest boy.	
I:	Aah. So you do have a younger brother.	
S:	No (laughs).	
I:	The oldest and only boy.	
S:	Only boy.	

I:	O.K. I am trying to get that straightened out.	
S:	Yeah. (takes up screwdriver and later puts down and takes up knife)	
S:	There are two things wrong with this. (puts knife down)	**verbal knowledge** - stating
I:	Is that right?	
S:	Yeah. Sure you can practically almost pull this white wire right through (picks up electrical cord). Is some where just connected. (lifts up back panel and then attempts to insert wire in switch)	**verbal knowledge** - stating
I:	It seems like you need to pull it a little more through the, through there. Is that right? For working I don't know. (he tries to pull cord)	
S:	Eh, no that is a safety switch so, not really a switch or anything but it keeps it. (examines the outside of sauna back panel)	**verbal knowledge** - stating
I:	In place.	
S:	Yeah. (begins working on switch)	
I:	So it won't go.	
S:	Out or in so it don't slip.	
I:	Aah, aah. (he works on assembling switch)	
S:	*O.K. now.*	
I:	Are you able to get it back in, into the switch?	
S:	*That's not needed, I don't think it is. Wait now. (picks up connector cap on table and examines inside of sauna)*	**verbal knowledge** - questioning
I:	What's that cap for?	
S:	This cap is just to keep these two wires together but I got them twined together simply. (lays cap down)	**verbal knowledge** - stating
I:	Mmh.	
S:	So, I shouldn't need it. *Now.* (switch falls apart) *Darn. O. K.* .	
I:	What is happening there now?	
S:	It just fell apart on me.	
I:	What your?	
S:	Not the thing that happened in the first place but every time I fix a problem another problem come up. (picks up knife and starts removing coating on disconnected wire) So. But you are right if I did have more white wire it would be a lot easier. (removing coating)	
I:	You want that to go in farther do you?	
S:	Yeah. I got to, now I got to tangle these two wires here together cause they just fell apart again.	
I:	That doesn't seem a very good connection does it?	
S:	No. The wires aren't long enough.	**verbal knowledge**

	(twists wires originally joined at cap, looks in box to the side) May be if I, that should do it (picks up extra wire).	- stating
I:	What are you going to use that for?	
S:	I am going to use this (wire just picked up) as sort of a joiner so I can get a longer wire, like to get that, that there (points to location of switch) and that together, like that one there is so long (points to longer wire) and this one is so short (wire to be joined to switch) so I'll just take this (new wire just obtained) and tangle it around this (wire originally joined in cap) and take this end and tangle around that (the other wire in the cord which is now disconnected) and I'll still have a good connection but I'll have extra wire to go around with.	**verbal knowledge** - inventing
I:	Mmh. Do you think that, that is safe enough?	
S:	I don't know see cause it might not be able to hold power from. Is there a circuit in this? (examines the inside of sauna) Eh.	**verbal knowledge** - questioning
I:	That is what I am thinking.	
S:	Yeah, cause this might get burnt out. Unless you, what, eh. (looks in box and gets more wire and then starts bending the wire to make it shorter)If you double these wires over a couple of times, then used it like that then I'll have extra wire. Can't burn out and it won't snap. It will be just as thick as that wire there. (bending wires) I think. Actually this here is going to be bigger so in a way it will be safer. (twists wires together)	**verbal knowledge** - inventing
I:	Safer in what respect?	
S:	In the respect that the, like from this wire (points to new wire) it won't burn out cause it is bigger than that wire there, like it is thicker and it can hold more power. And less chance of it catching on fire, I hope. (twists wire around one wire in the cord)	**verbal knowledge** - inventing
I:	You are putting that into the switch is that what you are doing? (attaches to orange wire originally in cap)	
S:	No, I was sticking it into this orange wire right here. (points to location of orange wire)	**verbal knowledge** - inventing
I:	Aah, aah.	
S:	So then I'll have enough space to work with.	
I:	O.K. (attaches to orange wire)	
S:	Get rid of the first problem before I go to the major ones. *There, there new, that's connection made (pause) those two there it is there.* (checks switch, removes clip from switch, bends clip with screwdriver, places clip back in switch and adjusts with	

	screwdriver) *Now.* (puts switch inside sauna and tips up back panel)	
I:	So is it all go there now?	
S:	Eh, soon it will be, hopefully. (attempts to put switch properly in place)	
S:	No. *That's I'll put one there, that's outside.* (looks in box and picks up electrical tape then puts tape down and returns to task) *Might not work because it is a conductor, or it is an insulator, so now.* (ponders over next move)	**verbal knowledge** - stating
I:	You were going to use some electrical tape were you.	
S:	Yeah but you can't because electric tape is an insulator.(tips up back panel, examines switch, attempts to reassemble switch and it falls apart)	**verbal knowledge** - stating
S:	*Darn.* These same two (clips) that keep coming out. *It will go back in eventually.* (reassembles switch, puts wire in place and readjusts) It would be a lot easier if you could solder it.	**verbal knowledge** - stating
I:	Mmh. What would you solder it to?	
S:	I'd solder it to those little copper pieces, that look like that.	
I:	Have you used, have you done soldering before?	
S:	A little bit here and there. (working on switch) *So far so good.* (working on switch and it falls apart) *Darn.* Came out again, so this one here (another clip) is a different one. (examines switch)	**prior experiences**
I:	Does your mother ask you to repair things with you father being gone?	
S:	Not that much, no. The only things I repair are my own things that she don't know that I broke.	**prior experiences**
I:	Oh I see you hide the fact they are broken.	
S:	Yeah. (reassembling switch)	
I:	She would not ask you to fix something.	
S:	She don't, well like she still thinks I am a little kid.	**social influences**
I:	Mmh. Is she afraid that you'd hurt yourself or?	
S:	Sometimes.	
I:	Or, do, you hurt the thing that you are repairing.	
S:	Both. (working on switch) *That's in tight.*	
I:	What about cars and trucks and stuff like that are you into much of that?	
S:	Yeah, I really like, like working around cars and trucks and things like that.	**prior experiences**
I:	Mmh.	
S:	I really like to learn about that.	**personal interest**

(assembles switch and puts inside)
I: What about planes? You said you want to be a pilot.
S: Yeah.
I: Do you want to look at the engines and stuff like that?
S: Yeah. (switch falls apart) Darn I got so close that time and the whole thing just fell. — **prior experiences**
I: Is that right? Do you have any friends you know a lot about this kind of stuff?
S: I have a couple. (exchanges screwdriver for knife) They don't like. I have my cousin, not Jim but Dave. He's Jim's brother. He's like he took an electrical course in vocational school. So he's really good right. (pulls on cord) — **social influences** - mentor
I: Mmh.
S: He's good at all kinds of things. (uses knife again to help loosen wire) — **social influences**
I: Mmh.
(he starts to re-assemble switch)
S: See I know how to fix it.
I: Mmh.
S: And I know what to do when I'm fixing it.
I: Mmh.
S: All that when it comes to putting the part actually into place after I have fixed it. It falls out.
I: Mmh.
S: So.
I: Does it matter where the wires are connected up in that switch?
S: Definitely. *That one goes in there and that one goes in there and that one goes in there, right.* (uses knife to adjust clips) — **verbal knowledge** - stating
I: Why? Why do you say definitely?
S: Because if you can turn it to high and it probably go to low. If you turn it off it will probably go on and you know things like that would happen. — **verbal knowledge** - stating
I: Mmh, mmh.
(he re-examines switch, uses knife to adjust clips, manipulates in place with fingers, uses knife and puts wire in place)
I: So you have repaired pacman what else, what other appliances did you say have you repaired sometimes.
S: I have repaired the toaster once. — **prior experiences**
I: Mmh.
S: Then we had to throw it away cause you know the wires were all frayed and that.
I: What did you work with switches in?
S: My pacman games and things like that. — **prior experiences**

I: Mmh.
(he bends clip with screwdriver)
S: *Darn it.* (bends clip and puts in switch))
I: You worked with anything with conductors and transformers in it?
S: Eh Transformer that's like the (assembling switch) Like the, like on a computer board there is little things sticking up, like the blue things and that. They are transformers right. **prior experiences**
I: Mmh.
S: Well I have seen them like in my pacman game but I never touch them or worked with them or anything and, I tried to build a crystal radio with them once it didn't work. **prior experiences**
I: Mmh. How did you try to build a crystal radio?
S: Well, I was, they gave me all the parts, or they didn't give me all the parts or anything cause it was already a open package right one of those build your own crystal radio things. (puts switch inside) **prior experiences**
I: Mmh.
S: And it, I guess I didn't follow the instructions right or something. (lifts up back panel, puts switch further in)
I: Do you follow instructions? Do you usually look for that when you are doing something? What about owner's manual for some stuff?
S: I always read the owner's manual. I made a mistake once by not reading it with my motor bike and fooled it all up. **prior experiences**
I: Is that right? What went wrong?
S: I forgot to turn on the gas. Just a simple thing like that. *That should be going on.* (works on putting switch in place)
I: Is the switch in now?
S: I got, I got the part that was broke fixed now (referring to clip) . *But (looks through dial hole in front of sauna and adjusts and then returns to back of sauna) there now. That should work.* (front dial falls out and is re-inserted, attempts tp put switch through from the back, works at front and back of sauna at once with both hands - one hand for the switch and one hand for the dial)
I: What advice would you give to someone who is trying to repair things?
S: Always turn off the electricity.
I: Mmh, anything else?
S: I haven't seen a switch like this before **prior experiences**

though. It must be old, I think.
I: Mmh.
S: Because usually they got, now they got these other things (referring to clips) that look a lot different. (assembles switch)
I: I guess that is a hard way to try to get it to go on there, the way you are doing it.
S: Yeah it is, it is really hard. (assembling switch) *Yeah I see it this wire, o.k. that wire goes in there, yeah.*
I: The red goes near the yellow is what, is that what you are saying?
S: Yeah. *And the black goes down by the white.* There, now that is the way it is suppose to be. (shows switch to interviewer) Like that, now that there has to go right on there. (points to back of switch) Hold it! I think you can take it out. — **verbal knowledge** - stating
I: That right?
S: Yeah. (removes back of switch from inside sauna) I might have done all this for no reason at all.
S: *It goes that (pause) that, that and that.* (places switch components in order on table)
I: I notice you are putting it in order is that important.
S: Yeah because I am very absent minded. (gets screwdriver and unscrews screw in dial)
I: Oh I see. (he removes front screw)
I: Are most people who fix things absent minded?
S: I don't know, but I am.
I: But you are.
S: I am very absent minded. (removing front screw)
I: There is a lot of little detail I suppose. (he shakes screw out)
S: Yeah. (turns sauna over and looks at back view)
I: So was that holding it in place.
S: That's it. (holds up back of switch)
I: Mmh.
S: *Now that's it, goes* (assembling switch) *down, that, then, then.* (putting components in place) *Then this part goes up the side, that goes there.* (assembles switch)
I: You would probably, not been able to put it in I guess.
S: No. If I didn't put that (back of switch) on I'd be lost forever.
I: That right?
S: Yeah. *Now this here should go here. Now still not doing it, so I'll put this in first.* — **verbal knowledge** - stating

(rechecks switch, unscrews switch and takes clip and wire out) That's my problem the whole time. Now, how to put these (clips) in. When I can't get them out when I want to get them out they don't come out and when I don't want them to come out they comes out.

I: Mmh, mmh.

(he reassembles clips in switch)

I: So would you describe yourself as a tinkerer?

S: Yeah.

I: Seems like it.

S: Yeah. (assembling switch) *Now that goes there like that and, that, should be able to go in there, like that, and then.* I was going at it the whole wrong way I think.

I: Mmh, mmh.

(he continues to assemble switch)

S: There's a weird little switch.

I: Mmh

(he continues to assemble switch)

I: How do you like things to work? Just work, work fairly or work well.

S: Work well. (tightens switch)

I: Why?

(switch falls apart)

S: Cause if it don't work well then, don't, like it don't give you, what you want. (adjusts clips) *O.K. (pause) that there is the crime the one that was doing it the wrong way. There, now.* That's it. We are not totally fixed but it is pretty close to it. (assembling switch)

I: Mmh.

S: All I had to do was to assemble it backwards. (assembling switch)

I: Mmh. Does most stuff work like that what you are doing there now?

S: No.

I: Mmh.

(he puts switch inside and takes switch outside again)

S: Bending these back that is going to be the problem. It is going to be a problem. (bends clips in switch by pounding with the handle of screwdriver)

S: Here.

I: Mmh.

(he pounds on clip in switch)

S: *Two unscrewed there. Now please make everything be in right.*

(end of day announcements)

I: Is Friday afternoon a bad time to be doing this?

S: Depends, on like, how far, like if it is after school, for me, yes! Cause like I can not stay after school. (takes a break and puts hands to head)

I: Oh, no, no I am saying it is a bad time. Friday afternoons are sometimes bad times.

S: Besides my bad luck now. A bad time to do it for me would be Monday.

Additional Comments:

Sean comes back on Monday morning first period and assembles switch with no problems. His earlier attempts had failed not because he did not know how to repair the appliance. He had thought the switch could only be inserted from the back whereas it was much easier from the front. Based on his discovering that information he completed the task in just a few minutes. The he proceeded to check out the sauna to see if it worked and it did. He was the only target subject who successfully completed this task.

Phases of Tinkering - he displayed all four phases of tinkering (searching, framing, solving and evaluating).

Actional knowledge - he displayed all three levels of actional knowledge (formative, repertoiral and inventive).

Task #6 (non-school type) To get a flashlight to work

The audio portion of this task was not recorded on the videotape but the visual was. The following is a description of how Sean completed the task.based on the visual portion and fieldnotes written immediately after the interview:

He opened the flashlight and discovered that the problem was a broken switch. His response was to make a switch with copper wire. The flashlight lit and he successfully completed the task in less than five minutes.

Additional Comments:

Phases of Tinkering - he displayed all four phases of tinkering (searching, framing, solving and evaluating).

Actional Knowledge - he displayed all three levels of actional knowledge (formative, repertoiral and inventive)

Overall Comments

Based on the overall categorization of Sean's transcript data the following categories were constructed:

1. Typology was described as:

(a) type - technological (as defined by the three criterion)
(b) proficiency - master
- he rarely consulted textbook but concentrated instead on doing the tasks
- he did not follow directions and often improvised
- he had excellent visual perception
- he was familiar with a wide variety of electrical apparatus
- he utilized the tools that were available

2. Tinkering was described as problem solving process consisting of searching, framing, solving and evaluating phases.
3. Tinkering was described as consisting of various levels of verbal (questioning, stating and inventing) and actional (formative, repertoiral and inventive) knowledge.
4. Three apprenticeship factors (experiential, social and personal) were described as influencing tinkering.

APPENDIX C: TRANSCRIPT OF SMALL GROUP DIALOGUE

This transcript contains a series of small group discussions which took place during one class period. The transcript contains two discussions at the lab stations and one small group demonstration. Two discussions ocurred at the lab stations of Haritha and Leann, and Sandra and Natasha.

Haritha's and Leann's Lab Station

After opening class discussion on the activities assigned for the lab period students move to their lab stations. The transcript highlights the discussion that takes place at Haritha's and Leann's lab station while working on the following activities:

1. Activity 13: To illustrate the magnetic force produced by an electric current
2. Activity 16: To use magnetism to produce an electric current

L: It is not going to work.	**verbal knowledge**
H: Jerm you are . . . you are!	- questioning
J: What?	
H: Oh my they are taping me and I said you are spastic Jerm. (rubbing of a magnet is heard)	
L: How do you get it to work?	**verbal knowledge**
H: I don't know. On when I worked it, it only vibrated that is all. Could you put it in?	- questioning
L: Yes, but it won't even vibrate now. (some rubbing is heard)	
L: Boys you are doing the wrong one. (some rubbing is heard)	**typology** (pragmatic)
L: You boys are doing the wrong one. You don't need compasses. You are doing number sixteen.	
J: You are doing the same one we are doing.	
L: You are doing number sixteen. Raymond. No you have to do sixteen first we do.	
J: Yeah . .	
L: O.K. let's go up and get these. (Teacher tells the class if the bar magnets are not strong enough that they have to remagnetize the magnets) (students are heard remagnetizing the magnets)	
L: It is a lot better.	
T: It makes a difference but I mean. I think there is a device that you are supposed to put across the top.	
H: What do I . . .here?	**verbal knowledge**
L: Wait now.	- questioning
T: Are you getting anything to happen?	
L: What are we supposed to do?	**verbal knowledge**
T: You are supposed to rub these.	- questioning

L:	Rub it over the wire right?	- questioning
T:	Yeah but your contacts have to be tight Leann. O.K.	
	(rubbing is heard)	
L:	It is not even moving. Did yours move?	**verbal knowledge**
	Yours is moving. What do we do?	- questioning
	(rubbing is heard)	
L:	Ours is not doing any thing.	- questioning
	(rubbing is heard)	
L:	There is nothing happening.	- questioning
T:	You are not getting it to move? Are these remagnetized?	
L:	Yeah.	
T:	You are not going to get much happening any way. Let's see. You are only going to get a very. It's moving. You see it moving?	
L:	Yeah.	
	(rubbing is heard)	
L:	Oh I thought it has got to be more than that.	**typology**(pragmatic)
T:	What do you think. You had better talk it over with Haritha. She is over there getting a wire cut is she?	
L:	Yeah.	
T:	You two try it and see if you can get it to work.	
	(rubbing is heard)	
L:	It is moving. Watch.	
	(rubbing is heard)	
L:	It only moves a little bit look. Haritha this is important o.k. . Haritha.	**typology** (pragmatic)
H:	Yeah.	
	(rubbing is heard)	
H:	It just vibrates.	
	(rubbing is heard)	
H:	Wind this around it.	
	(teacher says that for the coil they need about twenty turns)	
L:	Make sure you gets twenty.	**typology** (pragmatic)
H:	No Gary has it.	
L:	Are you going to have enough? There is only ten. Oh we have got to get a longer wire. We needs another piece of wire. You can't join it either.	**typology** (pragmatic)
H:	I'll get another piece of wire.	
L:	One now.	
H:	Ah.	
L:	One now.	
H:	That works.	
H:	That is about how much I had in the first place.	
L:	Is it will we needs that much more. We got to make twenty. I have got it. Just watch. Just watch. All you needs	**typology** (pragmatic)

is the ends done. Do that end over there.	
H: If you put it apart you take up more wire.	v. k. - stating
L: That's nothing you don't have to undo it.	typology (pragmatic)
H: I am done.	
L: Wait now. We have got to make them big.	typology (pragmatic)
H: If they are tight together they take up less.	v. k. - stating
L: No but they have got to be big.	typology (pragmatic)
H: Here they are. There it is moving. You pull it in and out.	v.k. - stating
L: Oh, come here. Come here.	
H: How did I tell you to do it. That's what he told me .	
L: We done it all the way in and out. Yeah it is moving look. See if you take it out it is hard to get back in every time. You are **suppose** to keep on doing it right. It is suppose to be.	typology (pragmatic)
H: It is working. Now it is working.	
L: It is **suppose** to be a steedy job see.	typology (pragmatic)
H: It is working now we will be able to do.	
L: Yeah.	
H: We will probably need this wire.	
L: Yeah, we needs that wire. Might as will keep this. We don't need I might as will bring this up.	
H: You got it.	
L: No, no.	
H: No compasses.	
L: There is compasses but there is no . (inaudible). Don't get any until.	
H: What experiment is that experiment with . (inaudible).	
L: Number thirteen. Number sixteen is what we just did.	
L: There is no switch we can't do it we have got to wait.	verbal kowledge - stating
T: Those students who weren't here yesterday are going to have to stay behind a few minutes so I can go over it with you.	
L: We did activity.	
T: Did you get it to work.	
L: Yes.	
H: Yes.	
T: With the coil did you get a fairly big.	
L: It was bigger than.	v. k. - stating
T: A big current.	
L: Yeah.	
T: O.K.	
L: We can't do that one because there is no switches left.	v. k. - questioning
T: Pardon.	
L: There is no switches.	
T: There are things you can use for a switch, like for instance Sean is using four	

batteries so what he is using to replace the switch is just touching the wire to the battery you know. You can improvise Leann. Did you see this Haritha.

H: What?

T: Did you see this?

L: (inaudible) . right.

L: Are you finished that?

H: Yep.

F: We needs this thing.

H: Yours might be off.

J: Are we supposed to leave this . (inaudible).

L: Yeah.

T: Can I have your attention now please.

C Yes.

T: What kind of results did you get in thirteen? What did you discover? (a number os students respond)

T: A magnetic field. There is a magnetic field created around an electric current. What are you trying to do there? You have a wire going up and when you turn it, when you turn the switch on electricity is flowing through the wire and what is the magnetic field. You know there is a magnetic field there why? Because your compasses are moving and it depends on how much current you got going through there you may move different degrees. If you have a whole lot of power going through there it may move twenty five degrees. If it has a small amount of current it may move only five degrees. In one way they will move around clockwise and reverse the contacts on the cell, the batteries and it will go counter clockwise. Electricity will flow in the opposite direction. Understand that? That part of your experiment proves that there is a magnetic field. Electricity when it is turned on will create a magnetic field.

Those you who were doing activity sixteen what was the purpose of your experiment?

H: To use magnets. To use magnets to produce electricity and then that.	**verbal knowledge** - stating
T: Can't hear you.	
H: To use magnetism to produce electric current.	**v. k.** - stating
T: To use magnetism to create an electric current. What did you do? Tell me	

what you did?
H: We got our things and then we put the magnet. We attached the wire and got the magnets and moved them around in the wire. v. k. - stating
T: What did you move?
H: The top one. v. k. - stating
T: The magnets or the wire?
H: Oh, the magnets. v. k. - stating
T: You moved the magnets over the wire.
H: Yeah.
T: Did you get, on the ammeter any electricity show up?
H: Yeah, just a little. v. k. - stating
L: A little bit.
T: What was the factor in that?
H: Magnets. v. k. - stating
T: If you rubbed it easy or you rubbed it hard did it make any difference? Pardon. Did it make any difference how hard you rubbed it? Did it make any differnce if you rubbed hard or gently or what?

(the teacher then continues the discussion with Jeremy followed by a demonstration of a hand generator, the bell rings)

END OF CLASS

The following discussion occurs at Sandra's and Natasha's lab station when near the end of the period they are still struggling with completing the activity:

(laughing)
T: Girls I would have thought that you would remember this. Here is the switch o.k. . One goes there and one goes there. That is just like touching a battery on the top when you got a battery on the bottom. When you have got it going across both terminals it won't work. Unless you have got them connected up parallel then you only get. Open and close your switch that is the only way you are going to know the difference, o.k. .
M: Got it to work.
T: Did you let me see? You should take a peep at what Trent is doing there too and see if yours is working similiar. Just go around come back and test things out.
S: We have got the wires too long. I have got this wire too long. typology (pragmatic)

N: Sandra. Do you think that we should go and talk to them how they done theirs or do this here.	**typology** (pragmatic)
S: They got . (inaudible).	
N: They got two wires connected.	
T: Those students who weren't here yesterday are going to have to stay behind for a few minutes I have got a few things I want to go over with you.	
N: We have got to take this off here and cut off some of that wire	**verbal knowledge** - stating
S: Yeah.	
F: Did you do it?	
S: Yeah.	
F: Did it work?	
N: No.	
S: We have **got** them too close together.	**typology** (pragmatic)
N: Yeah we have **got** to get the wire off it.	**typology** (pragmatic)
S: Let's try it. Try it now.	
N: I did . (inaudible)	
T: You got yours done yet?	
S: No.	
N: We are checking it out.	
S: What is wrong with that there sir.	**typology** (pragmatic)
T: O.K. got yours done yet?	
S: We have **got** to strip some of the wire off.	**typology** (pragmatic)
T: You don't need to strip that wire off there.	
S: Trent had bare wire going up through.	**typology** (pragmatic)
T: No it won't make any difference. It doesn't make any difference. You do not need to strip it.	
N: The compass is back on. What have you got done? Did they get theirs to work?	**typology** (pragmatic)
S: Yes.	
N: We put it away now do we? Can't get it off.	
S: Use the wire stripper to get it off. (a long section with no talking, they appear to be dismantling their materials)	
T: Tell Mr. A. they are going to be a few minutes late. Say, tell six students are down with me. Those who did number thirteen. What kind of results. Can I have your attention now please. Can I have your attention.	
C Yes.	
T: What kind of results did you poeple get on thirteen what results did you observe? What did you discover?	

DEMO AFTER CLASS

Afer class the teacher meets with students who were absent to discuss parallel and series circuits. The following students are present Haritha(H), Bill (B), Dennis(D), Jason(J), Natasha(N), and Sandra(S).

T: Series, o.k. now. This one over here is what?	
G: Parallel.	
T: Parallel. Now some of these bulbs are not all the same strength. Will this is a series, right. We all agree this is a series. There is no question on that I don't think. We got three volts in the battery here, o.k. . How much is it putting out? How much current is going out?	
J: Three volts.	v. k. - stating
T: Three volts. Basically we are talking about three volts. Now very quickly there is some reason or another why there is only one light lighting up I don't know why. For all three take my word for it, all three should light up equally. There is three volts coming out. How much is this bulb lighting up? How many volts coming through this bulb?	
H: One.	v. k. - stating
T: One volt. One volt coming through that one. How much coming through that one?	
G: One.	
T: How much coming through that one?	
G: One.	
T: Cause we only have three volts coming out and it is going to be evening distributed to all three bulbs. If we have six volts here how much would come to that one?	
J: Two.	v. k. - stating
H: Two.	v. k. - stating
D: Two.	
T: And two. You understand that? If we take out one bulb what will happen here now? Tell me before I do it.	
J: Two of them should light up.	v. k. - stating
H: Two.	v. k. - stating
T: Two of them light up? What do you think?	
H: Circuit is broken.	v. k. - stating
T: What do you (he is asking Natasha) think. Nothing. What do you (he is asking Sandra) think? I like for you to guess. What will happen do you think? Do you think it will light up?	
S: It will light up.	v. k. - stating
T: Let's try it. It won't light up.	
D: No it won't light up.	

T: Why won't it light up?
H: The circuit is broken. v. k. - stating
T: An unbroken circuit, it is no longer connected. The circuit is no longer connected there now. I don't know why the other one is not lighting up I really don't both bulbs were good. Do you understand that? It is actually three volts one volt coming here, one volt coming here and one volt coming here. You take out one bulb and break the circuit and none of them will light up. Understand that?

Now these bulbs will I got right here what are they in series or parallel? They are in series? These batteries not only are the bulbs in series the batteries are in series. So one and a half volts plus one and a half volts equals how many? Three volts. You actually add them together. Now if I put two of them like this. Pass over the srew driver to me please. If I use these two batteries like this here what is it called? They are parallel. If you put this strip across here. This won't work here. You can see it there now. How much volts is coming out now?
J: One. v. k. - stating
H: Three. v. k. - stating
T: How many volts coming out of the battery?
J: Three. v. k. - stating
H: Three. v. k. - stating
T: No
J: Two. v. k. - stating
D: One and a half.
T: There is only one and a half volts coming out now in this wire. You can see it there now. There is only one and a half volts coming out. Watch again I get this here. If there is only one and a half volt coming out what is coming through that bulb that is on there?
B: Two.
T: If there is only one and a half volts coming out. It is impossible to have two volts coming to there.
H: A half. v. k. - stating
T: How much?
H: A half.
T: A half. It is a half through that one, it is a half through that one and a half through that one. You understand that?
D: Mmm.
T: I only got one and a half volts coming. Why not use this right here?
J: It won't last as long. v. k. - stating
T: I still only got half a volt coming out. So what is the advantage of having two batteries parallel?

It will last longer probablely twice as long. That is the only advantage of this battery it will last twice as long. I got one and a half volts coming out now. There is a half through that one, a half through that one and a half through that one. I can get the same results by just using one battery. Still only one and a half volts coming out. If I use a flashlight I only got one of these in or two of them parallel I still only got one and a half volts coming out. But how long will it last?

H: Twice. v. k. - stating

T: Probablely twice as long. You understand that? Tell me if you don't know. Do you understand that? Now let's go over I will come back here in a second. Let's go over here now. I am going to put. What is the difference in this over here?

H: Parallel. v. k. - stating

T: That is parallel circuit. If I unscrew a bulb what will happen?

B: Still works.

T: It will still work it is like christmas tree lights. Most christmas tree lights are what?

J: (inaudible)

T: Most of them are parallel. Just watch. How would you look at these now?

H: Series. v. k. - stating

T: Series, o.k., got that?

J: Look at that.

T: This is a different type of bulb, o.k. . Now how many volts are going out?

J: Three. v. k. - stating

H: Three. v. k. - stating

T: Three volts going out. How many volts coming through this one and this one? I got three volts going out.

H: One. v. k. - stating

T: How much is going through that one?

H: One.

J: One. v. k. - stating

T: One. How much is coming through that one?

H: One.

T: How much do you think is going through that one?

D: A half.

T: No.

D: One.

T: How many think some thing is coming from the other one? Do you think it will make a difference? You think there is only one volt going out. I got three volts here, three volts coming through here and three volts coming

through here and I got three volts coming through here.
S: Oh yeah.
T: You undertand now if the two is parallel. If I use one of these how many volts do I have going out of the battery?
H: One point five. v. k. - stating
M: One and a half.
T: One and a half. How many is coming through here?
Males: One and a half.
T: How many is coming through here?
Males: One and a half.
T: How many is coming through here?
H: One and a half. v. k. - stating
T: Understand that? Now if I put two together in a series. How much is coming out?
H: Three. v. k. - stating
T: For each one? Three. If I do this I put two of them now parallel how much light is coming through each bulb there now?
H: One and a half. v. k. - stating
T: You say one and a half. What do you say?
B: Half.
D: I don't know.
T: What do you say?
J: (inaudible)
T: What did you say?
N: I don't know. One and a half. v. k. - questioning
T: What do you say?
S: (inaudible)
T: One and a half. It is one and a half. What is the advantage of using these in parallel?
H: Lasts longer. v. k. - stating
T: They will last longer. That is the only advantage. Now here is two batteries here. Here is one. This is how many batteries is in here?
H: Four. v. k. - stating
T: How many?
H: Four.
T: How many has seen this one?
J: Four. v. k. - stating
H: Four.
T: Now they are different. Aren't they?
J: Yeah.
T: How are these here arranged?
H: All the ends sticking out. v. k. - stating
T: No in terms of parallel or series.
J: Series. v. k. - stating
T: This one here is what you think?
H: Parallel. v. k. - stating
T: You think it is parallel what do you think

it is? Right here. Parallel or series.
S: Parallel. v. k. - stating
T: What do you think?
N: Parallel. v. k. - stating
T: What do you think?
J: Parallel. v. k. - stating
T: They are parallel. They are all the same like that there look. If I put, lodge down like that it is parallel, right. Isn't it? If I put one on top of the other, positive and negative they are now in what?
J: Series. v. k. - stating
T: Series. What is this one here?
J: Series.
T: In a series. It is going from positive to negative to positive to negative. How many volts do you think that battery is?
J: One and a half. v. k. - stating
T: How much you think?
D: One and a half.
T: How much do you think it is?
H: Six. v. k. - stating
T: What do you think it is?
B: One and a half.
T: What do you think?
N: One and a half. v. k. - stating
T: What do you think?
S: One and a half. v. k. - stating
T: What do you think it is now?
H: One and a half. v. k. - stating
T: It is one and a half sure. What is the advantage of that, that can only put out one and a half volts. It is marked here. That is all it will put out one and a half volts? What will that one put out?
M: One and a half.
T: What is the advantage of using that over this?
H: Lasts longer. v. k. - stating
J: Lasts lot longer. v. k. - stating
T: This will last up to four times as long that is all. It is only putting out one and a half volts it will last up to four times as long. They are all in what type of series? Or what type of circuit?
B: Parallel.
T: Parallel. What do you think the voltage in this one here is?
J: Six. v. k. - stating
T: What do you think?
H: Six. v. k. - stating
T: What do you think?
B: Six.
T: There is one and a half plus one and a half that's three, plus one and a half is four and a half plus one and a half is six. Six volts

that is what it is six volts. Why is it six volts?
H: Series. v. k. - stating
J: Series. v. k. - stating
T: They are connected in series. You said keep adding each one together. That way you get more power going out. You understand that? Which one got more resistance? What is resistance any how? What is resistance? What is resistance, we are talking about electricity, what is resistance in electricity? I am sure some of you must have an idea. You see the lights on that one use the same thing over here and it is going to be a lot less. The lights will not be as near as bright. In fact only one of them will come on. Resistance is any thing that which impedes or slows down or interferes with the flow of electricity. Some things conduct the flow of electricity very easily. Some things will conduct electricity very, very poorly. May be electricity will flow through aluminium much better than copper. May be it will flow through silver better than it will flow through aluminium or so. May be it will flow through gold even easier. Resistance is any thing which cuts down on the flow of electricity. Where is there more resistance is this one or this one?
B: That one.
H: This one. v. k. - stating
T: I am asking you. Series or parallel. Which one will have more resistance?
S: Series. v. k. - stating
T: You think series will. Eh, Natasha what do you think?
N: Series. v. k. - stating
T: You think in series. Why do you think? To you what do you think?
H: Series. v. k. - stating
T: Why do you think that way Haritha?
H: Cause if you put the batteries there it has to go from there. The electricity has to flow like that from the, like it has to flow in that wire to make it so if that is broken or anything the resistance is more. v. k. - stating
T: If it is broken?
H: Yes, the circuit. v. k. - stating
T: Is it sort of broken there then? Is it broken here?
H: No but if you got a light bulb there it will still work. v. k. - stating
T: O.K. so it is not broken in the parallel is that what you are saying?
H: Yeah.

T: You think it is here in the series?
H: Yeah.
T: Is that why you think there is more resistance?
H: Yeah, like yeah.
T: You got any questions on resistance? Jason?
J: No.
T: Which one do you think has the most resistance? Series or parallel.
J: Not sure.
T: You are not sure. But guessing.
J: I thought it would be parallel. v. k. - questioning
T: You thought it would be parallel. Any reason why?
J: I don't know.
T: What is necessary for it to light? Which one will light brighter when using this one here series or parallel?
J: Parallel. v. k. - stating
T: They look brighter here. They have to be. There has to be more resistance over here. Basically all the wire are connected here too. It is much easier for elcetricity to flow through here, through the wires because they are all touching each other including the wires too which the electricity is flowing through. Over here it has to go into through here up through the bulb out through the bulb and before it can go on. Every time it has to through a bulb it is going to be losing electricity. Resistance is any thing which basically cuts down on the flow of electricity.

Actally the current is the same thing through out even if it is only point five volts or half a volt as Haritha has said in series. Here you are getting say one point five if you are using one battery or three if you are using two. It should be the same throughout the circuit even though what is the diffence in these bulbs is that they have different potentials. They need different amounts of electricity to light them so that is why they were different but if we were to measure with ammeter which is what you were using today we should pick up the same current all throughout the wires. Because you can check the current. That is something extra I am telling you you don't have really have to worry so much about it?

Not only are the bulbs here in series and parallel but also the batteries parallel or in series. This way for example they will last twice as long. There is the same amount of electricity going out. In a series you are actually going to double the amount coming out. There is actually three volts going out. If you put another on you have four and a half volts going out in a series you have just got to add them up.

Any questions on the series and parallel circuit? What do you think Sandra? What do you think is basically have in your house the series and parallel circuit?

S: (inaudible)

T: Why do you think we have sreies and parallel circuits?

S: (no response)

T: What do you think Natasha?

N: (inaudible)

T: What is that?

N: (inaudible)

T: Excellent example. If one light goes out and it is not in parallel. If they are in parallel circuit if one will go out all the rest will stay one. If one goes out they will all go out. I don't think there is any worry in your house that this will happen.

If you have got christmas tree lights in a series one bulb goes you have got twelve bulbs and one goes out how do you know which one it is?

J: You don't know.

T: You don't know. What do you got to do then?

J: Check them all. — v. k. - stating

T: Check them all. In christmas tree lights there is one hundred and twenty volts. For argument sake you have got ten bulbs on this here how much is coming through each light?

S: Twelve. — v. k. - questioning

T: Twelve. Understand that? If you have christmas tree light in parallel circuit how much would be coming through each one.

B: One hundred and twenty.

T: One hundred and twenty, right. Because the amount going out is the same amount coming through when it is in parallel. If we have got three volts going out we have three showing up on each of the bulbs. In a series you have one third of the amount. If you have four bulbs then you have a fourth of what is going out?